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Of Molluscs and Middens: Historical Ecology of Indigenous Shoreline Stewardship along the Central Coast of California

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Committee in charge:

Professor Kent Lightfoot, Chair
Professor Junko Habu
Professor Anthony D. Barnosky

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Abstract

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Professor Kent Lightfoot, Chair

This dissertation presents three cases studies on the archaeology and Historical Ecology of Indigenous shoreline management practices on the Central Coast of California. These studies focus on various invertebrates and marine plants and algae that were harvested and stewarded by coastal Native peoples as foodstuffs and raw materials. The work was undertaken as part of a broader collaborative eco-archaeological research program and partnership between the University of California Campuses at Berkeley and Santa Cruz, The National Park Service (NPS), California State Parks, the Amah Mutsun Tribal Band (AMLT) and The Federated Indians of Graton Rancheria (FIGR or Coast Miwok) that has been carried out over the past decade. The research integrates approaches in collaborative archaeology and the application of eco-archaeological for revitalizing Indigenous Traditional Ecological Knowledge (TEK) and Traditional Resource Management (TREM) practices of coastal resources in California. In some cases, this knowledge has been repressed as a result of Spanish missionization and successive waves of colonialism during the Mexican and American periods.

Some of this information can be restored and revitalized through collaborative, community-based archaeological research that investigates Ancient Indigenous resource stewardship and management practices with the goal of providing baseline information for TEK revitalization and the restoration of TREM. The primary purpose of the dissertation is to provide crucial cultural and environmental data regarding Ancient and Historical marine resource harvesting that can be employed in contemporary shoreline stewardship by public land agencies and local Indigenous groups.

Dedication

This work is dedicated to my grandparents Patrick and Mary Fahy, and Dale and Viola Grone, whose determination and hard work built the foundation for the fortune and fortitude I've had in this life. I can only hope that they would be proud if they were here to see me complete this work.

Table of Contents

Chapter 1

Introduction: Eco-archaeology and Shellfish Harvesting on the Central California Coast

Chapter 2

Archaeological Signatures of Ancient Seaweed Harvesting Practices: A Case Study from the Central California Coast

Chapter 3

Ancient Mussel Bed Harvesting: Implications for the Revitalization of Indigenous Stewardship Practices on the Central California Coast

Chapter 4

Coast Miwok Stewardship of Clam Beds in Tomales Bay: An Eco-Archaeological Investigation

Chapter 5

Conclusion: The Archaeology of Shellfish and Shoreline Stewardship

List of Figures

List of Tables

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Chapter 1.
Introduction: Eco-Archaeology and Shellfish Harvesting on the Central California Coast

Along the Central Coast of California, changes in shoreline management practices and their subsequent effects on shellfish populations, fisheries, and kelp forests can be examined in the context of long-term human occupation, climatic and environmental variability, and the development of Indigenous, Spanish, Mexican, and American relationships with the environment. While extensive archaeological investigation regarding Indigenous *landscape* management practices has been conducted along California's Central Coast and the San Francisco Bay Area, comparatively little work has been done regarding Indigenous *shoreline* management practices affecting intertidal and wetland regions, such as kelp harvesting and the exploitation and management of shellfish populations.

To address this nascent research area in the regional archaeological literature, analyses focused on materials collected from nine sites along the shorelines of Point Reyes National Seashore in Marin County and six sites from Santa Cruz County over the summers of 2015- 2017 and analyzed in the California Archaeology Lab at UC Berkeley from 2015-2019. Invertebrate remains from these sites evidence diverse shoreline management practices spanning millennia, broadening our understanding of Ancient coastal California while restoring and revitalizing TEK and Indigenous management practices by working closely with local tribes (Amah Mutsun and Coast Miwok) and resource agencies.

Research Questions

1) Changes in invertebrate species diversity, ubiquity, and size in archaeological assemblages through time can reflect paleoenvironmental fluctuations, sustained management, or overexploitation. Is there evidence of sustained management of shellfish on the Central Coast of California?

2) "Non-dietary" or "incidental" marine invertebrates associated with marine macroalgae in archaeological assemblages can be analyzed to infer kelp and seagrass harvesting in the past. To what extent are these practices evidenced in these sites, how far back do they date, and what can they tell us about past human relationships with shoreline resources on the Central Coast of California?

3) How can eco-archaeological research be applied to contemporary resource management practices and be mobilized to revitalize "dormant" traditional ecological knowledge lost or suppressed during colonization?

These three questions are addressed in three case studies conducted by the author during doctoral studies at UC Berkeley. These case studies are presented in the following three chapters:

<u>Chapter 2:</u> Archaeological Signatures of Ancient Seaweed Harvesting Practices: A Case Study from the Central California Coast

Chapter 3: Ancient Mussel Bed Harvesting: Implications for the Revitalization of Indigenous Stewardship Practices on the Central California Coast

Chapter 4: Coast Miwok Stewardship of Clam Beds in Tomales Bay: An Eco-Archaeological Investigation

The remainder of this introductory chapter is a brief overview of relevant theoretical and methodological developments in California Archeology to provide theoretical and methodological context for the three case studies.

Background

Hunter-Gatherers in Anthropological Theory

Archaeological and ethnographic research in California has greatly contributed to theoretical and methodological developments in hunter-gatherer archaeology. Hunter-gatherers are now often recognized as socially complex, affluent groups who can be viewed as eco-engineers rather than passive, hand to mouth foragers as many early paradigms may have portrayed them (Arnold 1996; Gamble 2008; Habu 2008; Lightfoot 1993; Sassaman 2004). While the term 'hunter-gatherer' is a distinction typically meant to categorize subsistence strategies, these groups were often relegated in earlier anthropological studies to an inferior class of "savage", "barbarous", or "primitive" peoples by evolutionists and Social Darwinists, whose notions of unilineal evolution placed groups lacking agriculture and industrial technology at the bottom of a conceptual continuum of 'civility' (Ames 1994; Fitzhugh and Habu 2002; Trigger 1980). These perspectives often justified conquest of Native peoples by imperialistic colonial regimes, especially in North America, where European concepts of land ownership based on extensive tilling of soil justified the removal of Indigenous populations from their traditional homelands and territories (Lightfoot and Parrish 2009). Trends in anthropological thought at this time were guided by environmental determinism, which framed hunter-gatherers as passive groups who were shaped by their environments, with no agency or capacity to innovate (Sassaman 2004). This strain of thought continued for much of the early 20th century, but fresh perspectives regarding human relations with the environment would build upon these anachronistic approaches.

Indeed, contemporary perspectives in anthropology owe much to hunter-gatherers, not simply from a theoretical perspective but from early ethnographic encounters which revealed innumerable ways in which humans relate to their physical and natural surroundings (Bettinger 2001; Kroeber 1925; Sassaman 2004, Trigger 1980). Of course, it took some time before hunter-gatherer groups, both extant and archaeological, were viewed separately from their mistaken status as 'living relics' from a less civilized past and acknowledged as organized, sophisticated, and often ingenious agents of innovation and change (Arnold 1996; Ames 1994; Gamble 2008; Lightfoot 1993)

Human Behavioral Ecology and Optimal Foraging Theory

Perhaps the most influential body of work among California archaeologists studying hunter-gatherers today is derived from Human Behavioral Ecology, with many studies employing some component of Optimal Foraging Theory (OFT), which models foraging behavior and decision making as a rational calculation regarding energy expenditure in pursuit of resources (Bettinger 2001; Broughton 1994; Raab 1992). In this model, a forager will seek maximum net returns with minimal expenditure of time and energy, with natural selection favoring individuals and groups whose behavior coincides with these principles (MacArthur and Pianka 1966). Decisions to pursue prey species are contingent upon ranking and availability, with high-ranking prey offering greatest net gains and low-ranking prey yielding comparatively lower net gains (Broughton 1994; Osborn 1977). This theoretical framework can be employed to devise models built upon expectations for hunter-gatherer behavior to better understand their movement across the landscape, their foraging behavior, and their settlement patterns through time. Within this framework, multiple models can be used to understand choices regarding human mobility and resource acquisition strategies, such as the Ideal Free Distribution model, which posits that people will chose to inhabit an area that has the most productive natural resources, which are distributed unevenly across the landscape (Kelly 1995). The Patch Choice model suggests that people will target patches until the productivity of those patches diminishes and becomes less than neighboring resource patches, compelling them to move on to a different patch until the previous one regenerates (Charnov 1976). While these approaches have received their fair share of criticism, they have provided the foundation for a tremendous amount of research on hunter-gather behavior in California (Codding et al. 2012)

Niche Construction Theory

Concepts from Niche Construction Theory (NCT) can also be applied to eco-archaeological research that examines hunter-gatherers who employed purposive resource management and landscape manipulation practices. Indeed, NCT has been used to explain and analyze diverse landscape management practices among Indigenous people, providing a lens to interpret long-term, human-mediated relations with natural landscapes without constructing dichotomies between nature and culture (Cuthrell 2013; Laland and O'Brien 2010; Odling-Smee et al. 1996; Zeder 2012). Though some of the NCT literature is reminiscent of approaches used in OFT and Human Behavioral Ecology (Belovsky 1988), NCT acknowledges individual agency beyond aggrandizing as a mechanism for adaptation and change (Laland and Obrien 2010; Smith 2011). Like developments in hunter-gatherer research which give agency to past peoples' lifeways (Dornan 2002; Silliman 2001), NCT posits that species modify their environments to enhance their wellbeing, actively constructing a habitable niche rather than passively adapting themselves to their environments (Laland and Obrien 2010; Smith 2011). This theory is consistent with the view that humans are not 'dupes' to environmental processes but, rather, are active, ingenious eco-engineers who manage, sculpt and maintain their physical surroundings and potentially enhance resource abundance and sustainability, in effect minimizing ecological risks (Blackburn and Anderson 1993; Smith 2001)

Niche construction can be understood in terms of differential responses to selective pressures, whether organisms physically modify, or perturb their environments, or they actively move through space and relocate (Odling-Smee 2003). These differential responses can be further understood based on whether organisms respond to changing selective pressures or initiate them, in effect counteracting and stabilizing ecological risks (Odling-Smee 2003). NCT, when applied to small-scale societies, can involve the modification of vegetation communities, the sowing of annuals, the transplanting of fruit bearing species, the encouragement of economically important plants and root crops, and modifications of the landscape to increase prey abundance (Smith 2011). Although much of the work done using NCT to date has focused on agrarian societies and the domestication of plant and animal resources rather than the manipulation and management of 'wild' species, it is well suited for the study of hunter-gatherers (Smith 2011). It is especially relevant for hunter-gatherer research in California, where Indigenous populations employed a diverse array of landscape and shoreline resource management strategies (Anderson 2005; Cuthrell 2013; Erlandson 2013; Lightfoot and Lopez 2013).

Historical Ecology

Given the framework of NCT, the multidisciplinary research program of Historical Ecology serves to guide archaeological research from a diachronic perspective regarding human-mediated relations with the environment where active management and niche construction takes place. In order to investigate human-environmental relationships from a diachronic perspective, Historical Ecology uses the landscape as the medium of analysis. This concept of landscape is informed by non-equilibrium dynamics, in which fluctuation in a biotic community is the only constant (Balee 2006, 2018; Crumley 2003, 2018). In contrast, earlier theoretical concepts of the ecosystem imagined an ideal state of equilibrium which would be attained once an environment had fully matured, following a linear, progressive trajectory (Lee and Devore 1968). This treatment of the environment also moves away from dualistic notions of nature and culture and instead includes humans in the natural world (Balee 2006; Crumley 2018, Johnson et al. 2005; Rick and Erlandson 2006).

The research program of Historical Ecology is contingent upon four postulates. The first postulate is that humans affect their environments, and therefore, due to widespread human migration and habitation, nearly all environments on earth have been anthropogenically modified to some degree (Balee 2006, 2018; Crumley 2003, 2018). However, as the second postulate points out, humans are not inherently degrading to their environments (Balee 2006, 2018; Crumley 2003, 2018). Third, different societies affect their environments in different ways and, last, human-environmental interactions can be understood holistically (Balee 2006; Crumley 2003). This research program provides an excellent foundation to ask questions about human environmental relationships with a diachronic emphasis on changing landscape management practices. An emphasis on resilience is of special value when considering contemporary applications of this research, such as implications regarding policy decisions dealing with wildlife and fishery management in California (Braje 2010; Rick and Erlandson 2006).

Rethinking Hunter-Gatherers

Given the significant revisions in anthropological thought surrounding hunter-gatherers over the course of the 20th century, archaeologists today have a far more inclusive approach when considering issues surrounding hunter-gatherers through time (Ames 1994; Arnold 1996; Fitzhugh 2002; Habu 2008; Lightfoot 1993). While earlier theorists envisioned hunter-gatherer populations as nomadic, egalitarian, hand-to-mouth bands with no concept of land ownership, social hierarchy or individual agency (Kelly 1995; Binford 1962), contemporary theories acknowledge vast structural differentiation among hunter- gatherers. This recognition of *complex* hunter gatherers is characterized in some cases by hierarchical social divisions, seasonal sedentism, and technological sophistication (Ames 1981; Arnold 1992; Fitzhugh and Habu 2002; Gamble 2008; Habu 2008; Lightfoot 1993; Sassaman 2004). Until relatively recently this degree of complexity was commonly associated with agricultural groups, reflective of the archaic notions of cultural evolution and social organization present in early anthropological theory. Paradigms which viewed hunter-gatherers as minimally impactful, passive foragers who effectively maintained 'pristine' environments based on inherent conservation ethics and 'harmony with nature' were challenged and overtaken by the recognition that many hunter-gatherer groups were eco-engineers who actively cultivated, modified, and maintained their environments and, in some cases, overexploited their environments (Ames 1994; Arnold 1996; Erlandson 2013; Fitzhugh 2000; Habu 2008; Kirch 2005; Lightfoot 1993). Some scholars argue that the resource management practices of hunter-gatherer groups may have increased the productivity and diversity of ecological mosaics, reflecting long term, purposeful stewardship (Blackburn and Anderson 1993, Cuthrell 2013). In some cases, it has been argued that the extent and duration of these management practices are directly responsible for the distribution of contemporary ecological communities (Anderson 2005; Cuthrell 2013; Lightfoot and Parrish 2009). However, in other cases, it has been argued that the degree and extent of these practices has adversely impacted environments and led to resource depression, deforestation, erosion and other degraded states (Broughton 1994; Erlandson 2007; Kirch 2005).

California Archaeology

California was once home to some of the most densely populated hunter-gatherer societies in the world. Linguistic diversity in Native California was greater than anywhere else in North America, with up to 100 languages being spoken at the time of European contact (Lightfoot and Parrish 2009). This linguistic diversity underscores the degree of social complexity, political relations, economic ties and sophistication enacted by Native Californians. Far from passive, hand to mouth foragers, Native groups in California inhabited an incredibly diverse physiographic area ranging across alpine meadows, arid deserts, old growth forest, chaparral scrub mosaics, sandy beaches and rocky intertidal zones (Arnold 1996, Braje and Rick 2013, Lightfoot and Parrish 2009). According to current archaeological chronologies, humans have inhabited these lands back to the Late Pleistocene and the wealth of flora and fauna coupled with human innovation and engineering allowed them to accumulate surplus resources and, in some cases, population densities commonly associated with agriculture (Arnold 1996; Erlandson 2013; Lightfoot 1993). This web of social and environmental variables led to the development of sociopolitically complex cultures with maritime traditions and terrestrial adaptations which significantly altered and managed the landscape (Arnold 1992; Braje and Rick 2013; Erlandson 2013; Lightfoot et al. 2011).

The wealth of archaeological data in California regarding long-term human relationships with the environment is a critical resource for contemporary ecologists and resource managers alike (Braje and Rick 2013; Cuthrell 2013). The ability to do eco-archaeological research is increasingly complicated by anthropogenic factors including urban sprawl, logging, dam construction, agricultural tilling, and sea level rise connected to anthropogenic climate change. Coupled with natural factors such as micro-mammal burrowing and other forms of bioturbation and erosional forces of sea, wind, and rain, many sites in California are endangered and in dire need of archaeological assessment before they are lost forever.

Study Area

The three case studies presented in this dissertation focus on research conducted on archaeological sites on the Central Coast of California. Two case studies are from the Año Nuevo Study Area and the other one from the Point Reyes Study Area outlined in Figure 1.1. This study area extends from Sonoma County in the north and to the San Francisco Bay Area and Monterey County to the south. A rugged coastal environment of abrupt cliff faces, steep mountain valleys, and productive estuarine habitats reflect the intensive geologic forces of the San Andreas tectonic zone, which bisects this region. Characterized by long-term human occupation and modification of biotic communities (Cuthrell 2013; Hylkema and Cuthrell 2013; Jones 1991; Rick 2007; Rick and Erlandson 2006), the Central Coast is home to a diverse range of flora and fauna; productive fisheries of shellfish and bony fish are provided refuge in the kelp forests, as nutrient rich upwelling from oceanic currents creates a favorable environment for the proliferation of many marine species (Braje et al. 2006; Erlandson 2013; Rick and Erlandson 2006). Floral mosaics include chaparral scrublands, coastal redwoods, closed cone pines and evergreen forests. People inhabiting the San Francisco Bay Area

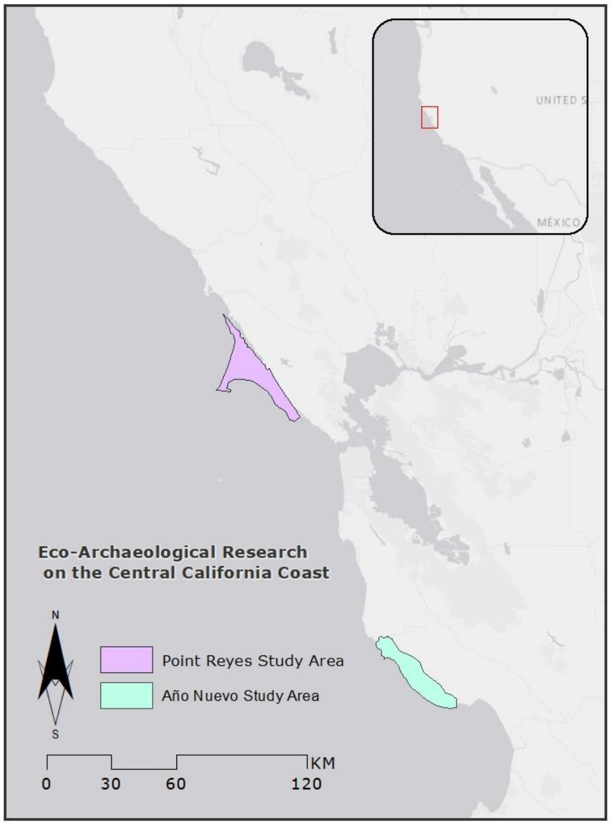


Figure 1.1. Map of study areas on the Central California Coast (Map by Alec Apodaca)

used tule reed boats for travel and fishing through the bay, yet little evidence for sea-faring vessels has been seen in the broader region (Hylkema 1991). Large populations of pinnipeds also inhabit these waters and beaches, with many long-standing rookeries established along the coast and on the Farallon Islands to the west (Hylkema 1991; Rick and Erlandson 2006; Rick et al. 2019). Despite a lack of evidence regarding seafaring vessels, evidence of pre-colonial hunting of pinnipeds is abundant (Lyman 1995; Jones and Hildebrandt 1995), though population impacts, and resource depression were significantly less than subsequent Russian colonial intensification of sea mammal hunting fueled by the fur trade (Lightfoot 2004).

Environmental Archaeology in California

California Archaeology has a rich tradition of environmentally focused research dealing with issues of settlement patterns, subsistence practices, seasonality of resource acquisition, foraging behavior, and human impacts on the environment (Arnold 1996; Braje 2010; Broughton 1994; Colten and Erlandson 1991; Heizer and Fenenga 1939; Jones and Raab 2004; Lightfoot and Parrish 2009; Morrato 2014). There has been considerable debate on the degree and extent of human impacts. Some archaeologists have argued that Native peoples in California gradually depressed natural resources as human populations increased over time, forcing them to shift from high-ranked prey species like terrestrial big game towards more low ranked species like shellfish and plants foods (Beaton 1991; Bettinger 2001; Broughton 1994). Others have demonstrated that the abundance and reliability of marine resources made coastal settlement a priority early on (Jones 1991; Erlandson et al. 2015). Still others have suggested argued that many of the settlement and subsistence decisions were largely driven by social variables such as prestige, suggesting that big game hunting increased in the Late Holocene and was likely a driving factors in social status as hunter-gatherer groups become larger and more sociopolitically complex (McGuire and Hildebrandt 2005). Some archaeologists and ecologists are now beginning to assess the impacts that resource management practices initiated by Native peoples had on the composition of biotic community’s across the state, arguing that Native peoples enacted diverse and sophisticated methods of enhancing economically important natural resources for thousands of years (Anderson 2005; Cuthrell 2013; Lightfoot et al. 2013). This vast body of work chronicles resource depression, stability, and enhancement through time, enabling a wide range of interpretations and predictive models to be incorporated in understanding the complex history of California’s Native peoples and their environments.

Traditional Ecological Knowledge and Resource Management

California provides an outstanding opportunity to investigate human-environmental interactions in Holocene and Historic times, especially those of complex hunter-gatherers who may have initiated various strategies of resource management. Recent research and a vast body of ethnographic and ethnohistoric data demonstrates that prior to European contact Native Californians were employing a diverse range of practices to increase the abundance of economically important plants, for both construction and subsistence purposes (Anderson 2005; Arnold 1996; Blackburn and Anderson 1993; Cuthrell 2013; Lightfoot and Lopez 2013; Lightfoot and Parrish 2009; Rick et al. 2006). Many of these groups employed diverse landscape management practices, actively mediating floral and faunal distributions via eco-engineering and delayed return strategies of resource management. Indeed, it has been argued that many of the environmental mosaics of North America have been largely influenced and sculpted by human mediated management practices

This perspective has been met with opposition, with critics arguing that Ancient societies did not have such lasting impacts on the environment as some scholars would like to claim. As argued by Vale (2002), the characterization of pre-colonial North America as a vast mosaic of human regulated and modified landscapes is as much a myth as earlier notions of Native people coexisting harmoniously with nature with little to no impact. This dichotomy of *humanized* vs *pristine* landscapes, according to Vale (2002), is representative of the problematic nature of Western peoples' tendency to romanticize the past on extreme ends of a given spectrum. In this view, the degree, extent, and continuity of the humanization of landscapes are ambiguities difficult to quantify, while leaning towards one end of the spectrum or another can have as much to do with empirical evidence as it does disciplinary training and political or economic interest. However, it has been posited that in some cases, the management of ecological communities by hunter-gatherer populations enabled resource surplus and complexity commonly associated with agriculture (Lightfoot 1995). Indeed, many archaeologists argue that these people were not farmers per se, but rather hunter-gatherers who were characterized by complex social hierarchies with specialized harvesters and task groups who enacted sophisticated resource management practices and maintained extensive and diverse territories (Anderson 2005; Arnold 1996; Braje and Rick 2013; Lightfoot and Parrish 2009). In either case, these relationships with the environment can be understood through the lens of Historical Ecology, bringing multiple disciplines and evidentiary lines together to support claims about anthropogenic impacts on landscapes through time (Balee 2018; Crumley 2018).

Marine Resource Management

While extensive archaeological investigation regarding Indigenous landscape management practices has been conducted along California's Central Coast and the San Francisco Bay Area (Cuthrell 2013; Lightfoot et al. 2011), comparatively little work has been done regarding shoreline management practices affecting intertidal and wetland regions, such as the construction of fishing weirs and the management of shellfish populations. Evidence of these practices is well documented along the Pacific Northwest coast (Ames 1994; Byram and Witter 2000; Lepofsy and Caldwell 2013; Erlandson and Moss 2001) and efforts are underway in parts of this region to re-implement traditional Indigenous management practices that have proved to increase fish and clam abundance (Byram and Witter 2000; Groesbeck et al. 2014; Lepofsky et al. 2013). Eco-archaeological research that focuses on human responses to past environmental and climatic events such as flooding, sea level rise and local climate change is especially relevant for providing baselines for contemporary comparison. The three case studies presented in this dissertation outline similar research programs regarding Indigenous exploitation of marine resources along the coast of

California, providing a more complete picture of the antiquity of human impacts on California's intertidal ecosystems.

Many people, ecologists and archaeologists included, once believed that the oceans were far too vast to be impacted by pre-industrial societies, who were often seen as living in harmony with nature and lacking the sophistication to significantly alter their surrounding ecosystems (Jackson et al. 2001). Today it is widely accepted among marine scientists that the current state of the Earth's oceans reflects intensive overexploitation, pollution, loss of habitat and species diversity, acidification, and other wide-ranging ecological impacts directly related to human influences (Jackson et al. 2001). While ecologists and fishery managers typically have recourse to temporally limited shallow data sets regarding ecological resilience and change, the archaeological record holds information and evidence relating to human impacts on marine ecosystems spanning millennia (Braje 2010; Rick and Erlandson 2007). Though the antiquity of human relationships with coastlines is poorly understood due to drastic sea level rise in the past 20,000 years which has inundated much archaeological data regarding human coastal migrations and interaction (Erlandson et al 2007), by incorporating multiple lines of geographic, genetic, and biochemical evidence to trace the depth of maritime expansion and exploitation by *Homo sapiens* and earlier Homo species, scholars are beginning to accept a much deeper temporal relationship of human impacts on marine ecosystems (Erlandson 2013; Jackson et al. 2001; Kirch and Hunt 1997). Indeed, it may be that the wider array of resources available in marine ecosystems allowed for and encouraged the geographical expansion of humans throughout the world (Erlandson et al. 2007).

Shell Midden Archaeology

Recent studies of shell middens demonstrate that people have been exploring the ocean and benefiting from its bounty for hundreds of thousands of years (Balbo et al. 2011; Erlandson et al. 2007; Marean et al. 2007) In fact, it has been argued that the wide array of resources available in nearshore marine ecosystems allowed for and encouraged the geographical expansion of humans throughout the world and into the Americas (Erlandson et al. 2007). Along the Southern and Central coasts of California and San Francisco Bay Area archaeologists have been investigating and analyzing shell middens for decades, asking questions about social organization, settlement patterns and subsistence strategies employed by the people who created these mounds (Heizer and Fenenga 1939; Heizer and Cook 1956; Lightfoot et al. 2011; Milliken et al. 2007; Schneider et al. 2012). As noted by Claassen (1998), interpretations regarding shell mounds was the "one area of archaeological interpretation before 1900 where Native peoples were credited with a history of progressive change". Shell middens can provide high resolution data often spanning centuries of zooarchaeological information regarding settlement patterns, foodways, technology, and impacts on environments through time (Claassen 1998; Lightfoot 1985; Waselkov 1987). Analysis of middens provides valuable information regarding exploitation and harvesting of marine resources, including shellfish, bony fish and pinnipeds (Rick and Erlandson 2006). Shell mounds are excellent for their high-resolution chronologies, providing a diachronic perspective of human practices of marine resource harvesting and environmental responses as evidenced in shifting population demographics of targeted species (Heizer and Cook 1956; Lightfoot 1985; Lightfoot and Luby 2002; Schneider et al. 2012).

Shellfish have been a critical component of human diets for millennia, and California is no exception. (Braje 2010; Claassen 1998; Erlandson 1988; Jones 1991). In fact, archaeological evidence of Native foodways demonstrates an early focus on shellfish beginning in Late Pleistocene and Early Holocene times. The work suggests that these protein-rich resources were stable and reliable enough to allow for long-term strategies of harvesting that persisted for millennia and contributed to an otherwise carbohydrate-rich diet which made coastal settlement a priority for some groups (Claassen 1998; Erlandson 1988; McGuire and Hildebrandt 1994; Jones 1991; Erlandson et al. 2009). Rich in protein and iron, shellfish have provided essential macro and micronutrients to human diets for hundreds of thousands of years (Erlandson 1988; Waselkov 1987). Many shellfish, such as oysters and mussels, are sessile animals which stay rooted in place. This plant-like adaptation has made them a reliable and predictable resource for many cultures throughout the world. These soft bodied invertebrates create hard, protective, and often ornate calcium-based shells to withstand the pressures in the dynamic environments they inhabit. These shells preserve exceptionally well in archaeological contexts and have been extensively studied in California for the past century, yielding insights into past subsistence practices, seasonality and settlement patterns, trade and exchange networks, as well as paleoenvironmental conditions through time (Claassen 1998; Erlandson 1988, 2013; Glassow and Wilcoxon 1988; Waselkov 1987)

Archaeologists have employed stable isotope analysis of molluscan shells for creating models to assess past sea surface temperatures and season of harvest of shellfish in the past (Burchell 2013; Eerkens et al. 2013; Kennett and Voorhies 1996; Killingly 1981; Leng and Lewis 2016). These data can be used to study patterns in harvesting practices employed by Native peoples, helping archaeologists infer whether regions were occupied seasonally or year-round. Case Study 2, as presented in Chapter 3, outlines and applies these approaches more in depth.

Studies of coastal hunter-gatherers in Central California have highlighted changes in shellfish populations signaling resource depression and greater labor intensification in the Late Holocene (Braje and Campbell 2015; Bouey and Basgall 1991; Broughton 1994; Erlandson 1988, Jones 1994; Raab 1992). These foundational studies chronicle increases in the quantity and diversity of low-ranked invertebrate remains, depression of high ranked large-bodied prey species, and a shift towards storage-based economies, which are argued to be evidence for increased pressures on the environment through time as a result of human predation and population growth. Most of these studies acknowledge non-anthropogenic variables such as environmental variation, habitat, sea surface temperature, tidal elevation, and predation that also influence shellfish populations that can complicate archaeological interpretations (Blanchette et al. 2008; Claassen 1998; Thakar et al. 2017).

It is reported that in some cases, resource intensification led to the reduction of key primary species and degradation of food webs (Broughton 1994; Braje 2010) as population growth and increased sedentism required people to increasingly exploit secondary, more costly resources within their local territories. In order to study these changes in population in response to overharvesting, archaeologists typically look for evidence along three parameters: decrease in mean shell length over time, reduction in modal size of exploited shell species that are significantly smaller than unexploited shells of the same species, and finally, species which are more difficult to harvest will increase in number (Claassen 1998). Though these analytical measures can be problematic to interpret given such factors as cultural preference, they generally provide a solid framework for studying demographic shifts in shellfish populations in response to human exploitation (Claassen 1998). Case Studies 2 and 3, as presented in Chapters 3 and 4 of this dissertation incorporate and refine these approaches, assessing the degree of shellfish harvesting intensity through time and whether these practices led to resource depression or stability.

Collaborative and Indigenous Archaeology

The present and future of North American archaeology is contingent upon continued engagement with Native peoples, not merely as consultants and stakeholders, but as active participants and leaders of research and curation (Atalay 2006; Gonzalez et al. 2006; Sassaman 2004). Native scholars and non-Native archaeologists alike have called for an emphasis on community-based participatory research programs in archaeology, signaling a paradigm shift towards collaborative Indigenous approaches in California Archaeology. Atalay (2006) argues that if archaeology is to be sustainable it must be in the hands of Native stakeholder communities, building capacity for people who have, in many cases, become disenfranchised from their past through legacies of colonialism and archaeological practices of the 19th and 20th centuries. She outlines three issues that are critical for the future of North American archaeology: that archaeology must have contemporary relevance, appropriate audiences, and community benefits. This engaged approach can be a decolonizing, reciprocal practice which can help reduce tensions built up over years of unethical archaeological practices.

Increasingly, North American archaeologists are placing a strong emphasis on tribal collaboration regarding research questions and directions (Atalay 2006 Silliman 2008; Lightfoot and Lopez 2013), coupled with minimally invasive survey techniques which enable surgically precise excavation procedures designed to avoid sensitive cultural materials and human remains (Gonzalez et al. 2016; Lightfoot 1995; 2008). Collaborative archaeology is beneficial not only for aiding in the interpretation of archaeology materials and fostering the use of multiple lines of evidence, such as Native oral histories and oral traditions, but for supporting Indigenous education, participation, and reclamation of traditional knowledge and management practices. These data can also be mobilized to restore traditional forms of knowledge suppressed during colonial encounters. I use my work with the Federate Indians of Graton Rancheria and the Amah Mutsun Tribal Band to illustrate these points, which will be further elaborated upon in the three case studies below (Chapters 2, 3 and 4).

Archaeology and Conservation Biology

Archaeology is uniquely situated to address human impacts on local and regional environments through deep time and has much to offer conservation biology and restoration ecology (Braje and Rick 2013; Wolverton and Lyman 2012). Integrating data regarding long term human-environmental relations across disciplines of social and natural sciences can provide a more robust and holistic understanding of past ecological baseline conditions, which in turn enable more nuanced approaches to managing contemporary environments (Wolverton and Lyman 2012). Episodes of environmental degradation as well as sustainable management of biotic communities are represented in the archaeological record, providing both cautionary tales and long-term examples for policy makers and wildlife managers making decisions about the stewardship of our natural resources. Human-induced species extinction is well documented in the archaeological record, though most species represented are terrestrial (Erlandson 2007). However, it can be difficult to differentiate between natural and anthropogenic extinctions and ecological fluctuations if data lack high resolution (Claassen 1998; Cuthrell 2013; Grayson 2001; Grayson and Meltzer 2003; Habu 2008; Martin 1967; Wolverton and Lyman 2012). Thus, integrative, interdisciplinary research programs incorporating multiple lines of evidence should be developed to address such issues and provide examples for best available science and management of natural resources (Braje and Rick 2013; Lightfoot et al. 2013a). These examples come at a time when our biosphere is undergoing the most extreme extinction event in the planet's history, which scientific research has unequivocally correlated with anthropogenic climate change, industrial agriculture, deforestation, overfishing, the extinction and extirpation of many keystone species, and countless examples of local, regional, and global mismanagement of resources (Barnosky et al. 2012; Ceballos et al. 2015, 2020; Steffen et al. 2018). In order to mobilize archaeological data for conservation biology and restoration ecology there must be integration of data across disciplines as well as dialogue reaching beyond the halls of academia and into political discourse at the local, state, and federal level.

Archaeology and the Anthropocene

In recent years, rising environmental awareness of the extent and degree to which humans have altered the biosphere has led to the proposal of a new geological era characterized by intensive human impacts and modifications of the earth's ecosystems, referred to as the *Anthropocene* (Barnosky et al. 2011; Crutzen and Stoermer 2000; Steffen et al. 2015, 2018; Waters et al. 2016). However, in developing a definition of this new epoch, the voices of archaeologists have largely been left out until recently (Braje et al. 2014; Edgeworth et al. 2015; Erlandson and Braje 2013; Lightfoot et al. 2013b; Steffen et al. 2011, 2015. This omission is due in part to the initial designation of the Anthropocene as starting at the Industrial Revolution, around 1850 AD, in effect leaving out millennia of intensive human impacts on the environment and ecoengineering via irrigation and agriculture, earthwork architecture, human influenced extinctions, modifications of floral and faunal distribution and abundance, the use of fire, and many more practices that imply human dominion over nature (Braje et al. 2014; Lightfoot et al. 2013b). This classification of the Anthropocene also has far reaching effects for the public perception of anthropogenic ecological change, especially regarding climate change and depletion of the ocean's fisheries (Erlandson and

Braje 2013). Archaeology is well suited to inform these discussions due to its breadth and depth of data regarding human relations with the environment from demographic and ecological perspectives (Braje et al. 2014; Erlandson and Braje 2013; Kirch 2005). Perspectives drawn from debates surrounding the definition of an epoch dominated by humans are important not only for understanding long-term ecological fluctuations and anthropogenic vs. natural influences, but for contextualizing impacts of colonialism on the environment. This is especially relevant in California where fire suppression, logging, industrial agriculture, ranching, commercial fishing, and other environmentally damaging practices were introduced by European colonialists (Anderson 2005; Lightfoot et al. 2013b)

Case Studies

Given this extensive body of work regarding human relationships with California's diverse landscapes and seascapes, the goal of this dissertation is to build upon this work and address questions regarding human impacts on shoreline resources through time, incorporating archaeological, ethnographic, ethnohistoric, and Native Historical data in a comparative, diachronic framework guided by the research program of Historical Ecology to assess the three research questions outlined in the beginning of this chapter and re-stated below:

1) Changes in invertebrate species diversity, ubiquity, and size in archaeological assemblages through time can reflect paleoenvironmental fluctuations, sustained management, or overexploitation. Is there evidence of sustained management of shellfish on the Central coast of California?

2) "Non-dietary" or "incidental" marine invertebrates associated with marine macroalgae in archaeological assemblages can be analyzed to infer kelp and seagrass harvesting in the past. To what extent are these practices evidenced in these sites, how far back do they date, and what can they tell us about past human relationships with shoreline resources on the Central Coast of California?

3) How can eco-archaeological research be applied to contemporary resource management policies and be mobilized to revitalize "dormant" traditional ecological knowledge lost or suppressed during colonization?

These questions will be addressed using multiple evidentiary lines in the following three chapters in the following manner:

Chapter 2. Archaeological Signatures of Ancient Seaweed Harvesting Practices: A Case Study from the Central California Coast

This case study will address research questions 2 and 3.

Chapter 3. Ancient Mussel Bed Harvesting: Implications for the Revitalization of Indigenous Stewardship Practices on the Central California Coast

This case study will evaluate research questions 1 and 3.

Chapter 4. Coast Miwok Stewardship of Clam Beds in Tomales Bay: An Eco-Archaeological

Investigation

This case study will consider research questions 1 and 3.

Chapter 2:
Archaeological Signatures of Ancient Seaweed Harvesting Practices: A case study from the Central California Coast

Introduction

Seaweed and kelp have been important resources for humans throughout the world for thousands of years, used for a wide range of purposes including food, medicine, building material, preservatives, cosmetics, thickening agents, mulch, fodder for livestock, fertilizers, renewable energy, and other utilitarian and non-utilitarian purposes (Bell 1981; Mouritsen and Mouritsen 2013; Steneck et al. 2002; Turner 2003; Turner and Clifton 2006; Vellanoweth et al. 2003). They also serve many critical ecosystem services, providing habitat and sustenance for a variety of animals that humans rely on, as well as accounting for a significant amount of carbon fixation and oxygen production (Steneck et al. 2002). This is especially true for kelp forest ecosystems, which are among the most diverse and productive environments on the planet (Erlandson et al. 2007, 2015). The giant kelp forests that stretch from Alaska to Baja California provide habitat for fish, invertebrates, and marine mammals that have been critical components of human diets and economies for millennia (Aaronson 1986; Ainis et al. 2015, Braje 2010; Dillehay et al. 2008, Erlandson et al. 2007; Jones 1991; Lightfoot and Parrish 2009; Steneck et al. 2002). Ethnographic, ethnohistoric, and Native oral histories and traditions document closely interwoven relationships between Indigenous people and kelp forests (Kelly et al. 1991; Lightfoot and Parrish 2009; Turner and Clifton 2006).

However, the use of marine macroalgae as a resource has been understudied archaeologically due to preservation issues in most archaeological contexts (Ainis et al. 2014; Bell 1981; Dillehay et al. 2007), resulting in a dearth of information regarding human-seaweed relationships through time. To address these preservation and recovery biases, Ainis et al. (2014) have recently suggested several methodological approaches for detecting potential uses of seaweed, including the presence of phytoliths, diatoms, and starches associated with different seaweeds and seagrasses. To this end, Ainis et al. (2014) have suggested the analysis of smaller size fractions is required to detect the presence of incidental or non-dietary gastropods (NDG) which may be associated with kelp and seagrass (Black 1976; Coyer 1979; Lindberg 1990) and serve as a proxy for seaweed harvesting practices in the past. Based on these previous studies, my study aims to build upon this initiative and refine techniques and sampling methods for observing archaeological evidence of kelp and seagrass associated invertebrates from several sites along the Santa Cruz coast during the last ~7000 years.

Background

Seaweed as a Resource

Ethnographic and ethnohistoric data document rich traditions of seaweed and kelp harvesting around the world by Native people from Japan, Ireland, Scotland, Alaska, Canada, and the Pacific Coast of the Americas (Ainis et al. 2014; Anderson 2005; Bell 1981; Dillehay et al. 2008; Erlandson et al. 2007; Felger and Moser 1973; Lightfoot and Parrish 2009; Turner and Clifton 2006), highlighting that seaweed is an enduring component of human diets and economies around the globe. Along the California coast, people have interacted with kelp forest ecosystems for millennia (Erlandson et al. 2007). These giant underwater forests help prevent coastal erosion by buffering waves as they approach the shore and provide habitat for schooling fish, abalone, sea otters, and many other species. Indeed, the abundance of resources present in kelp forest ecosystems may have helped enable the geographic expansion of *Homo sapiens* into the Americas, travelling along the "Kelp Highway" on boats, as suggested by (Erlandson et al. 2015). Some have even speculated that consumption of seaweed may have provided early humans with key nutrients to enhance the growth and development of brain function, improving the cognitive abilities of early peoples and encouraging technological and cultural innovation (Cornish et al. 2017).

Archaeological research regarding marine resources in California has largely focused on the exploitation of fish, shellfish, and marine mammals (Braje 2010; Broughton 1994; Erlandson et al. 2005; Hildebrandt and Jones 1992; Sanchez 2018; 2020). From a caloric perspective, seaweeds are ranked much lower than marine and terrestrial animals (Broughton 1994; Charnov 1976). Indeed, some archaeologists have viewed marine resources as marginal, only to be targeted after more highly ranked resources were depleted (Broughton 1994), while others (Erlandson et al. 2015; Jones 1991) suggest that the role of coastal resources in Ancient economies was critical for cultural development as well as the spread of humans along the Pacific coast.

The rich suite of vitamins, minerals, and polyunsaturated fats found in kelp and seaweeds combined with their abundance and relative ease of harvest made them an important component of Native diets along the Pacific coast (Burtin 2003). Seaweeds and kelp are a reliable food source that is available much of the year and can also be dried with minimal effort for long term storage, providing critical nutrients during periods when other resources were less available (Ainis et al. 2014; Lightfoot and Parrish 2009). However, like shellfish, macroalgae can retain harmful toxins such as heavy metals, so harvesting seaweed for food from polluted areas can be risky and is not advised. An increase in agricultural and industrial runoff since European colonization of the Americas has greatly contributed to the presence of these chemicals in our coastal waters, an issue which was likely less severe during precolonial times.

Seaweeds and kelp have been used for a wide range of utilitarian and technological purposes by Native peoples in North America, with ethnographic and ethnohistoric accounts documenting the use of kelp holdfasts for anchoring and securing boats, the use of bull kelp stipes for cordage and fishing line, seagrass being woven into cordage and rope, and kelp blades being used for cooking and steaming other foods (Lightfoot and Parrish 2009; Turner and Clifton 2006).

Fast growing and requiring no fertilizer or irrigation, seaweed is a sustainable resource and a key component of global economies (Turner 2003; Mouritsen and Mouritsen 2013). Commercial harvesting of giant kelp and edible seaweed off the California coast fuels a global market. Algin, a protein found in brown algae is widely used as a thickening agent and in medicine. Agar, derived from red algae, is used in gelatin. Carrageenan, also derived from red algae is used as a thickening agent, emulsifier, and preservative. Fucoidan, derived from brown algae, is currently being used in medical research for its anticancer, antiviral, and immunity boosting properties. Green algae of many species are consumed across the world for their flavor and health benefits. Kelps are even being researched for applications in the biofuel industry as their rate of growth and abundance makes them a highly productive and replenishable energy source (Kraan 2013).

The health of kelp forests is inextricably linked to the wellbeing of humanity. Seaweeds and seagrasses found in these environments account for a significant amount of global oxygen production and carbon storage (Steneck et al. 2002). Unfortunately, kelp forests are shrinking at an alarming rate (Krumhansl et al. 2016) due to factors ranging from trophic cascades following the removal of sea otters, to externalities of anthropogenic climate change such as ocean acidification, increased water temperatures, and industrial and agricultural pollutants. In California, the purple sea urchin (*Strongylocentrotus purpuratus*) poses an imminent threat to these sensitive habitats, as they eat kelp from its base, leaving the rest of the kelp to float away and die, creating dead zones known as “urchin barrens” (Steneck et al. 2002). Sea otters (*Enhydra lutris*), are a keystone species in kelp forest ecosystems who prey upon urchins and regulate their numbers. However, overhunting of otters has led to these animals being functionally extinct in most of California, allowing the proliferation of sea urchins and the destruction of kelp forests (Erlandson et al. 2005; Lightfoot 2006; Steneck et al. 2002). In some areas, such as Monterey Bay and Fort Bragg, divers have begun culling urchins to slow the onslaught of urchins and help kelp hold on. Stewardship and protection of kelp forests at the local and global scales will be critical in securing a more stable future in the face of anthropogenic climate change, ocean acidification, and local and global reductions in marine biodiversity and productivity. Archaeological data sets are uniquely situated to address questions of long-term environmental change and human pressures on kelp forests ecosystems over millennia, providing critical perspectives for the management of these important resources.

Study Area

A team of researchers from the University of California campuses at Berkeley and Santa Cruz, California State Parks, and tribal scholars from the Amah Mutsun Tribal Band (AMTB) have been incorporating archaeological, ethnographic, Historical, and ecological data sets to assess the extent and degree of Indigenous resource management practices on the coast of Santa Cruz and San

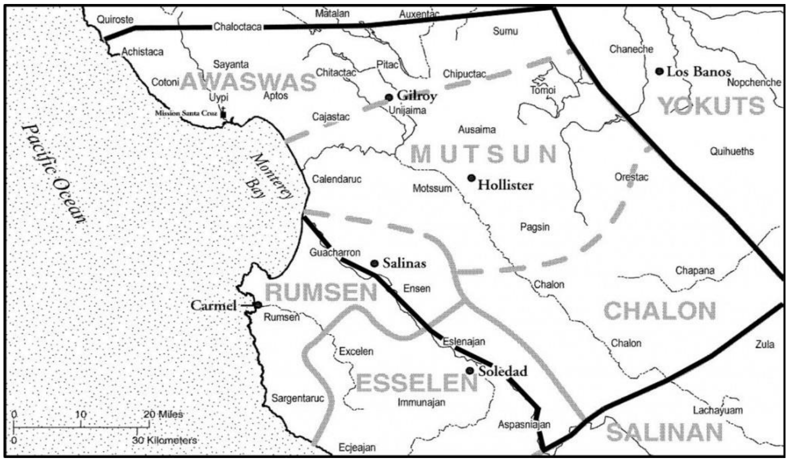


Figure 2.1. Map of Amah Mutsun territory, from (Amah Mutsun Tribal Band 2020b)

Mateo county. This work has focused largely on terrestrial resource use, specifically the use of fire by pre-colonial Indigenous peoples to manage coastal grasslands and enhance the productivity of culturally important resources used for food, technology, and medicines (Cuthrell 2013; Lightfoot and Lopez 2013). Existing ethnographic literature and ethnobiology data are also focused largely on terrestrial resources as documented in the AMLT digital ethnobiology database (Amah Mutsun Tribal Band 2020a) based on ethnographic field notes and extant tribal knowledge. Of over 1000 entries to date in this continuously growing database, there are only 34 marine resources represented, with only four mentions of seaweed and/or kelp. Personal communication with tribal chairman Valentin Lopez made clear the desire to restore Traditional Ecological Knowledge (TEK) and Traditional Resource Management (TREM) of coastal resources in their tribal territory (see Figure 2.1). To address this initiative, this study demonstrates the utility of collaborative approaches in archaeology for revitalizing TEK and TREM of coastal resources including fish, shellfish, and seaweed. Seaweeds are especially abundant in the study area along the coast of Santa Cruz and San Mateo counties, part of the cold temperate region that stretches from Pt. Conception to Alaska (Erlandson et al. 2015; Steneck et al. 2002). The study area includes three sites within Amah Mutsun Tribal Territory with substantial midden components, illustrated in Figure 2.2 below. CA-SCR-7 is a Mid-Holocene coastal village site with a diverse assemblage of faunal, paleoethnobotanical, and lithic remains. The three column samples taken from CA-SCR-7 used in this study have radiocarbon dates ranging from cal 4787 BCE -2202 BCE, making this one of the oldest known sites on the Central Coast. CA-SCR-14 is a Late Holocene upland village/hinterland site, with radiocarbon dates ranging from cal 1159 CE-1918 CE. CA-SMA-216 is a Late Holocene coastal midden processing site with a diverse assemblage of faunal, paleoethnobotanical, and lithic remains, with radiocarbon dates ranging from cal 1307 CE-1635 CE. Data regarding radiocarbon dates are further presented in Appendix A. The diversity and geography of these sites and assemblages enables a long term, diachronic comparative analysis of intertidal resource exploitation and Ancient seaweed harvesting practices.

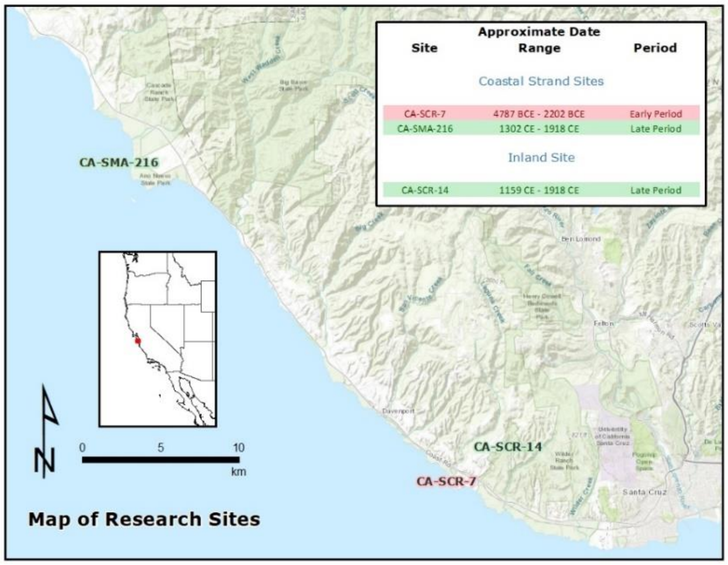


Figure 2.2. Map of sites within study area (Map by Alec Apodaca)

Methods and Materials

Survey and subsurface sampling strategies adhere to minimally invasive and tribal friendly approaches undertaken within a collaborative archaeological research program (Gonzalez et al.

2006; Gonzalez 2016). As previously mentioned, this began with addressing tribal interests to develop research questions, followed by extensive geophysical survey using Ground Penetrating Radar, Magnetometry, and Electrical Resistivity to avoid culturally sensitive remains. Extensive surface survey was carried out, using a catch and release method (Gonzalez 2016; Lightfoot et al. 2013a) to determine artifact densities and site boundaries without removing archaeological materials. Data obtained from surface survey and subsurface geophysical testing guided excavation strategies, which involved the use of augers, opportunistic column samples of exposed and eroding profiles, and limited excavation units. Bulk sediment samples were taken from arbitrary levels at intervals of 10 cm for columns samples and excavation units and 20 cm for augers. Bulk sediment was then subject to flotation to separate heavy fraction and light fraction materials for further analysis. Samples from these contexts were processed in the California Archaeology Laboratory at UC Berkeley. Heavy fraction materials were passed through geological soil sieves to separate materials into the following size classes for ease of analysis: >4 mm, 2-4 mm, 1-2 mm, <1 mm. The driving force behind these fine-grained recovery strategies was the systematic archaeobotanical sampling program developed by Cuthrell (2011), which incorporates discrete and non-discrete sampling and recovery of intact features such as ash lenses, earth ovens, house floors, and refuse dumps. This approach has enabled increased resolution of data and nuanced interpretations of human relationships with the environment though time, especially regarding grassland resources and the use of fire as a management tool.

Recent research stemming from the same sampling strategy displays the utility of sampling smaller size fractions for detecting Ancient shoreline management practices and net fishing of forage fish such as herring and sardines (Sanchez et al. 2018; Sanchez 2020). The following case study extends the assessment of marine resource management on the Central Coast from fisheries to kelp and seaweed.

Analysis of invertebrate remains collected from three sites spanning Middle to Late Holocene occupation in the study area have revealed insights regarding marine resource exploitation in this region dating back 7000 years. Invertebrate remains from a total of 103 flotation samples collected at these sites have been sorted and speciated down to a resolution of 4 mm and were sampled exclusively for NDG in the 2-4mm fraction. Analysis of smaller size-fractions (1-2 mm, 2-4 mm) indicated these samples were generally composed of highly fragmented shell that would be too time intensive to process systematically based on the quality of data they might yield. However, sampling of the 2-4 mm size class has revealed a significant increase in relative abundance and minimum number of individual (MNI) counts of “non-dietary gastropods” (NDG) or “ride-along” taxa, such as the examples in Figure 2.3. MNI counts for gastropods were determined using only specimens that retained their apices.

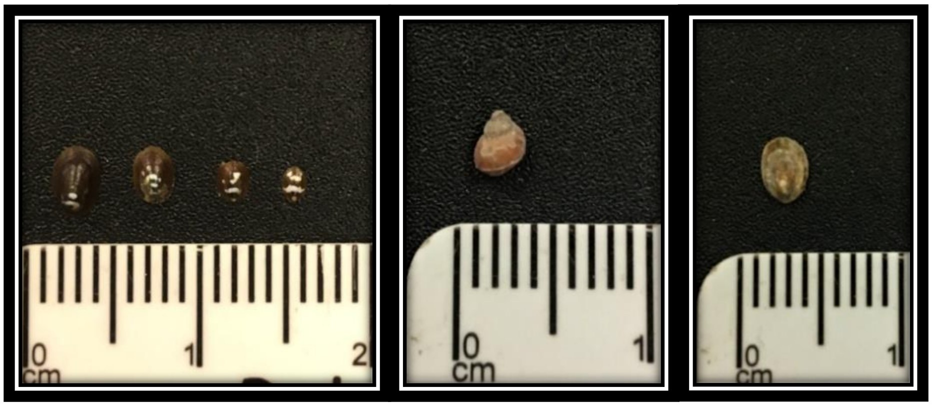


Figure 2.3. Examples of NDG including modern *Lottia insessa,* modern *Lacuna vincta, and archaeological Lottia insessa,* from left to right

NDG remains were identified with the aid of modern reference collections gathered from Pescadero State Beach and Pleasure Point in Santa Cruz, California, which are housed in the California Archaeology Lab at UC Berkeley. Quantitative measures of invertebrate remains included weight, relative abundance, density (grams of shell/ liter of soil, listed as g/l), MNI, along with isotopic and morphometric data to be presented in upcoming publications. The paper focuses primarily on the recovery of NDG from these sites.

Results

These diverse assemblages are primarily composed of rocky intertidal taxa and California mussel (*Mytilus californianus*) and acorn barnacles (*Balanus spp.*) are the most abundant and ubiquitous constituents, respectively. While mussel and barnacle remain the most abundant and ubiquitous species represented in >8 mm and 4-8 mm materials, notable species that increase in abundance in the 4-8 mm and 2-4 mm include the Seaweed limpet (*Lottia insessa*), along with *Littorina littorea,* and *Lacuna vincta*, which are both surfgrass (*Phyllospadix scouleri)* and seaweed associates.

The results of the analysis are presented in Table 2.1, which lists the number of NDG recovered from the three size-fraction samples (> 8 mm, 4-8 mm, 2-4 mm) for the three sites. Table 2.2 lists the dominant shellfish taxa recovered from the three sites, which are dominated by *Mytilus californianus* and *Tegula funebralis*. While NDG make up a small component of these assemblages by weight, density, and abundance, they are more established in the 2-4 mm samples.

Size Fraction	**n of NDG recovered**	**Percentage of assemblage**
>8 mm	11	1%
4-8 mm	165	14.6%
2-4 mm	985	87.3%

Table 2.1. The Number and Percentage NDG Recovered in Different Size-Class Samples

Site	**Context**	**Shell Density**	**Shell Weight**	**Dominant Taxa**
CA-SCR-7	Col 1	72.3 g/l	6582.9 g	77.6% *Mytilus*, 19.1% *Balanus*
CA-SCR-7	Col 2	80.9 g/l	8376.4 g	80% *Mytilus*, 27.2% *Balanus*
CA-SCR-7	Col 7	135.2 g/l	1690.8 g	87.8% *Mytilus*, 7.3% *Balanus*
CA-SCR-14	Unit 1	8.1 g/l	179.2 g	86% *Mytilus*
CA-SCR-14	Unit 2	68.4 g/l	1812.3 g	93% *Mytilus*
CA-SMA-216	Exc 1	121.8 g/l	1971.1. g	39.2% *Tegula*, 37.6% *Mytilus*
CA-SMA-216	Exc 2	122.0 g/l	1572.0 g	45.5% *Mytilus*, 35.0% *Tegula*

Table 2.2. Invertebrate Assemblages by site for all size-class samples

As displayed in Table 2.2, *Mytilus californianus* dominates these assemblages by weight. While NDG comprise a comparatively small component of these assemblages by weight, their MNI counts increase dramatically when smaller size fractions are analyzed, as evidenced in Table 2.1 and Figures 2.4-2.11. Despite their low relative abundance, the fact that they are not dietary suggests that their presence and ubiquity is enough to infer seaweed and kelp harvesting practices. In fact, perhaps NDG are not easily comparable to abundances and densities of dietary shellfish. Most archaeological studies of shellfish focus on dietary contributions based on weight or counts of shell remains, and there has been considerable debate on the relative merits and utility of using weight or counts as a more accurate measure of the relative importance of shellfish species in archaeological assemblages (Claassen 1998; Glassow 2000; Mason 1998), but the presence of NDG in archaeological must be considered in light of broader dietary interpretations, providing indirect evidence for another resource (seaweed and kelps), rather than providing quantifiable metrics for their caloric content and dietary contributions. The graphs below depict the differential MNI representation of NDG, including kelp and seagrass associated limpets (*Lottia spp.*), and seagrass associated snails (*Littorina spp.* and *Lacuna spp.*) by fraction size (i.e. >8 mm, 4-8 mm, 2-4 mm) for each site assemblage.

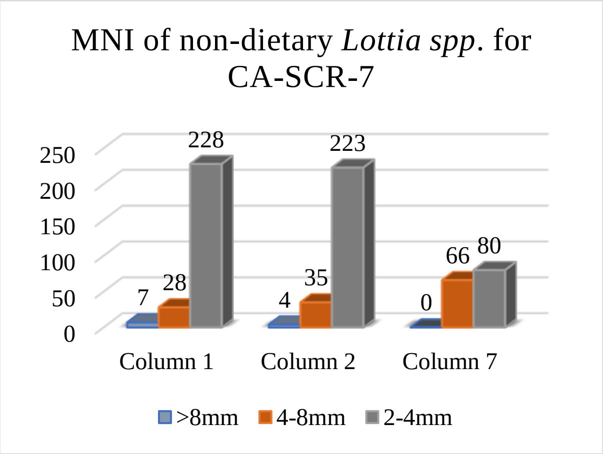


Figure 2.4. MNI of non-dietary *Lottia spp.* from CA-SCR-14 assemblages

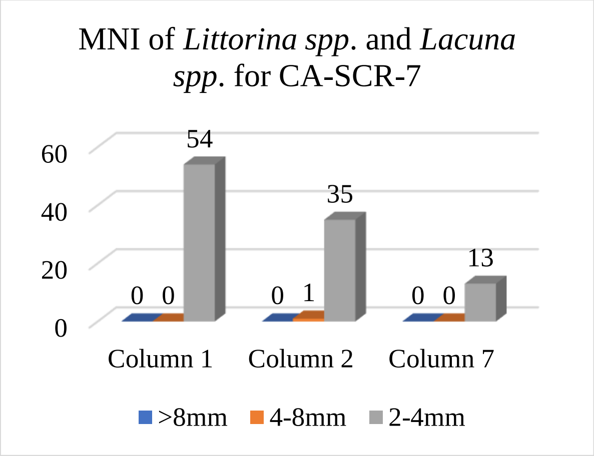


Figure 2.5. MNI of *Littorina spp.* and *Lacuna spp.* for CA-SMA-216 assemblages

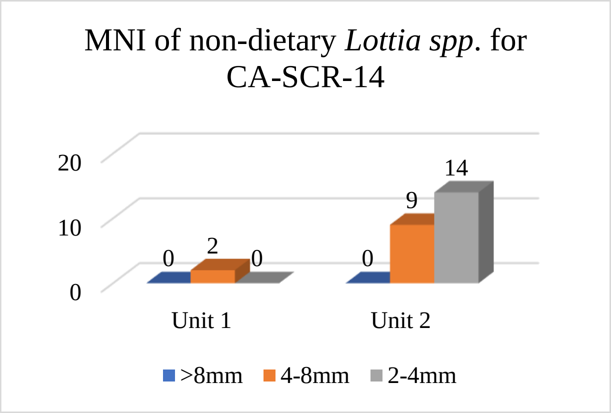


Figure 2.6. MNI of non-dietary *Lottia spp.* from CA-SCR-14 assemblages

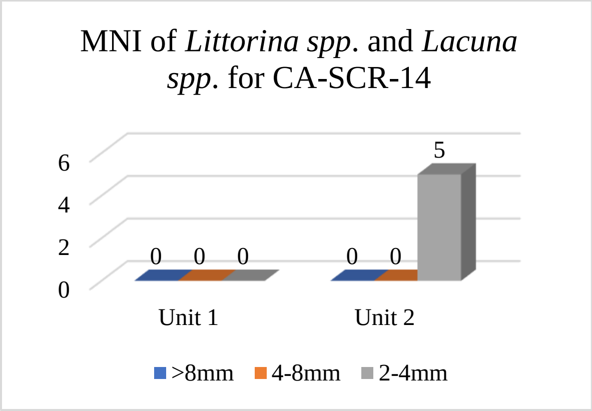


Figure 2.7. MNI of *Littorina spp*. and *Lacuna spp*. for CA-SCR-14 assemblages

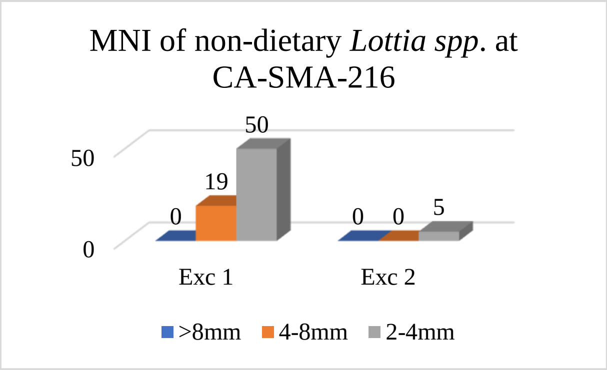


Figure 2.8. MNI of non-dietary *Lottia spp*. for CA-SMA-216 assemblages

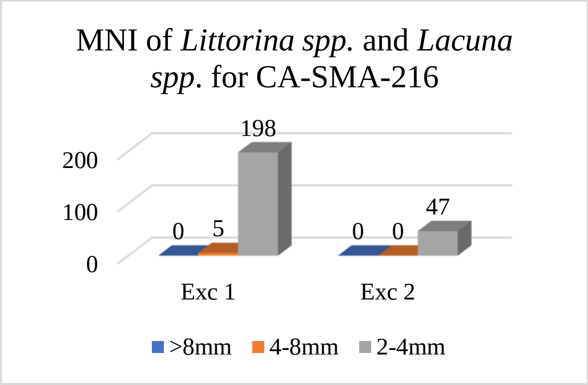


Figure 2.9. MNI of *Littorina spp*. and *Lacuna spp*. from CA-SMA-216 assemblages

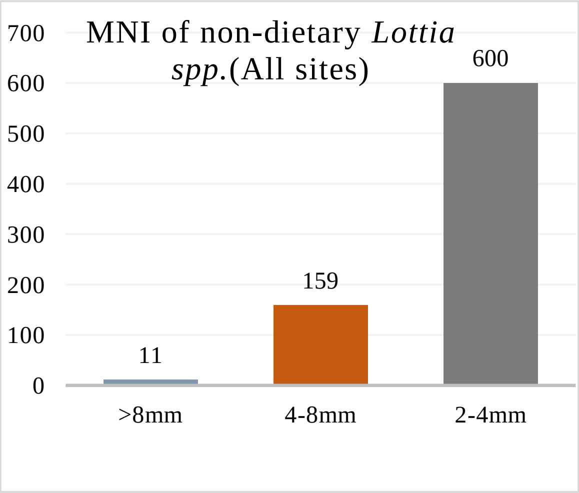


Figure 2.10. MNI of non-dietary *Lottia spp*. from all site assemblages

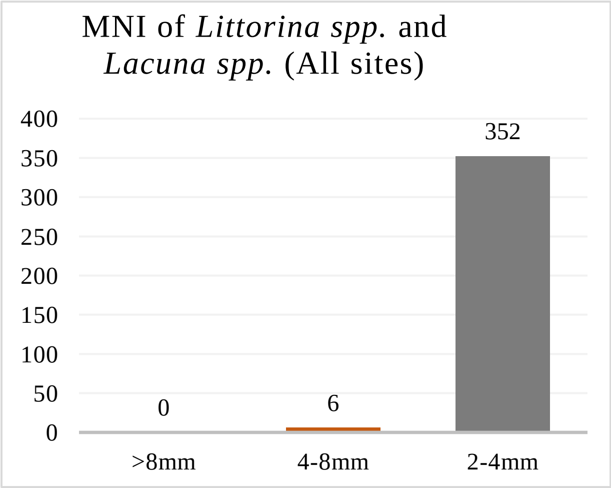


Figure 2.11 MNI of *Littorina spp*. and *Lacuna spp*. from all site assemblages

The results of this analysis display a wide range in the presence and abundance of NDG in different size of classes of heavy fraction materials, with the vast majority of NDG present in the 2-4 mm size class. The assemblages of NDG from samples taken from CA-SCR-7 are outlined in Figures 2.4 and 2.5. MNI counts increase drastically for non-dietary *Lottia spp.*, *Littorina spp.*, and *Lacuna spp*. in the 2-4 mm size class, suggesting harvesting of kelps, seaweeds, and surfgrass dating back to the Mid-Holocene on the Santa Cruz coast. While CA-SMA-216 (assemblages represented in Figures 2.8 and 2.9) had considerably more non-dietary *Lottia spp.* in the 2-4 mm size class, the MNI of *Littorina spp*. and *Lacuna spp*. was drastically higher in the 2-4 mm, suggesting that surfgrass (*Phlyllospadix scoulerii*) harvesting was significant during the Late Holocene on this part of the San Mateo coast. While not edible, surfgrass can be used for technological purposes such as cordage (Turner 2003; Vellanoweth et al. 2003). Upland site CA-SCR-14 assemblages are outlined in Figures 2.6 and 2.7 and have very few NDG overall. There is a trend in the presence of NDG based on site type and proximity to the sea, with coastal strand sites CA-SCR-7 and CA-SMA-216 exhibiting much higher MNI counts of NDG compared to upland site CA-SCR-14. This may suggest that the processing of seaweed and kelp was a primarily coastal activity. Kelp and seagrass tend to wilt quickly and are best when dried early, and ethnographic accounts documents seaweed being dried on beaches close to where they were collected (Turner 2003; Turner and Clifton 2006; Lightfoot and Parrish 2009). Interpretations of these data are outlined in Table 2.3 below.

Site	Presence of NDG	Site type	Interpretations
CA-SCR-7	High	Mid Holocene Coastal strand	Coastal processing of kelp and seaweeds
CA-SCR-14	Low	Late Holocene Inland/ Upland	Little processing or transport of seaweeds inland
CA-SMA-216	High, mostly seagrass associates	Late Holocene Coastal Strand	Coastal processing of seagrass, likely for cordage

Table 2.3. Interpretations of NDG assemblages by site

The desiccation of kelp and seaweed also leads to the desiccation and demise of gastropods who live upon them, who tend to fall off once they have died. The relative shortage of NDG at upland CA-SCR-14 coupled with the dominance of *Mytilus californianus* suggests that kelp was not likely being transported upland before being dried and processed. However, it is possible that the drying process may cause associated gastropods to die and fall off kelp and seaweeds, leaving no measurable trace once they are transported inland. These data suggest that analysis of these smaller size fractions can reveal a great deal about Ancient seaweed harvesting practices.

The ubiquitous presence of the seaweed limpet *Lottia insessa*, (formerly *Acmaea insessa*) a fast growing annual species which lives exclusively on the Feather Boa Kelp (*Egregia menziesii*), from samples at CA-SCR-7 and CA-SMA-216, both coastal middens, suggests kelp harvesting practices reaching back to the Middle Holocene and continuing into the Late Holocene and Historic times (Ainis et al. 2014; Black 1976; Kuo and Sanford 2013). Drying kelp on beaches is a common practice evidenced in ethnographic literature (Lightfoot and Parrish 2009) and a common practice among recreational harvesters even today. Seaweed limpets settle on kelp blades and stipes in the spring, establishing habitat and allowing an optimal window of growth prior to storms in the winter that often uproot and destroy kelp (Kuo and Sanford 2013). These animals can also destroy kelp, often reaching abundances so great by the fall that their feeding degrades the structural integrity of kelp (Black 1976; Lindberg 1990). In the assemblages analyzed, 78% of kelp associated limpets were found in the 2-4 mm size range, suggesting they had not reached maturity at the time of death as fully mature seaweed limpets can reach up to 2 cm. Modern comparative assemblages of *Lottia insessa* collected by the author in spring and winter display a considerable size difference, with limpets collected in spring being less robust and conical and all under 6 mm in length while winter limpets were more robust, conical, and measured up to 1.76 cm in length. The small size (2-4 mm) of most limpets found in these archaeological assemblages and the association of smaller limpets with the seasonal proliferation of kelp may suggest harvesting of young, tender kelp in the spring. Due to this observed seasonal trend in body size, I argue that sampling <4 mm size fractions of invertebrate assemblages is essential for detecting NDG and should be incorporated into coastal midden analysis.

The findings of this research are not just relevant for understanding Indigenous coastal practices in Ancient and Historical times, but also in working with contemporary tribal members and coastal agencies in the stewardship of our coastal resources and preservation of kelp forest habitats. This information is being mobilized to revitalize Traditional Ecological Knowledge of the Amah Mutsun Tribal Band and their Coastal Stewardship Program, who have a sacred duty with their creator to steward the lands and seas in their territories, providing stability for seven generations into the future (Valentin Lopez personal communication 2019) Archaeological data from their ancestral homelands display an intensive reliance on and relationship with coastal resources for thousands of years, setting a precedent for the revitalization and restoration of traditional resource management practices as well as using best available science to develop stewardship practices for the modern world and future generations. Ongoing collaboration with California State Parks and the Amah Mutsun tribal band will help combine the best available science with traditional ecological knowledge, traditional resource management practices, and Indigenous cultural revitalization to better steward important and sensitive habitats.

Conclusion

Sampling <4 mm size fraction for non-dietary gastropods provides different data resolution than larger size fractions. While most dietary invertebrate remains become highly fragmented and painstaking to identify, smaller invertebrates like whelks, limpets, and periwinkles which are often associated with kelp and seaweed preserve relatively well and can be identified to species level with the aid of comparative collections. Based on the findings of my analysis, I suggest coastal midden analysis should include analysis of smaller size fractions to detect smaller kelp and seagrass associated species which can provide proxy information for Ancient harvesting practices. Further analyses could include the development and integration of seasonality assessments using stable isotopes to provide another line of evidence for the timing of harvesting events. The increased resolution of non-dietary invertebrate assemblages allows for broader interpretations regarding marine resource harvesting and seaweed use. Such insights are especially useful for assessing of the importance of marine resource exploitation and human reliance and pressure on these ecosystems through time, providing baseline data for California State Parks monitoring and restoration effort. This information is also critical for the revitalization of Amah Mutsun traditional ecological knowledge and seascape stewardship.

Chapter 3:
Ancient Mussel Bed Harvesting: Implications for the Revitalization of Indigenous Stewardship Practices on the Central California Coast

Introduction

Marine resources have been critical components of Native foodways on the Central California Coast for millennia (Braje et al. 2006; Erlandson 1988; Rick and Erlandson 2008; Jones 1991; Lightfoot and Parrish 2009). The abundance and diversity of shellfish, fish, and marine mammals, combined with a carbohydrate-rich diet from plants, enabled human populations densities and social stratification often associated with agriculture in some areas (Erlandson 1988; Erlandson and Moss 2001). Indeed, the presence and antiquity of shell middens worldwide demonstrates an early focus on lower-ranked resources like shellfish, suggesting shellfish harvesting practices that persisted for millennia and contributed to an otherwise carbohydrate-rich diet which made coastal settlement a priority for some groups (Claassen 1998; Erlandson 1988; McGuire and Hildebrandt 1994; Jones 1991). Shellfish have been viewed in the archaeological literature as a low-ranked resources based on the amount of caloric energy they provide for the amount of time and energy required to access and harvest them, with most shellfish offering lower net gains than larger bodied prey (Osborn 1977; Raab 1992). However, shellfish are high in critical micro and macronutrients such as iron and protein while also being abundant, stable, and seasonally reliable in coastal environments (Erlandson 1988).

Background

The archaeological investigation of shellfish resources in this region has demonstrated changes in their populations that have been interpreted as resource depression and intensification in the Late Holocene (Campbell and Braje 2015; Basgall 1987; Broughton 1994; Erlandson 1988; Jones 1994), a trend that is well documented in Central California during the Late Holocene (Beaton 1991; Broughton 1994; Wohlgemuth 1996). Resource intensification is here defined as decreased foraging efficiency due to increased pressure from human predation, leading to more reliance on low ranked resources like shellfish and plant foods due to decreases in the presence of more highly ranked resources (Belovsky 1988). These foundational studies chronicle increases in the diversity of low-ranked invertebrate remains, depression of high ranked large-bodied prey species, and a shift towards storage-based economies, all indicating increased pressures on the environment through time as a result of human predation and population growth. Most of these studies acknowledge non-anthropogenic variables such as environmental variation, habitat, sea surface temperature, tidal elevation, and predation that also influence shellfish populations and potentially confound archaeological interpretations (Blanchette et al. 2008; Claassen 1998; Thakar et al. 2017). It is reported that in some cases, resource intensification led to the reduction of key species and the degradation of food webs (Broughton 1994) as population growth and increased sedentism required people to increase the productivity of resources within their local territories.

However, people are not inherently inclined to degrade or improve their environments, though both scenarios have played out through time around the globe. There is a growing body of literature that suggests Native peoples enacted various practices which increased the productivity of their local landscapes through stewardship and landscape management (Anderson 2005; Cuthrell 2013; Lightfoot et al. 2013a). In some areas people developed sophisticated management strategies to increase the productivity and extent of vital resources for food, medicines, and technology (Anderson 2005; Lightfoot and Parrish 2009).

For example, a rich body of ethnographic literature, Native oral traditions, and archaeological data documents the importance of marine resources to Indigenous peoples on the Pacific Northwest Coast of North America. Research in this region has demonstrated that Indigenous peoples managed the intertidal zone through the construction and maintenance of clam gardens and fish weirs (Ames 1994; Byram and Witter 2000; Erlandson and Moss 2001; Lepofsky and Caldwell 2013; Lepofsky et al. 2015; Groesbeck et al. 2014; Menzies 2006; Smith 2001). These management practices also serve as cornerstones of socio-ecological systems, with four aspects of traditional management systems highlighted by Lepofsky and Caldwell (2013): harvesting methods, enhancement strategies, tenure systems, and worldview and social relations. The last two of these require ethnographic or oral tradition, while the first two may be detectable in archaeological deposits.

While there has been considerable archaeological research regarding Indigenous stewardship and management of marine resources in the Pacific Northwest, especially the construction and maintenance of clam gardens, comparatively less emphasis has been placed on the study of similar practices on the California coast (Anderson 2005; Erlandson and Rick 2010; Lightfoot et al. 2011; 2013a; Whitaker 2008). I recognize from the outset that assessing the possibility of Ancient Indigenous shoreline management practices in the archaeological record on the Central Coast of California is complicated by the paucity of known built environments, such as rock-walled clam gardens and fish weirs. While these features may be hard to detect in this region, systematic efforts to detect and record such features have not yet been undertaken. Fortunately, there are numerous examples of archaeometric approaches for assessing shifts in populations through time resulting from human predation and harvesting practices (Apodaca 2018; Campbell and Braje 2015; Sanchez 2019; Singh and McKechnie 2015). Such methods are particularly pertinent for the study of California mussel (*Mytilus californianus*), as they can be employed to examine archaeological faunal assemblages to evaluate if they were exploited so intensively that their populations became depleted or harvested in a sustainable manner that maintained their populations for many decades or centuries.

Assessing Indigenous stewardship practices in this region is further complicated by coastal development, agriculture, sea-level rise, and successive waves of Euro-American settlers who removed Native peoples from their homelands. A significant legacy of colonialism is that many coastal Indigenous people have been denied access to their resources through land ownership, laws restricting gathering, etc. This has resulted in the suppression of traditional ecological knowledge regarding many marine resources in central California. The effects of removal from traditional territories are especially true for the Amah Mutsun Tribal Band, whose traditional homelands stretch from the coast of San Mateo County down to Monterey Bay and eastward to the Central Valley (Figure 3.1). Historically comprised of more than 20 politically distinct tribelets, the modern tribe represents the surviving descendants of these groups who were taken to Mission Santa Cruz and Mission San Juan Bautista. Research in the ancestral homelands of the Amah Mutsun demonstrates the use of traditional resource management (TREM) practices increased the extent and productivity of coastal grasslands in the Late Holocene (3000-500 BP) on the northern coast of Santa Cruz County and the southern coast of San Mateo County (Cuthrell 2013; Cuthrell et al. 2012; Lightfoot and Lopez 2013). It is possible that there are comparable scenarios in which alternative harvesting methods and stewardship practices were employed to maintain stability in targeted shellfish populations over time, making this region especially interesting for exploring the possibility of shoreline management practices evidenced in the archaeological record. Researchers have suggested that practices which enhanced the productivity and extent of terrestrial plants may have been mirrored by management of shellfish populations such as clams and mussels (Baker 1992; Blackburn and Anderson 1993; Mirschitzka 1992). This paper evaluates whether Native people may have employed similar kinds of resource management practices used for enhancing the productivity of terrestrial resources for mussel beds in this region.

Study Area

For the past decade, a team of scholars from the Amah Mutsun Tribal Band, California State Parks, and the University of California campuses at Berkeley and Santa Cruz have been investigating coastal sites along the northern Santa Cruz and southern San Mateo coastlines spanning the Middle Holocene (7000-3000 BP), Late Holocene (3000-500 BP) to Historical times (Cuthrell 2013; Lightfoot and Lopez 2013). Changes in Indigenous resource management practices in this region can be examined in the context of long-term coastal occupation, climatic and environmental variability, and the development of Indigenous, Spanish, Mexican, and American relationships with the environment. According to evidence summarized by Lightfoot et al. (2013a) Indigenous peoples used fire in this region during the last 1,300 years to enhance the extent and productivity of grassland seed foods through the maintenance of coastal prairies. These resource stewardship practices are argued to be part of sophisticated stewardship practices which may have been necessary to sustain increased anthropogenic pressures on the environment during the Late Holocene (Cuthrell 2013). They also likely reflect indigenous worldview, resource management and land ownership, and long-term stewardship of the environment (Lepofsky and Caldwell 2013).

This research program incorporates multiple lines of evidence to understand the Historical Ecology of landscapes in this area, providing crucial information to the Amah Mutsun for restoring traditional ecological knowledge and resource management practices as well as to California State Parks ecological restoration efforts. Much of this work has focused on the study of traditional resource management (TREM) practices employed to enhance terrestrial resources in the Late Holocene on the coast of Santa Cruz and San Mateo counties. To address questions of tribal interests, our research team is now building upon this work and extending our research foci to marine resources such as small schooling fish, shellfish, and seaweed. To assess this, I propose a Historical Ecological approach using multiple lines of evidence to examine broader regional trends in shellfish harvesting practices through time, incorporating stable isotope analysis and experimental morphometrics to assess changes in seasonality and population size through a comparative, diachronic framework.

Previous work in the study area by Cuthrell (2013) outlines approaches including experimental morphometrics, stable isotope analysis, mussel integrity indices, and the relative abundance of mussel bed associates such as the gooseneck barnacle *(Pollicipes polymerus*) for assessing harvesting practices of mussels that may have led to resource depression, expansion, or stability. This study builds upon this body of work by comparing invertebrate assemblages from Middle and Late Holocene coastal and upland sites to assess whether Native peoples were enacting harvesting practices for shellfish populations analogous to those used on terrestrial resources in the region.

Shellfish and other marine resources such as seaweed and small schooling forage fishes were an important component of Amah Mutsun foodways for millennia, as evidenced by ethnographic and archaeological data (Amah Mutsun 2020a, Cuthrell 2013). However, of over 1000 words in the constantly growing Amah Mutsun ethnobiology database, (a database of tribal ecological knowledge owned by the Amah Mutsun Land Trust compiled using ethnographic and archaeological data), only 34 relate to marine and intertidal resources (Amah Mutsun 2020a). The suppression of traditional ecological knowledge of marine resources is due in part to the forcible removal of the Amah Mutsun from the coast and displacement to Mission's Santa Cruz and San Juan Bautista during the Spanish Mission Period. Many others fled the region and headed further inland to escape the brutal conditions experienced in the missions (Valentin Lopez personal communication 2019; Rizzo 2016). This combined with current restrictions to accessing the coast via private land and restricted harvesting of traditional resources due to policies of public agencies in the past create a scenario with limited opportunity for the Amah Mutsun to access and steward their traditional shorelines. Today, members of the tribe are widely dispersed throughout California, citing both Historical factors of removal and high rent and real estate prices in their traditional homelands as challenges to returning to the Santa Cruz coast (Valentin Lopez personal communication 2019).

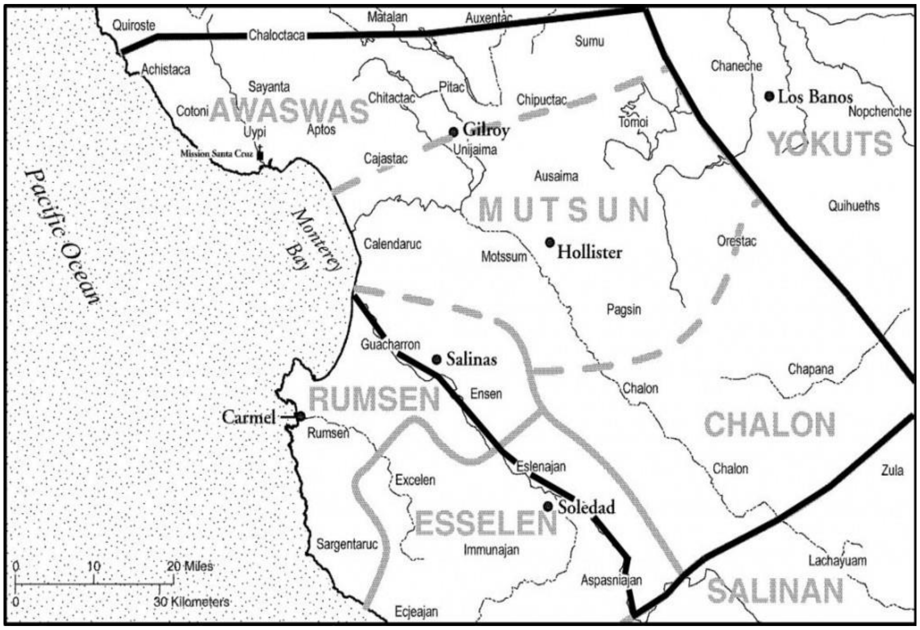


Figure 3.1. Map of Amah Mutsun Territory, (ATMB 2020)

Despite this history of missionization and removal from ancestral lands, the Amah Mutsun Tribal Band (AMTB) are mobilizing ethnographic and archaeological data to aid in awakening dormant knowledge they recognize is critical to restoring and reclaiming their traditional practices and lifeways. This concept of "Dormant Knowledge" was first introduced to our research team by Tribal Chair Valentin Lopez who recounted the shame and historical trauma felt by many Amah Mutsun members who have lost touch with traditional forms of knowledge due to removal from traditional homelands and the lasting effects of colonialism. Lopez maintains that this knowledge is not lost but lying dormant and awaiting rediscovery and revitalization. According to the Amah Mutsun creation story, Creator bestowed upon them the duty to steward their lands and the plants and animals that relied on them. That obligation was never rescinded, regardless of missionization, removal, and the struggles they face in returning to their traditional territories (Lopez 2013). To that end, the Amah Mutsun Tribal Band and Land Trust (AMLT) are now making efforts to revitalize dormant Traditional Ecological Knowledge, partnering with researchers at the UC campuses at Berkeley and Santa Cruz using eco-archaeological data to inform and restore Ancient traditional resource management practices in their traditional territories.

Understanding Ancient methods of mussel harvesting can be directly applied to current efforts to restore connections to coastal resources and food sovereignty for the Amah Mutsun. Access to and control of the production of cultural foods is a critical factor in food sovereignty and community wellness efforts (Hoover 2018). Within this narrative, archaeology can provide critical information for restoring traditional foodways and revitalizing dormant TEK of the Amah Mutsun by providing insight for reinstating modified TREM practices. Thus, Ancient data can inform new strategies among the AMLT and their Native Stewardship Corps for managing the lands and coasts in their traditional homelands, in close collaboration with archaeologists and ecologists. Evidence of terrestrial foodways practiced by the Amah Mutsun has been aided by information from ethnography, oral traditions, and the archaeological record. Efforts are underway to establish tribal led prescribed burns as a management tool for cultural foods and terrestrial resources. Building upon this applied work, our study hopes to extend the scope of traditional management practices to marine resources, providing the tribe with critical information for their developing Coastal Stewardship Program. This study demonstrates how tightly interwoven marine resource management was with Indigenous foodways and efforts of resistance and persistence. Indeed, one of the sites I include in this study extends well into the Historic period and displays continuity of Indigenous foodways and mussel harvesting practices despite the pressures of colonialism. Such interpretations of hinterland sites are important for increasing our understanding of varied Native responses to colonial pressures, helping to dispel notions of colonial takeover and passive Indigenous societal collapse (Schneider et al. 2012; Panich 2013; Lightfoot et al 2013b)

California Mussels as a Resource

California mussels played a critical role in Native diets for millennia, and have been the subject of much archaeological inquiry, as they are often the most abundant and ubiquitous shellfish taxa in coastal Californian middens (Braje and Erlandson 2009; Erlandson 1988; Jones and Richman 1995). Rich in protein and many vitamins and minerals, California mussels provided key nutrients for diets based primarily on grasslands seed foods otherwise rich in fats and carbohydrates (Erlandson 1988; Cuthrell 2013). These sessile, low trophic level filter feeders are also a very sustainable and easily accessible resource. Though filter feeders can be affected by harmful algal blooms, as displayed by the annually observed mussel quarantine in California from May 1 to October 31 due to an increase in domoic acid (which causes paralytic shellfish poisoning) in their tissues during this period, they can provide a temporally and spatially predictable resource base throughout much of the year (Jones and Richman 1995; Jones et al. 2008). It is also likely that harmful algal blooms or “red tides” were less frequent and intense in the past, due to recent warming sea surface temperatures and the increased presence of nitrogen rich fertilizers in California’s coastal waters resulting from agricultural runoff, though our understanding of Ancient red tide extent and severity is still poor (Waselkov 1987). Work by Jones et al. (2008) suggests year-round harvesting and seasonal stability of mussel on the Central Coast, with most harvesting taking place during the summer months.

There has been considerable research and debate centering on the issue of differentiating the cause of changes in mussel assemblages through time (Braje 2010; Flores 2014; Thakar et al. 2017; Glassow and Wilcoxon 1988), with archaeologists assessing the relative influence and impacts of natural and environmental variability versus human predation on mussel populations. As demonstrated by Thakar et al. (2017), size differences in *Mytilus californianus* populations vary along tidal gradients, with increased growth rates and larger terminal sizes observed in lower tidal elevations and reduced growth rates and smaller terminal sizes observed in higher tidal elevations. This variation within habitats may contribute significantly to variation in mussel size represented in the archaeological record, along with many other zoological factors (Campbell 2015). In their study of mass harvesting of molluscs in coastal environments, Braje and Erlandson (2009) suggest that prey size is not necessarily an accurate measure of prey rank in coastal environments due to habitat variability. They have argued that these interpretations must be backed up by solid archaeological data. Ultimately, interpretations regarding diachronic changes in mussel size as an indication of resource depression or habitat variation must be offered cautiously and in the context of broader patterns of regional prehistory and local ecology (Braje et al. 2017).

Seasonality

The issue of seasonality of shellfish harvest on the California coast throughout the Holocene has been addressed using isotopic ratios of ^{18}O and ^{13}O as a proxy for seasonal harvesting patterns (Eerkens et al. 2013; Jones et al. 2008; Jew et al. 2014). On the Central Coast , previous work by Jones et al. (2008) suggests that coastal people were harvesting mussels nearly year-round during the Middle Holocene. Based on expectations laid out by Thakar and others (2017), a harvest profile of mussels harvested year-round rather than seasonally would likely be comprised of more individuals from higher tidal margins, as year-round harvesters would be subject to more neap tides than seasonal harvesters likely focused on more advantageous spring tides. This study uses isotopic analyses of mussels from Middle Holocene and Late Holocene sites on the coasts of Santa Cruz and San Mateo Counties to assess variation in seasonal harvesting practices through time.

Harvesting Strategies

It has been argued that sessile bivalves can be easily overharvested. If bivalves were intensively exploited over some length of time, then archaeologists expect to see a decrease in mean shell size and an increase in the diversity of lower ranked invertebrate resources exploited through time as a signal of resource depression and intensification (Beaton 1991; Braje et al. 2006; Broughton 1994; Claassen 1998; Erlandson 1988; Rick and Erlandson 2008). However, like plants which are also sessile, filter feeding shellfish can be harvested for either short-term efficiency by taking all of the largest members of a population and gradually depressing the resource, or for long-term productivity by employing methods of sustainable harvest that allow for resource stability (Whitaker 2008). For example, research in the Pacific Northwest documents traditional shellfish harvesting practices which enhance substrate for larval clams which has shown to improve the development, continuity, and sustainability of clam populations through time (Lepofsky and Caldwell 2013; Groesbeck et al. 2013).

Researchers have devoted much time to developing methods for assessing the archaeological signatures of different harvesting strategies of California mussel (Bettinger et al. 1997; Basgall 1987; Cuthrell 2013; Jones and Richman 1995; Whitaker 2008). Two primary methods of harvesting have been proposed and modeled: plucking individual mussels or stripping entire beds. According to a study conducted by Bettinger et al. (1997), plucking is always a superior method of harvesting based on energy expenditure return rates. However, it has been demonstrated (Bouey and Basgall 1991) that return rates for California mussel beds are higher when mussels beds have been periodically disturbed by human predation, similar to some plants (e.g. native grasses) that become more productive when subject to disturbances, such as fires. This could suggest that contexts with high numbers of smaller mussels could have resulted from harvesting and disturbing the same patch, in effect increasing the rate of return of that patch relative to unharvested patches over the long term.

The exploitation of mussel populations for long-term productivity and sustainability via stripping by Native people in California has been proposed by Whitaker (2008). He suggests that stripping entire patches of mussel beds at two-year intervals would result in an assemblage of small to medium (40 mm) mussels. I expect that a two-year interval of mussel harvesting would be evidenced in the archaeological record by an assemblage of small to medium mussels with a seasonally specific range of harvest, suggesting consistent harvesting practices which allow mussels to grow back to a size of around 40 mm before being harvested again. Three small to medium mussels can occupy the same space as one large mussel, according to his study. A patch that can yield six small to medium mussels every four years is therefore more productive than patch with one large mussel. Which is to say, just because smaller mussels show up in the archaeological record does not necessarily mean they are the consequence of resource depression but may simply reflect harvesting strategies focusing on higher tidal margins where mussels tend to be smaller, as noted by (Thakar et al. 2017) and/or that a stripping method of harvesting focusing on smaller to medium sized was being employed. While Bouey and Basgall (1991) suggest that a stripping method of harvest will always be less optimal than plucking larger individuals, stripping could be a component of harvesting strategies aimed to enhance the extent or productivity of locally owned mussel beds over the longer term, where continued disturbance of patches leads to greater net gains over time (Whitaker 2008). This can be compared to terrestrial resource management practices like burning different patches on rotational cycles for grassland production, allowing for fallow periods for regrowth and renewal (Anderson 2005; Cuthrell 2013; Lightfoot et al. 2013a) Just as burning a grassland might temporarily reduce the amount of harvestable food available but eventually lead to greater productivity and returns, so too could a method of stripping harvesting at regular intervals produce greater net gains in the long run, as suggested by Whitaker (2008).

While stripping leaves areas once populated by mussels and their associate species barren until recolonization, which can take up to two years, Claassen (1998) argues that human predation on mussels is unlikely to lead to extirpation of these ubiquitous invertebrates. There are additional reasons that people would strip beds even if it was not the most optimal strategy, such as cultural and individual taste, preferred methods of cooking, ease of transport, or for critical micronutrients such as iron (Bettinger et al. 1997). In order to detect these practices in the archaeological record one must consider several variables including size of mussels harvested, the ability to detect individual harvesting events, season of harvest, as well as the presence of other species associated with mussel beds which suggest stripping events (Cuthrell 2013; Jones and Richman 1995; Whitaker 2008)

Modeling archaeological shellfish remains for nuanced harvesting strategies that may not always operate at maximum efficiency but employ strategies aimed towards long-term productivity can be an elusive task (Lepofsky et al. 2013). Through morphometric analyses of modern and archaeological *Mytilus californianus* specimens, archaeologists have developed multiple regression formulae for estimating the length of individual mussels from anatomical landmarks (Campbell and Braje 2015; Singh and Mckechnie 2015). By making the most of fragmented archaeological remains, the methods can help us reconstruct individual size and harvest profiles through time, which may suggest methods of harvesting for either short-term efficiency or long-term productivity, or both (Whitaker 2008)

To further evaluate evidence for a stripping method of harvesting, I call upon the presence of taxa often considered to be “ridealongs” that share substrate with mussels and frequently clump together in their beds. I propose that the presence of these species in archaeological deposits is indicative of a stripping method of harvest, where entire patches of mussels are removed from their substrate and the animals clumped with them come along for the ride. A plucking method of harvest may also result in a few ridealongs, though likely significantly less than a stripping method. Our analysis indicates a relative abundance of these associated species suggest stripping of beds rather than plucking of individual mussels.

The gooseneck barnacle (*Pollicipes polymerus*) is one of these associates which turns up in assemblages from the sites included in the analysis with increased relative abundance in <8 mm size classes, bolstering evidence of a stripping harvest method as proposed by Cuthrell (2013). The file dogwinkle (*Nucella lima*) is a predatory whelk that preys upon mussels and is also present in most of these assemblages. As previously stated, an increase in lower ranked prey in the archaeological record, such as these smaller-bodied barnacles and snails, is viewed in the archaeological literature as an indication of intensification and resource depression due to increased human harvesting pressures. The presence of the ridealongs, however, may be an exception to that rule, as they would not have been targeted directly for food but end up in the archaeological record as a proxy for other targeted resources (Ainis et al. 2014). As demonstrated by Braje and Erlandson (2009), sites with an abundance of smaller bodied shellfish cannot automatically be considered as evidence of resource intensification but must be considered in the light of broader regional trends and local habitat, such as mussel beds.

Expectations/ Approach

It is likely that there are examples of resource depression of mussel populations as well as sustainable management at local and regional scales, and that these practices may change in an area over time (Jones and Richman 1995; Broughton 1994; Whitaker 2008). Regardless, California mussel was an integral part of Native foodways, and evidence of resource depression or sustainable management practices can help inform current efforts to integrate mussels into Native foodways. This study aims to assess harvesting practices along the central coast spanning over 6000 years to test these hypotheses employing expectations for different harvesting strategies, as outlined in Table 3.1.

Harvesting practices	Expectations	Archaeological Evidence
Stripping	-Small to medium size (40 mm) -Narrow range in size -Seasonally specific -Mussel beds associates would also be removed	-Morphometric reconstructions -Isotopic Seasonality data displaying seasonal trend -Presence/ Absence of ridealongs
Plucking	-Larger size earlier, decrease in size through time -Annual, opportunistic	-Morphometric reconstructions -Isotopic Seasonality data displaying no seasonal trend -Presence/ Absence of ridealongs

Table 3.1. Table outlining measurable expectations for detecting harvesting practices

This study uses a diachronic, comparative approach to assess changes in *Mytilus californianus* population size collected from several sites along the coast of Santa Cruz and San Mateo counties to detect harvesting practices and resource exploitation through time. I expect that the presence of a wide range of size classes with small to medium average size is likely indicative of a stripping method of harvesting. I also expect that harvesting profiles occurring at two-year intervals, as evidenced by morphometric and stable isotopic analysis, are also indicative of a stripping method of harvesting. Furthermore, assemblages with a significant presence of non-dietary, ridealong species associated with mussels may be indicative of stripping practices and/or the harvesting of other marine resources such as kelp and seaweed. For detecting plucking harvesting practices, I expect to see a decrease in shell size through time with non-seasonally specific harvesting practices. I also expect to see a greater average size and greater minimum size in the earliest deposits at shell midden sites.

Considering these expectations and prior research, I investigate the following questions: Can I detect discreet harvesting practices of *Mytilus californianus* in these archaeological deposits? Do these data suggest resource depression or stability and sustainability of mussel populations over time? How can his data inform contemporary Indigenous stewardship practices and restore Traditional Ecological Knowledge for the Amah Mutsun Tribal Band?

Methods and Materials

This study analyzes data from three sites within Amah Mutsun territory with dates ranging from 4750 BCE to 1700 CE, as outlined in Figure 3.2. As part of a collaborative approach and in keeping with the tribe's request to minimize impacts to ancestral sites, we employ low-impact, surgically precise field methods to avoid disturbing sensitive cultural materials. This begins with surface pedestrian survey, followed by systematic "catch-and-release" surface survey technique (Gonzalez 2008). This includes the use of minimally invasive geophysical survey techniques including ground penetrating radar, electrical resistivity, and magnetometry. These approaches provide high resolution of subsurface features such as house floors, burials, and middens lenses, which guides placement of subsurface sampling. In some cases, augers are used to assess site depth, integrity of deposits, and terminal dates. Opportunistic column sampling was employed when midden deposits were eroding from exposed faces. Finally, limited excavation units were used to reduce impacts to the sites and the possibility of disturbing sensitive materials. Members of the Amah Mutsun Stewardship Corps participated in each phase of this process, learning these methods and providing non-tribal members with critical Indigenous perspectives and cultural knowledge.

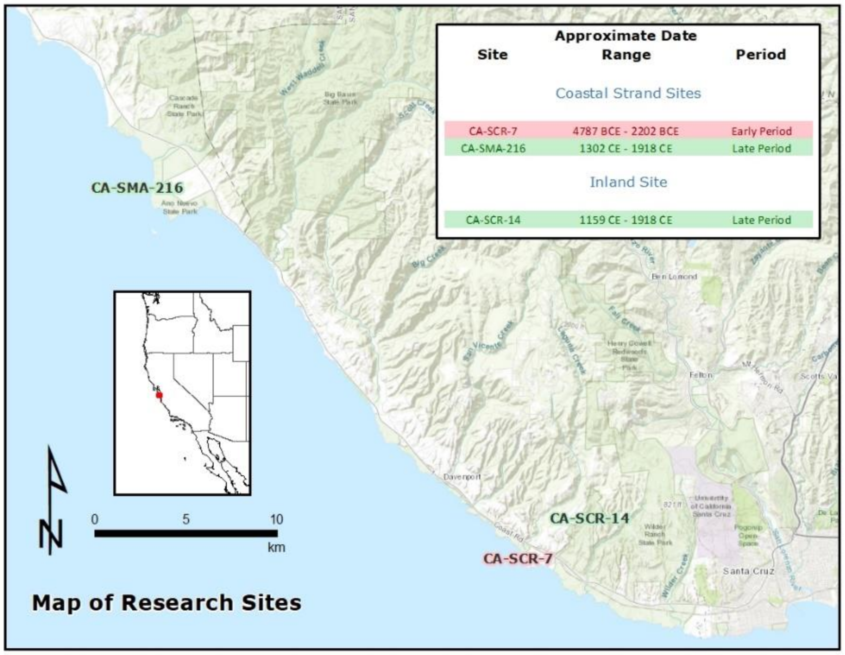


Figure 3.2 Map of study area and sites sampled (Map by Alec Apodaca)

Bulk sediment samples from column samples and excavation units were processed via flotation methods developed by Dr. Rob Cuthrell to separate light and heavy fraction materials. Sorting of 1-2 mm, 2-4 mm, 4-8 mm, and >8 mm heavy fraction materials separated with Tyler sieves was conducted in the California Archaeology Lab at UC Berkeley. Invertebrate remains were then separated from the >4 mm size fraction, as smaller fractions were generally composed of highly fragmented shell that would be too time intensive to sample based on the quality of data it might yield. However, the 2-4 mm were sorted exclusively for non-dietary gastropods, which provide proxy data for seagrass and kelp harvesting practices (Ainis et al. 2014). Shell remains were identified with the aid of comparative collections housed in the California Archaeology Lab. Quantitative measures included weight, relative abundance, density (grams of shell/ liter of soil, listed as g/l) and MNI for taxon with non-repetitive elements. Bivalve MNI counts were determined by counting all umbos and dividing by 2, whereas MNI for gastropods was determined by specimens that either retained their apices or columella’s. Data regarding radiocarbon dates are further presented in Appendix A.

Site Comparisons

Sites	**Site Type**	**Age Range**	**Most Abundant**	**Second Most**	**Third Most Abundant**
CA-SCR-7	Coastal Midden	4787BCE-2202BCE	*Mytilus ca* (70.4%)	*Balanus spp.* (28.7%)	*Pollicipes polymerus* (.9%)
CA-SMA-216	Coastal Midden	1302CE-1640CE	*Mytilus ca (40.9%)*	*Tegula funebralis (37.4%)*	*Mopalia spp.* (8.3%)
CA-SCR-14	Upland Village	1159CE- 1918 CE	*Mytilus ca* (93.2%)	*Balanus spp.* (2.9%)	*Pollicipes polymerus* (1%)

Table 3.2. Table outlining most abundant shellfish taxa by site

Taxa from all sites display a heavy reliance on marine resources in the Middle Holocene through to Late Holocene, evidenced by a broad range of species which span the entirety of the intertidal zone. CA-SCR-7 invertebrate assemblages are characterized by a wide range of intertidal resources, though primarily dominated by mussel and barnacle. Of the seven columns and two augers analyzed from CA-SCR-7, *Mytilus californianus* and *Balanus spp*. were ubiquitous and high in relative abundance throughout all samples and levels. The average density of shell in these samples was 87.4 grams of shell per liter of soil, with a range of 35.06 g/l to 135.26 g/l. *Mytilus ca*. remains in the assemblages comprise 70.4% of the 12,197.6 grams of invertebrate remains sorted from all samples. In smaller size fractions (4-8 mm, 2-4 mm) a much greater diversity of intertidal taxa was represented, especially limpets, leaf barnacles, chitons, urchins, and turban snails, suggesting broad spectrum and intensive harvesting of shoreline resources. Mid Holocene aged CA-SCR-7 is a multicomponent site with midden and hearth features, and invertebrate assemblages from this site can be interpreted as the result of processing, cooking and discard. The column samples analyzed in the study were taken from the northwest side of the site (see Figure 3.3), from an eroding midden with radiocarbon dates spanning nearly 3000 years across the Middle Holocene.

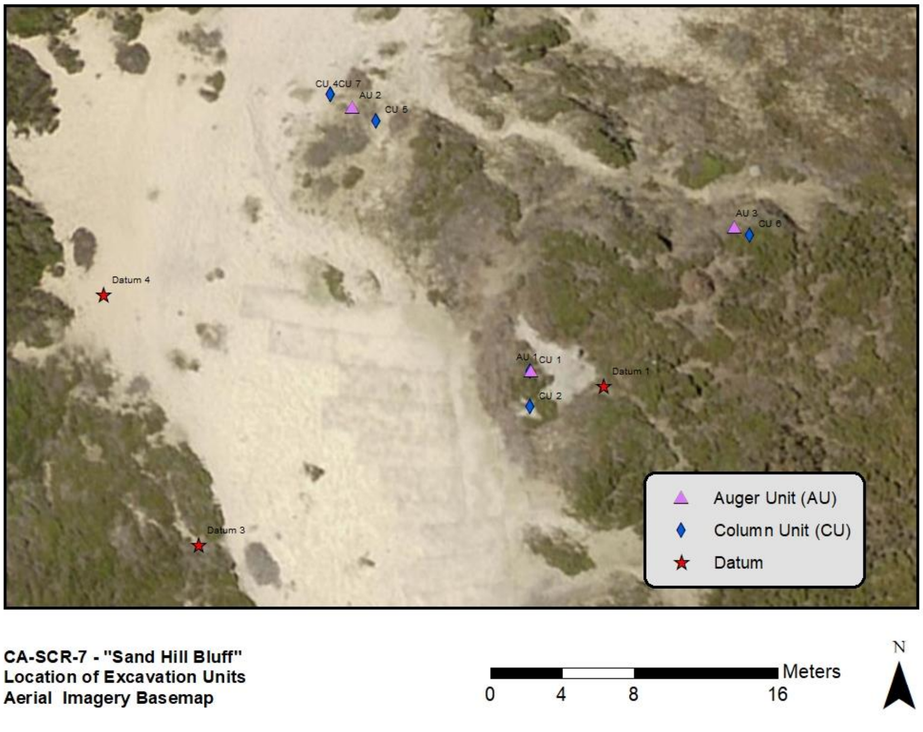


Figure 3.3. Map of samples taken from CA-SCR-7 (Map by Alec Apodaca)

CA-SMA-216 evidences a diverse assemblage of intertidal invertebrate remains with much greater density and relative abundance of *Tegula funebralis* than other sites (see Table 3.2), consistent with expectations of resource intensification and focus on lower ranked marine species in the Late Holocene, though mussels still dominated at 40.9%.

Two excavation units from CA-SCR-14, another Late Holocene site upland from CA-SCR-7 yielded a great diversity of intertidal species. Unit 2 had a high density of shell at 68.4 grams per liter and the greatest diversity of invertebrate taxa represented of all samples taken from all sites. While *Mytilus californianus* (93.2%) and *Balanus* spp. (2.9%) were again the most abundant taxa represented (Table 3.2), other taxa such as limpets, chitons, urchins, whelks, and turban snails were present in low quantities in nearly all levels. Purple sea urchin, (*Strongylocentrotus purpuratus*) was ubiquitous in the unit, as well. Field workers collected 1132 Mytilus umbos from this unit, which will provide evidence for mussel harvest profiles through time. The mussel bed associate *Pollicipes polymerus* was present in all the assemblages, with an increased presence in fractions <8 mm.

CA-SCR-7 appears to be a multi-component site, with a rich assemblage of artifactual and ecofactual remains and features, suggesting processing, cooking., and habitation for thousands of years. Differences between Late Holocene site assemblages from CA-SCR-14 and CA-SMA-216 likely reflect differences in settlement patterns as well as processing and transport of shellfish rather than widely different harvesting practices. The abundance and diversity of intertidal invertebrates in assemblages from coastal CA-SMA-216 suggests that this was specialized processing site for shellfish and other marine resources. CA-SCR-14 is an upland village site with a diverse artifact assemblage and relatively homogenous invertebrate assemblage comprised mostly of California mussels. Other studies have shown that bivalves, such as mussels, transport well because of their ability to seal themselves retain moisture longer than most other marine invertebrates (Jazwa et al. 2013), suggesting that differences in these assemblages may be more a factor of processing and transport than harvesting and subsistence practices. Mobility on the landscape, well-defined tribal territories, and resource processing/ transport strategies were surely important components of Indigenous lifeways in the Late Holocene, and likely account for great variability between coastal and upland assemblages and subsequent interpretations regarding subsistence practices and localized resource management (Hylkema 1991).

Using *Mytilus californianus* umbos to reconstruct harvest profiles

Recent research on mussel assemblages have resulted in multiple regression formulae to make the most of fragmented *Mytilus ca.* remains, providing one approach for measuring mussel umbones to reconstruct individual size (Campbell and Braje 2015; Singh and McKechnie 2015). While there is some debate about the use and interpretation of these formulae (Campbell 2015; Singh et al. 2015), they appear to be an effective way to estimate mussel size using archaeological materials. These formulae were developed using modern comparative specimens collected in Southern California. Due to the observed biogeographical morphological variation of *Mytilus ca*. north and south of Point Conception (Glassow and Wilcoxon 1988), I developed my own experimental morphometric formulae from n=151 modern specimens collected from Pescadero State Beach by Dr. Rob Cuthrell. After measuring the same elements used by Campbell and Braje (2015) and Singh and McKechnie (2015), I also decided to use umbo thickness as it tends to be the most well preserved in archaeological specimens and had a strong correlation, as outlined below in Figure 3.4.

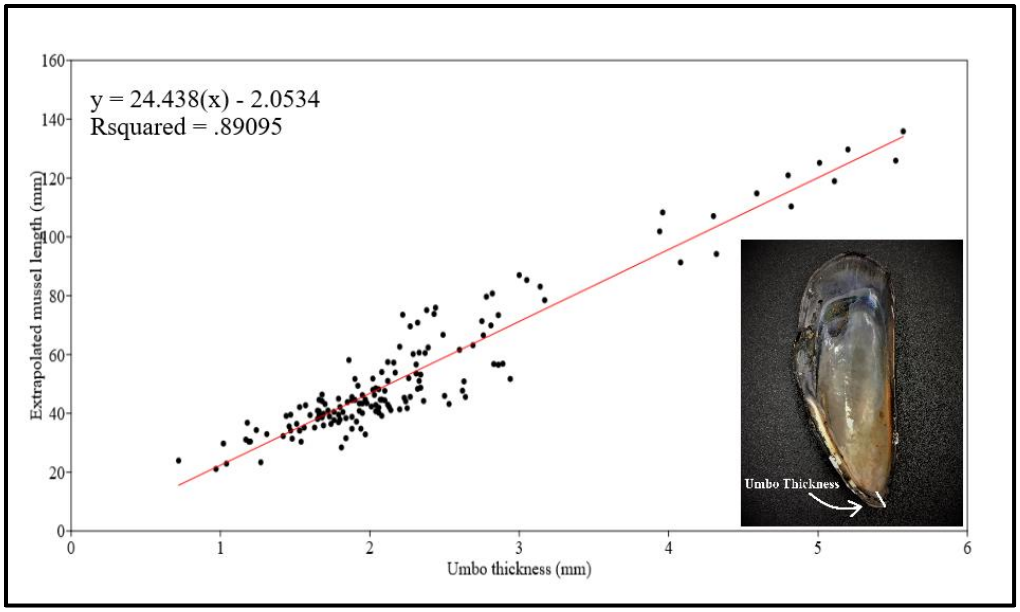


Figure 3.4. Graph depicting regression formula for predicting total mussel length from umbo thickness

In order to further understand the archaeological signatures of mussel harvesting practices I conducted stable isotope analysis of mussel shells from the contexts sampled in the morphometric study. For brevity and simplicity, the results are summarized below, with a full experimental study in preparation for a future publication.

Using δ^{18}O isotopes in *Mytilus californianus* to Estimate Season of Harvest

Stable oxygen isotopic ratios in biogenic carbonate has been used for several decades to reconstruct paleoclimate records, land use, settlement patterns, and subsistence strategies. Archaeological studies of shellfish harvesting practices often incorporate the isotopic composition of shell carbonate to reconstruct seasonal harvesting patterns (Eerkens et al. 2013; Jew et al. 2013; Jones et al. 2008; Leng and Lewis 2016). These studies typically determine the season of death of individual specimens by comparing the temperature conditions (estimated from an oxygen isotope ratio-temperature regression relationship) under which the terminal growth band (TGB) formed and the apparent temperature trend, based on samples from preceding growth bands. These data are then compared to changes in sea-surface temperature (SST) over the course of the year in the location where the specimens were likely gathered. Historical SST data was used to calibrate an estimator for season of death as a function of mean temperature and temperature trend as recorded in distal growth band oxygen isotope values. This method is employed to examine the seasonality of mussel harvesting for the shellfish assemblages analyzed for CA-SCR-7, CA-SMA-216, and CA-SCR-14.

The goal of the study was to compare and predict season of death from the mean temperature values of 200 stable oxygen isotope (δ^{18}O) microsamples taken from the distal growth bands of archaeological mussel (*M. californianus*) samples (n = 40) from the three coastal and upland sites dating from the Middle Holocene to Late Holocene. First, 100 years of instrumental sea surface temperature data was normalized to remove the linear increasing scale caused by modern warming trends. Second, temperature trends were simulated in a *M. californianus* population to statistically evaluate seasonality hypotheses. Third, a standard nonlinear least squares regression was employed as a predictor for the mean temperatures recorded in archaeological isotopic oxygen microsample transects.

The stable oxygen isotope geochemistry of (*n* = 40) archaeological *Mytilus californianus* specimens was analyzed to estimate the seasonality of mussel harvesting at CA-SCR-7, CA-SMA-216, and CA-SCR-14. The selection of specimens for analysis was done systematically and based on meeting three parameters: 1) a visible terminal growth band (TGB) on the specimen, 2) the specimen is from intact deposit with established AMS dates, and 3) the specimen is free of any observable pre-and-post life trauma, pathology, or modification (*e.g.* burned, predation scars). Once prepared, samples were submitted to the Stable Isotope Geochemistry Lab at UC Berkeley for analysis. The modeling of this data will be presented elsewhere, but here relevant data is presented for further interpretations regarding the harvest profiles of mussel in in the study area.

Results

To assess mussel harvesting practices I consider morphometric data, stable isotope analysis, and ridealong presence to model mussel harvesting profiles through time (presented in Table 3.9). First, the morphometric formula was applied to n=2901 umbones from SCR-7, SCR-14, and SMA-216 (spanning 4787 BCE to 1918 CE). The results of the estimated size ranges of the mussels for different phases of occupations within sites are outlined below in Figures 3.5-3.10 and Tables 3.3-3.8 below. Figures 3.5-3.10 present the morphometric data in boxplots with Tukey's honestly significant difference test (HSD) to assess statistical significance of variation and trends in the estimated size of mussels over time. Tukey's HSD tests can be used to compare the differences in the means of values of multiple groups, making them ideal for comparing mean estimated sizes from multiple stratigraphic levels within an archaeological context and determining whether there are statistically significant differences between these means. The circles on the right side of these graphs, labelled All Pairs Tukey-Kramer .05, reflect this variation, with the size of the circles representing relative size of a group of data (i.e. number of umbos measured per level) and the overlap or lack thereof reflecting statistical variation. Simply put, variation is displayed by overlap of the circles, with considerable overlap reflecting no significant differences and little to no overlap reflecting significant difference. I follow this with an analysis of n=40 stable isotope samples taken from mussel shells within the same contexts as those used in the morphometric study. Finally, these data are considered alongside ride-along presence in assemblages from each site and compare these three lines of evidence to the expectations laid out in Table 3.1 to integrate and interpret harvesting profiles in Table 3.9.

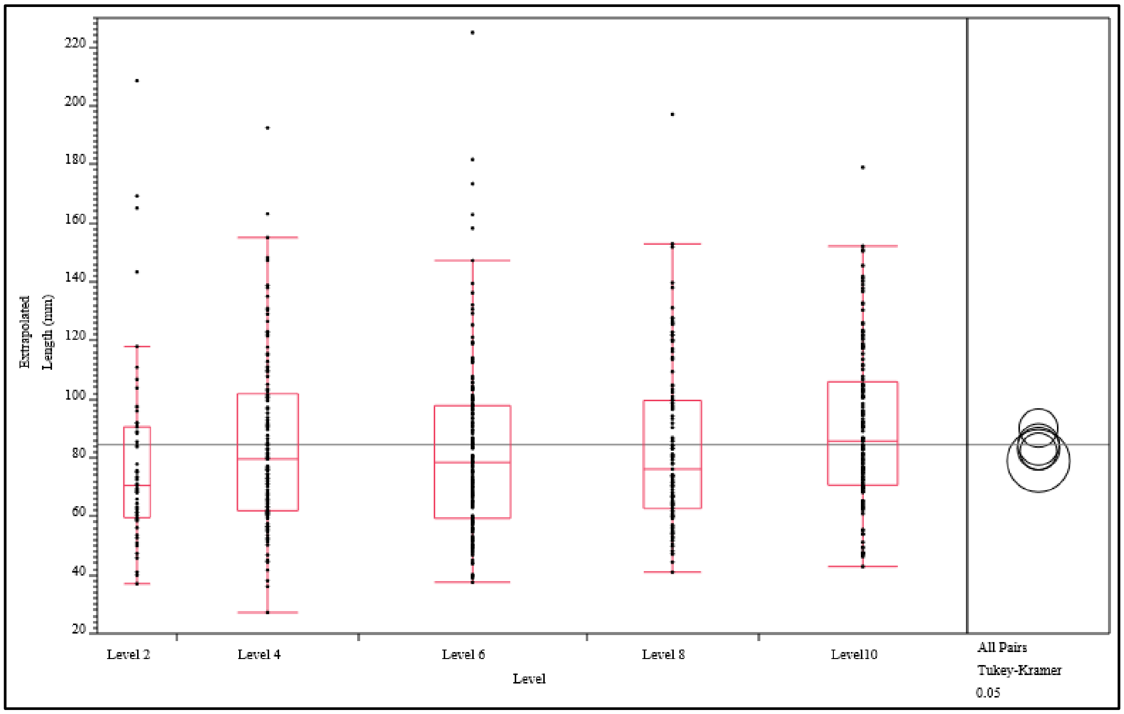


Figure 3.5. CA-SCR-7 Column 1; 2202 BCE-3776 BCE; n total = 603

Level	Age	N=	Average size	Std. dev.
2	2300-2202 BCE (0.99)	55	7.9 cm	3.0 cm
4	2286-2246 BCE (0.43); 2235-2195 BCE (0.36); 2173-2145 BCE (0.19)	126	8.5 cm	2.9 cm
6	2579-2488 BCE	158	8.2 cm	2.9 cm
8	3635-3621 BCE (0.13); 3606-3522 BCE (0.87)	119	8.3 cm	2.8 cm
10	3776-3694 BCE (0.97)-	145	9.0 cm	2.7 cm

Table 3.3. Average sizes of mussel from column 1 at CA-SCR-7

The results of the analysis of column 1 from CA-SCR-7, which was taken from the northwest side of the midden from an eroding face, are outlined in Figure 3.5 and Table 3.3. The mean size of mussels in all levels averaged over 7 cm, with a slight decrease in average size over time, though the Tukey's HSD does not suggest that this is a significant decrease. These results are consistent with expectation of a plucking style of harvest, which would target larger mussels in a population and gradually depress the resource, leading to decreased size.

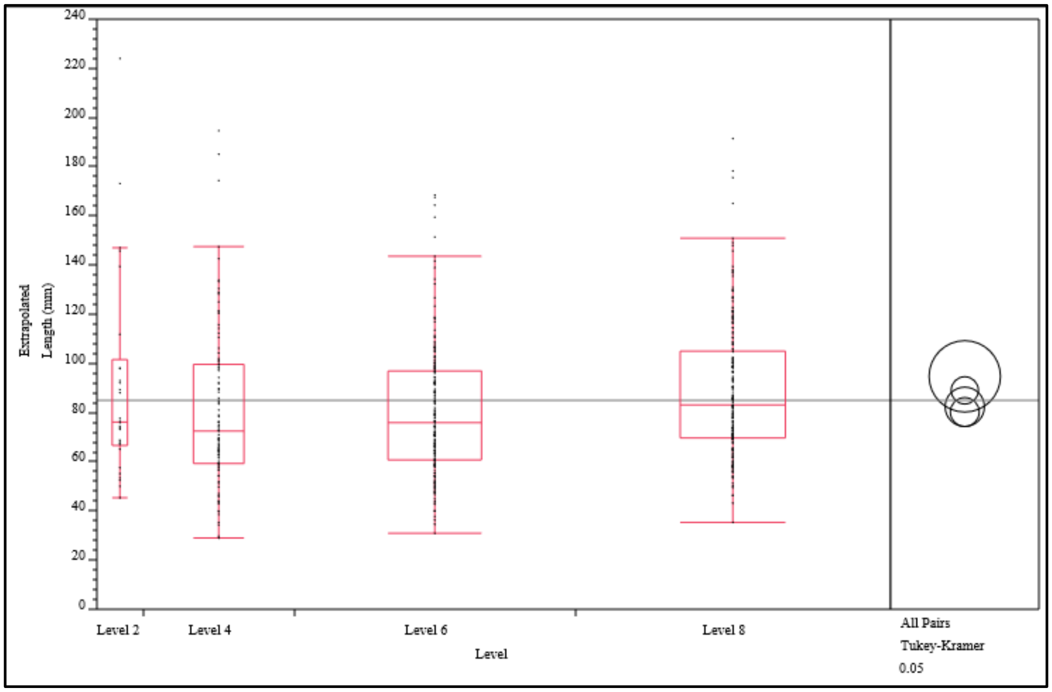


Figure 3.6. CA-SCR-7 Column 2; AMS Date Range: 2418 BCE- 3939 BCE; n total=520

Level	Age	n=	Average size	Std. Dev.
2	NA	30	9.5 cm	4.7 cm
4	2457-2418 BCE (0.09)	99	8.0 cm	3.7 cm
6	2463-2335 BCE (0.93); 2324-2303 BCE (0.07)	184	8.2 cm	2.7 cm
8	3939-3869 BCE (0.61); 3813-3765 BCE (0.38)	207	8.9 cm	2.7 cm

Table 3.4. Average sizes of mussel from Column 2 at CA-SCR-7

The results of the analysis of column 2 from CA-SCR-7, which was also taken from the on the northwest side of the midden from an eroding face, are outlined in Figure 3.6 and Table 3.4. The mean size of mussels in all levels average 8 cm or higher, with no significant decrease or increase in size through time. This profile is consistent with expectation of a plucking style of harvest, as evidenced by large average mussel size. However, the data does not indicate any reduction in size through time.

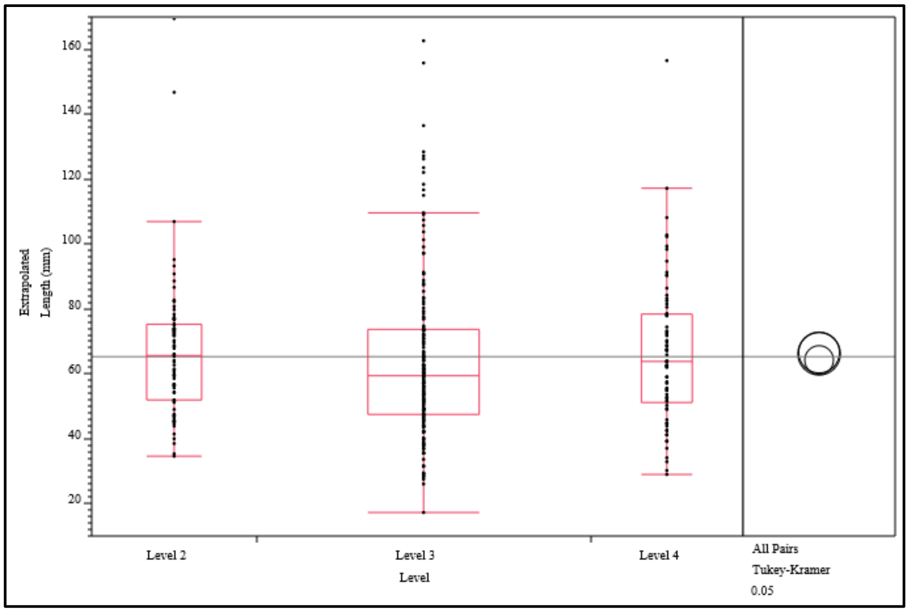


Figure 3.7. CA-SCR-7 Column 7; AMS Date Range: 4555 BCE-4787 BCE, n total = 316

Level	Age	n=	Average size	Std. Dev.
2	4686-4577 BCE (0.90); 4575-4555 BCE (0.10)	162	6.7 cm	2.1 cm
3	4780-4694 BCE	80	6.4 cm	2.6 cm
4	4787-4713 BCE	74	6.6 cm	2.2 cm

Table 3.5. Average sizes of mussel from column 7 at CA-SCR-7

The results of the analysis of column 7 from CA-SCR-7, which was taken from the northwest side of the midden, are presented in Figure 3.7 and Table 3.5. The average size of mussels stays between 6.4 and 6.7 cm in all the contexts sampled, suggesting resource stability through time that may have been the result of both stripping and plucking harvesting. The average size is smaller than other contexts sampled from CA-SCR-7, which is interesting because this column is the oldest context sampled, suggesting mussel size did not significantly decrease through time at CA-SCR-7. In sum, in examining the three plots for CA-SCR-7, it appears a wide range of mussel sizes in earlier assemblages from SCR-7, yet no statistically significant difference in mean size of individuals harvested from 6500 to 4000 BP, suggesting stability in mussel harvesting practices in this region during the Middle Holocene. However, the average mussel size from CA-SCR-7 is considerably larger than the assemblages from CA-SCR-14 and CA-SMA-216, which may be indicative of resource depression over time and a combination of plucking and stripping harvesting practices represented in the CA-SCR-7 assemblages. The standard deviation of mussel sizes is also greater for CA-SCR-7, displaying a wider range in sizes which may also indicate a combination of stripping and plucking harvesting practices.

The results of the analysis of unit 2 from CA-SCR-14 are presented in Figure 3.8 and Table 3.6 below. The data displays a statistically significant increase in the average size of mussels through time, with most mussels falling in the small to medium size range, consistent with expectation of a stripping method of harvest and resource stability. As previously mentioned, the average size of mussels from CA-SCR-14 is much smaller than CA-SCR-7, suggesting that people in the Late Holocene may have been interacting with a coastal environment that had been subject to resource depression of mussel by previous inhabitants. The same could be said for the mussel assemblage at CA-SMA-216.

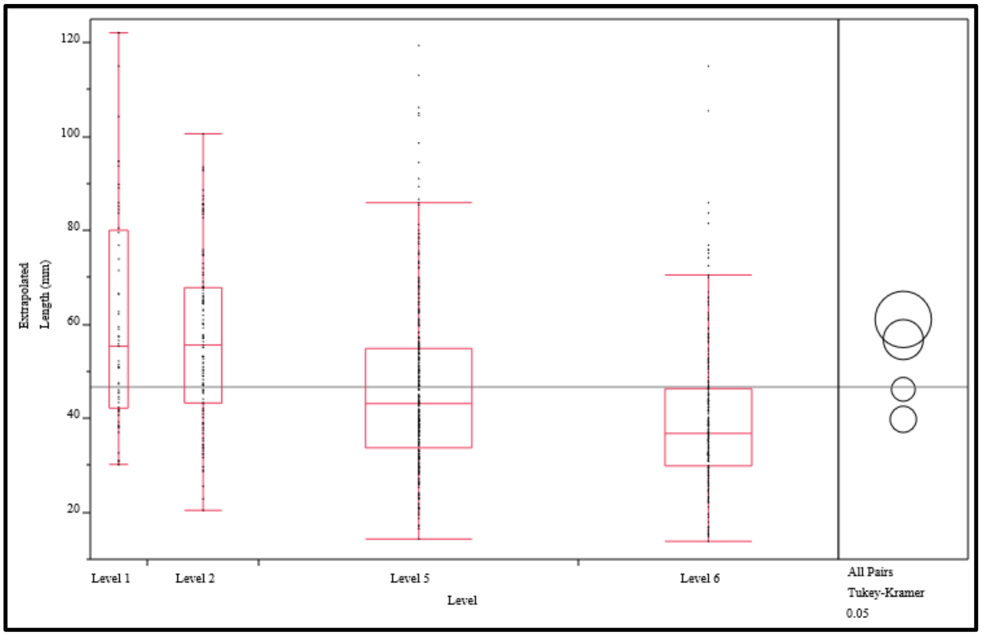


Figure 3.8. CA-SCR-14 Unit 2 AMS Range 1159 CE- 1918 CE; N total= 696

Level	Age	n=	Average size	Std. Dev.
1	NA	55	5.9 cm	2.4 cm
2	1695-1726 CE (0.27); 1813-1838 CE (0.20); 1868-1918 CE (0.49)	113	5.7 cm	1.8 cm
5	1267-1411 CE	321	4.6 cm	1.8 cm
6	1159-1212 CE	262	4.0 cm	1.5 cm

Table 3.6. Average size of mussel from Unit 2 at CA-SCR-14

The results of the analysis of area 1 and 2 at CA-SMA-216 are outlined in Figure 3.9 and Table 3.7, which displays and increase in the average size of mussels through time, with most mussels falling in the small to medium size range, consistent with expectation of a stripping method of harvest and resource stability during the Late Holocene.

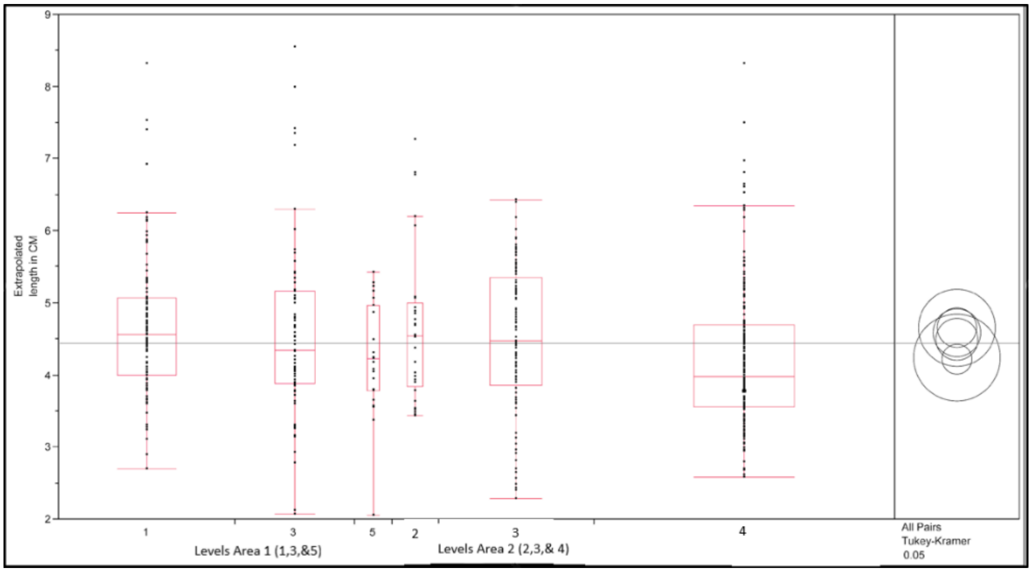


Figure 3.9. Area 1 and 2 CA-SMA-216: AMS Range 1302 CE-1640CE; n total= 796

Area/ Level	Age	n=	Average size	Std. Dev.
1/1	NA	186	5.0 cm	1.5 cm
1/3	1302 CE-1420CE	105	5.2 cm	1.8 cm
1/5	NA	27	4.8 cm	1.1 cm
2/2	NA	37	4.7 cm	2.1 cm
2/3	1460CE-1640CE	129	4.9 cm	1.8 cm
2/4	NA	312	4.5 cm	1.4

Table 3.7. Average of mussel from Area 1 and 2 at CA-SMA-216

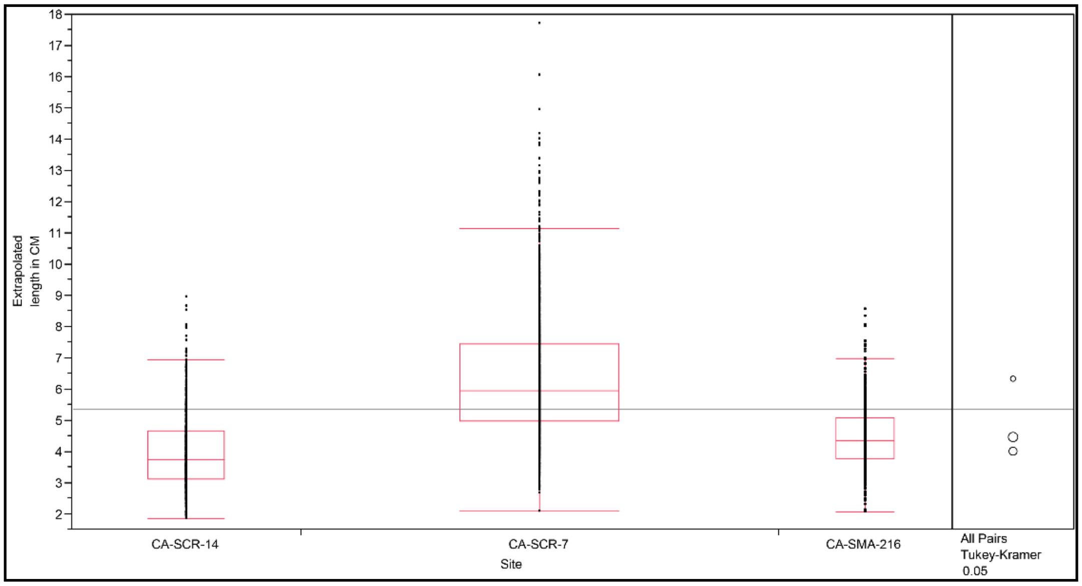


Figure 3.10. Comparison average mussel size between sites displaying statistically significant differences between sites

Site	Age	n=	Average Size	Std. Deviation
CA-SCR-7	4787BCE-2202BCE	1409	8.0 cm	2.9 cm
CA-SMA-216	1302CE-1640CE	796	5.0 cm	1.9 cm
CA-SCR-14	1159CE- 1918 CE	696	4.7 cm	1. 8 cm

Table 3.8. Average sizes of mussels from all three sites

Comparison of Harvesting Patterns at the Three Sites

As displayed in Figure 3.10 and Table 3.8, the average size of mussels is significantly greater at CA-SCR-7 than CA-SCR-14 or CA-SMA-218. This trend suggests that the mean size of mussels decreased in size over time from Middle Holocene to Late Holocene times consistent with expectations of resource depression through time. However, while there is a smaller average size in the two Late Holocene sites, the average size increases slightly through time at these sites. These data suggest that people may have employed harvesting methods that maintained the stability of the mussel populations over several centuries in Late Holocene times. There is also a greater density of umbones per sample in the two Late Holocene sites, which may suggest mass harvesting events of greater numbers of individuals mussels than in earlier sites. These harvesting profiles may be indicative of a stripping method of harvesting, as laid out by Whitaker (2008), which could account for both the reduced size and greater number of individuals per context. The standard deviation of mussel size is also less for CA-SMA-216 and CA-SCR-14, consistent with expectations of a stripping method of harvest. When compared to CA-SCR-7 there is a higher standard deviation of mussel size, which may be indicative of plucking larger members as well as stripping entire beds. When considered alongside the results from the following study on seasonality of these contexts, broader interpretations can be drawn regarding harvesting practices through time.

Seasonality of Mussel Harvests

To add another line of evidence to the study of mussel harvesting practices, stable isotope data from *Mytilus* shells in these contexts to assess season of harvest was modeled. Figure 3.11 shows maximum likelihood reconstruction of mussel harvest dates. Each colored dot represents one of the 40 mussel shells sampled for oxygen isotope analysis and is positioned at the date on which that specimen is estimated to have been harvested. This is based on a regression equation relating harvest date to reconstructed sea surface temperature (SST) at time of harvest using modern SST data collected at Hopkin's Marines Station to establish seasonal variation in water temperature and its influence on stable isotope ratios in mussel growth bands. Due to random variation in seasonal SST and mussel growth rates, this maximum likelihood estimate comes with error bars. (Imagine a bell curve centered on each colored dot.) However, since it is reasonable to expect that these errors are uncorrelated, a reasonable estimate of harvest seasonality can be obtained by averaging those per-specimen bell curves together to generate the site-specific (black, red, and purple lines) and collective (gray fill) harvest likelihood curves shown in Figure 3.11. (Note that this reconstruction relies not on the individual harvest date estimates themselves, but instead on the distribution of these estimates over the year.)

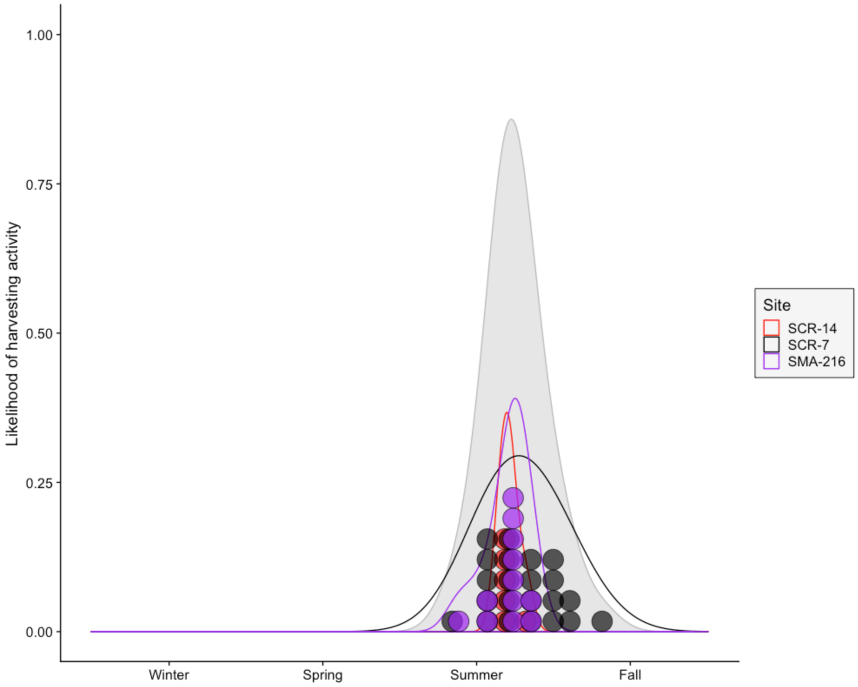


Figure 3.11. Reconstruction of seasonal harvest profiles from archaeological mussel

This analysis reconstructs the bulk of mussel harvesting activity from early August through mid-October. Since the sample was by no means exhaustive, I cannot discount the possibility that further sampling of mussel remains from these sites might reveal specimens harvested during other times of the year, other than early fall. However, given that none of the samples analyzed here appear to have been harvested outside of this range, and that this reconstruction broadly agrees with the metrical and ecological data presented above, I feel that confidence in these preliminary conclusions is warranted. Further statistical analysis will be pursued in a subsequent publication, including corrections for potentially confounding biological and paleo-oceanographic factors.

Discussion

The observed reduction in mussel size over time from the Middle Holocene at CA-SCR-7 to the Late Holocene at CA-SMA-216 and CA-SCR-14 is consistent with expectations of resource depression, which would expect that people would target larger mussels earlier to optimize foraging returns but eventually deplete the resource and be left with reduced foraging returns on smaller mussels. Despite this observed reduction in mussel size trough time, Late Holocene assemblages provide some interesting insights on how people may have dealt with a mussel population that had been subjected to resource depression during the Middle Holocene. For example, the average size of umbos from Late Holocene occupations at CA-SMA-216 and CA-SCR-14 fit with Whitaker's (2008) expected two-year harvest profile, with the average extrapolated length of mussels around 40 mm and displaying a seasonally consistent harvesting trend of late summer/ early fall for both sites. This would follow expectations of a stripping method of harvesting that could provide greater long-term productivity by focusing on harvesting small to medium sized mussels at regular intervals. The slight but gradual increase in size of mussels through time in the Late Holocene sites suggests stability and sustainable harvest of this resource rather than depression. When considered alongside seasonality assessments, these data would suggest that during the Middle Holocene people were harvesting medium to large mussels with a combination of plucking and stripping practices in the early fall. In Late Holocene times, these data suggest people were harvesting small to medium mussels in the early fall using a stripping method of harvesting, as outlined in Table 3.9.

Site	Size	Seasonality	Ridealong Presence	Interpretation
CA-SCR-7	Large	Early Fall	Abundant	Plucking AND Stripping
CA-SCR-14	Medium	Early Fall	Abundant	Stripping
CA-SMA-216	Medium	Early Fall	Abundant	Stripping

Table 3.9. Interpretations of harvesting practices from all sites based on size, seasonality, and ridealong presence

This interpretation is further suggested by Indigenous TEK of mussel harvesting resuming when elderberries ripen, typically in early fall and continuing throughout the year during months with an R (September-April) (Anderson 2005). Rather than depleting their resources, perhaps the people who lived in these coastal environments were refining their harvesting methods to account for increases in populations, enacting practices that may have coincided with their preferences and long-term plans. They also may have been dealing with an environment that had been subject to resource depression from increased anthropogenic pressures in the past and learning from these lessons to develop and implement more sustainable methods of harvesting mussels. These practices may not have always operated at maximum efficiency but could employ long-term strategies as a component of seasonally flexible foodways that demonstrate a deep understanding of dynamic seascapes. Of course, interpretations of harvesting practices signaling management strategies must be made cautiously and consider broader regional trends, which point towards intensification and resource depression of intertidal resources in the Late Holocene (Beaton 1991).

Conclusion

Developing archaeological research programs for assessing the management of shellfish populations in the absence of physical features such as rock terraced clam gardens is still incipient, though some have laid out expectations for what these signatures may look like (Whitaker 2008). Interpreting evidence of resource intensification, depression, expansion, stability, or management may also be largely influenced by theoretical underpinnings and data modeling. Future directions in this line of inquiry should include a larger number of coastal sites dating to Middle and Late Holocene times, the integration of more seasonality assessments using stable isotope geochemistry to enhance the resolution of invertebrate harvesting profiles through time, as well as building a better comparative data base of sites assemblages along the coast into a similar research program.

This work also addresses goals of applied collaborative archaeology and community engaged research with the Amah Mutsun Tribal Band. The data recovered during this project has implications and applications for the Amah Mutsun Land Trust and their developing Coastal

Stewardship Program. Such an intensive focus on marine resources, coupled with terrestrial resource management practices reflects a deep level of engagement with their environment from sea to summit prior to European contact. Instances of resource depression and over exploitation can serve as a cautionary tale, while evidence of sustained management can provide a model for addressing contemporary issues in fisheries management and developing stewardship practices based on traditional ecological knowledge and resource management for the present and future.

Chapter 4:

Coast Miwok Stewardship of Clam Beds in Tomales Bay: An Eco-Archaeological Investigation

Introduction

Clams have been an important resource along the Pacific coast of North America for thousands of years. Their savory meat has been the stuff of soups, stews, and bakes, while their shells have been used for a vast array of technological, monetary, and symbolic purposes. A discussion of coastal cuisine is incomplete without mention of the many varieties of clam that inhabit the waters of the Pacific coast and the myriad ways people have been interacting with them for millennia. However, since the onset of European colonization, these waters have undergone the introduction of non-native species, pollution from agricultural and industrial runoff, ocean acidification, coastal development, and policies which infringe upon traditional ecological knowledge and resource management practices of Native peoples who interacted closely with clam populations for thousands of years.

Background

A robust corpus of research from the Pacific Northwest Coast region highlights the role of aquaculture practices of First Nation people and implications for local ecosystems, long-term sustainability, and the construction of "clam gardens" to increase food productivity (Ames 1994; Cannon and Burchell 2008; Erlandson and Moss 2001; Lepofsky and Caldwell 2013; Lepofsky et al. 2015; Groesbeck et al. 2014; Menzies 2006) and efforts are underway in parts of this region to continue traditional Indigenous management practices that have proved to increase fish and shellfish abundance. There is also evidence for the stewardship of clam gardens in California. Along the Central Coast of California in Tomales Bay, ethnographic sources and Coast Miwok elder accounts document the presence and management of clam beds by Native people before, during, and after European colonization (Baker 1992; Collier and Thalman 1996; Ortiz 1998; Gilbert Zoppi personal communication 2019). This information is vital for understanding the past, present, and future of human relationships with clams in this region, and along the entire Pacific coast.

While archaeological investigations of Indigenous landscape management practices has been conducted along California's Central Coast and the San Francisco Bay Area (Cuthrell 2013; Lightfoot et al. 2013a), less has been done regarding shoreline management practices that may have augmented the productivity of intertidal zones, such as the management of shellfish populations and even cultural burning of wetland vegetation in this region (Anderson 2005). Recent zooarchaeological work in Tomales Bay (Sanchez et al. 2018; Sanchez 2020) suggests Indigenous management of nearshore and shoreline resources such as herring and anchovies via net fishing which was size selective for intermediate sized fish, allowing juveniles to mature and larger, more reproductively fit individuals to spawn more, leading to a sustainable fishery for over 1000 years.

Despite several ethnographic sources of clam bed tending by Coast Miwok peoples (Baker 1992; Collier and Thalman 1996; Ortiz 1998), the timing and scale of these practices have yet to be established from the archaeological record. If Native people employed management strategies to bolster the productivity of coastal resources such as small schooling fish, then it is likely that shellfish populations may have received similar treatment. Archaeology can provide another line of evidence to bolster and enhance tribal histories and ethnographic accounts of clam bed tending by Coast Miwok peoples (Baker 1992; Collier and Thalman 1996; Ortiz 1998), specifically the timing and scale of these practices on Tomales Bay. The purpose of this paper is to examine the antiquity of Coast Miwok stewardship of clam populations using eco-archaeological data derived from recent investigations of Tomales Bay sites.

I begin this paper by providing, Historical and contemporary ethnographic accounts of traditional resource management practices of clam bed tending by Coast Miwok people. I then address the question of the antiquity and extent of clam bed tending in Tomales Bay by examining two evidentiary lines: (1) eco-archaeological research on invertebrate assemblages from three sites along the western shore of Tomales Bay radiocarbon dated from nearly 1300 years ago to Historic times, and (2) archaeometry to estimate the size of clams and harvest profiles from archaeological shell fragments. I conclude with a discussion about the value of these data for Coast Miwok and other land managers interested in the Historical Ecology and management of shellfisheries in Tomales Bay. In accordance with the wishes of FIGR and to protect sacred and culturally important places, site names will be omitted and referred to simply as sites A, B, and C and location will be kept regional rather than specific (i.e. the western of shore or Tomales Bay in Point Reyes National Seashore)

Eco-archaeological research on Indigenous stewardship of intertidal resources is compelling for several reasons. Archaeological assemblages of native clam varieties are abundant and preserve well, providing an abundance of comparative data sets from coastal middens. Based on my and others research, relatively inexpensive and simple approaches can be employed for gaining a higher resolution of interpretive data from archaeological invertebrate assemblages (Braje and Campbell 2015; Lepofsky and Caldwell 2013; Singh and McKechnie 2015). Ethnographic and ethnohistoric examples can support and enhance our understanding of clam population dynamics as well as Coast Miwok harvesting techniques and preferences through time. Much of this knowledge is still held by Native elders, providing a repository of living memory and elder accounts. In Tomales Bay, the deep history of clamming for foodways and recreation, combined with the Historic ban on Native practices and the current state of clamming/ shellfisheries in the bay sets a precedent to improve our understanding of this shoreline through time. To that end, archaeological data provides an important lens that has the potential to aid in revitalizing Native stewardship practices and influencing wildlife management and fisheries policy in the bay.

Study Area

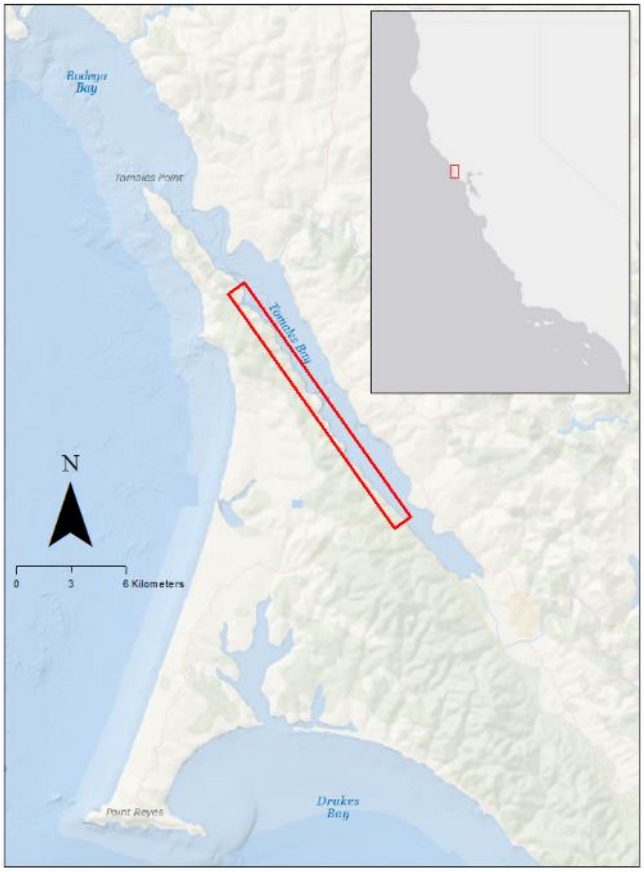


Figure 4.5. Map of Tomales Bay Study Area (Map by Alec Apodaca)

Tomales Bay is a 19.3 km long, linear body of water atop the San Andreas Fault whose eastern shoreline is best characterized as dry and grassy, while the western shore is lush and forested with Bishop Pine (*Pinus muricata*) and Douglas Fir (*Pseudotsuga menziesii*) (Avery 2009). The climate is Mediterranean and enjoys cool, wet winters and hot, dry summers. Tomales Bay is situated along a dynamic rift valley, displayed in Figure 4.1 that supports an abundance of migratory waterfowl, fisheries, wildlife, recreational activity, and ranching (Galloway 1977).

Despite being one of the most studied bodies of water on the Pacific Coast, little attention has been paid to Indigenous systems of shellfish management in Tomales Bay, which once supplied one-fifth of California's commercial oyster crop (Avery 2009). It remains one of the most productive shellfisheries on the Pacific coast. The late 1800s witnessed the collapse of abalone populations in the bay, due to overharvest coupled with the introduction of multiple species of non-native oysters for commercial purposes. Shellfish producers from the San Francisco Bay area recognized that Tomales Bay presented an alternative habitat to raise oysters given its fresh silt conditions and mercury free waters (Avery 2009). Contemporary and Historic shellfisheries focus on growing non-native shellfish species such as Giant Pacific oyster (*Crassostrea gigas),* Manila clams (*Venerupis philippinarum*), and blue bay mussels (*Mytilus edulis*). In the words of Gregory Waselkov (1987), many a seduction has begun with oysters, and indeed the allure of Tomales Bay's oyster industry has drawn many to its shores. However, for the Coast Miwok, who tended and managed these waters for millennia, it is clams that make the bake.

Clamming in Tomales Bay

The beaches of Tomales Bay are characterized by tidally influenced scalloped bays, gently sloping shorelines, soft sand, and enough rocky substrate to create favorable conditions for the development and continuity of clam populations. This makes Tomales Bay a particularly pertinent area for investigating the possibility of shoreline management practices, as its unique geography and history makes it a highly productive body of water along the California coast. Similar geographic conditions are found in other regions where human management of clam gardens is evidenced in the archaeological record, such as the Pacific Northwest (Lepofsky et al. 2013). Clams have been harvested in Tomales Bay for thousands of years and continue to be exploited both commercially and recreationally to this day (Baker 1992; Collier and Thalman 1996; Gilbert Zoppi personal communication 2019). However, the availability of native shellfish species is now in jeopardy. As noted by Willie Lawson, a generational clammer and land manager at Lawsons Landing located at the mouth of Tomales Bay, there are increasing concerns about the diversity and sustainability of native clam populations. He notes that "Washington's (*Saxidomus gigantea*) are hard to find, and the locations are closely guarded to recreational clammers" (Willie Lawson personal communication 2018). On-going research by shellfish biologists in Swinomish territory in Washington State document a similar decline of native Littleneck *(Leukoma staminea)* clams (Barber et al. 2012; 2019). Archaeological and ethnographic sources in collaboration with tribal elders and scholars are uniquely situated to address problems in contemporary fisheries management (Braje and Rick 2013). Understanding the Historical dimension of clamming in Tomales Bay leads to better available science and more holistic, community-based approaches to address conservation and management issues.

Methods and Materials

Coast Miwok Traditional Resource Management

Coast Miwok continued to access tideland resources in Tomales Bay, participating in emerging regional economies during the Historic era (Avery 2009; Schneider et al. 2018). Tomales Bay's clam gardens were the focus of the State's earliest attempts at "conservation" in the 1930's by severely limiting the catch limit that a family can harvest per day in hopes to keep habitats "pristine". These prohibitions and policies were a function of settler colonialism which attempted to remove Indigenous people from the landscape and reconfigure Indigenous landscapes into environments filled with non-native species that could be exploited for commercial gain. This extractive relationship with the environment is directly associated with settler colonial attitudes and practices of the time. This certainly increased pressure for Coast Miwok families to seek livelihood elsewhere, by stifling the persistent culling of worthwhile clams and subsequent eviction during wartime (Avery 2009; Baker 1992; Field 2008). Baker (1992) argued that the removal of Native clamming practices along the shorelines of Tomales Bay resulted in the disruption of native clam populations. He points to the combination of prohibitions on clam harvesting and the removal of Indigenous people and practices as the primary culprits of the proposed destabilization of native bivalve biodiversity of Tomales Bay:

> *"By limiting the number of clams that could be harvested, they (the State) sought to conserve the clambeds of areas like Tomales Bay... Fifty years later, Tomales Bay has yet to recover ... Of the three clam varieties... two were extinct by 1945 (including the prized but tough horseneck) and the third was barely hanging on…Yet such limitations clearly did not work at Tomales Bay, just as the Coast Miwok people who managed the bay's 23 fertile beds for thousands of years predicted…It was the act of harvesting... that was keeping the clambeds*

> *healthy…When they (Coast Miwok) stopped digging the way they used to, there was really a good bit of loss because the young clams had no room to grow." [Baker 1992:28-29]*

It appears that Native tending practices contributed critical manipulation and enhancement to these beds, such as the aeration of soil and removal of larger clams to free up space and nutrients for larval and juvenile clams to propagate. My interview with tribal elder Gilbert (Gill) Zoppi and his nephew Peter Nelson (October 2019) confirmed the importance of the practices. Born in 1924 (according to census data), Gill lived on the eastern shore of Tomales Bay just south of Marshall near the Marconi telegraph station (formerly "Fisherman's") where the bulk of Coast Miwok people were living on the Bay at that time, though there were individual families spread throughout mostly the east shore of the Bay and a couple on the west (Gilbert Zoppi personal communication 2019). Here he dug clams, picked fruit, hunted fowl and rabbits, and "picked" oysters until he was 17 years old. He would row his boat across Tomales Bay to dig for clams at beaches on the western shore.

Based on these experiences, Gill noted that smaller species of clam were dug with a hoe, while larger and deeper burrowing species were dug out with a stove pipe. One form of habitat modification and enhancement strategy described by Gill was the removal of rocks from favored beds. A method of stewardship and sustainability was size selectivity, and clams were measured with a scale on the hoe and put back if they were smaller than 1.5" (3.81 cm). "Mines" or areas with high density of clams were kept secret, and sometimes a good haul of clams would compel them to camp out overnight. Gill says that the best clams were dug from lower tidal margins, as clams living in higher tidal zones were more likely to go bad. He noted people were poisoned who didn't understand tidal preference. While clams were dug year-round, oysters were harvested using a miner's pick only in the months with an R (September- April). Gill recounted a tale of a neighbor, Mrs. Webb, who would transplant smaller clams into her own clam garden near her house, effecting a tenured system of ownership, habitat modification, and enhancement. This is in keeping with Greg Sarris' comments on Indigenous worldview, which were so well put by Field (2008)

> "What Sarris's comment clarify is one facet of indigenous worldview- knowledge about harvesting particular foods as property- that created barriers to the overharvesting of those foods. Even the smallest insights into those worldviews- and Sarris's was not a small one- might help to loosen the stranglehold of the conservationist paradigm so pervasive in the study of indigenous resource management" (Field 2008)

Such a worldview also stands in contrast to settler notions of "wild" vs domesticated foods and agricultural thinking in general, wherein Native peoples forge relationships with resources rather than either asserting their control and dominion over them or disregarding them (Nadasdy 2007). However, the pressures of settler colonialism sought to change those relationships and Native peoples adopted new practices and adjusted old ones to persist considering new social, political, and economic regulations affecting their traditional foodways. For example, clams served as a form of money and were traded (all species same price by weight) for other groceries like flour and eggs at the local store in Marshall, providing a critical component of Native subsistence practices and trade and exchange networks. However, restrictions on clamming in 1935 limited the numbers of clams that could be taken daily, disrupting Coast Miwok traditional resource management practices, foodways, food security, and income. As outlined by Rob Baker (1992) the removal of Native stewardship of clams in Tomales Bay, coupled with increased commercial focus on non-native shellfish led to the degradation of these once well-manicured and cared for clam beds. Table 4.1. (below) outlines the actions, techniques, and examples of these practices.

Action	**Techniques**	**Observations of these practices**
Harvesting	-Digging with garden hoe or stove pipe -Measuring device on digging tools (Gill)	-Clams discarded in midden deposits -Gilbert Zoppi personal communication 2019
Enhancement Strategies	-Remove larger individuals -Return smaller clams -Aerate clam beds via digging and removal of rocks	-Archaeometric analysis of clams -Baker 1992 -Gilbert Zoppi personal communication 2019
Regimes and Tenures	-Best spots (“mines”) kept secret -Privately owned gardens enhanced via transplanting -Ownership created barriers to overharvesting -Resources shared with other tribes in exchange for being able to collect resources in other areas even though there were boundaries that you had to ask permission to cross	-Baker 1992 -Kelly et al. 1991 -Gilbert Zoppi personal communication 2019
Foodways	-Source of income -Traded for groceries	-Gilbert Zoppi personal communication 2019

Table 4.1. Actions and techniques involving clam stewardship

Archaeological Investigation of Tomales Bay Clams

Archaeologists have often viewed shellfish resources as low-ranked foods, i.e. having limited caloric returns in relation to the energy required to obtain them (Osborn 1977). In this framework, shellfish would only be targeted after more highly ranked resources, generally large bodied mammals, were depleted (Broughton 1994). However, the reliability, relative ease of harvest, and suite of micronutrients and protein found in most shellfish have made them a key component of human diets around the world for thousands of years (Braje 2010; Claassen 1998; Erlandson 1988; Jones 1991; Waselkov 1987). The antiquity and ubiquity of shellfish remains in coastal middens around the world suggests that human-shellfish relationships have been an ongoing and developing saga for hundreds of thousands of years. With the geographical expansion of *Homo sapiens* throughout the world following many coastal routes, it is likely that reliable coastal resources like shellfish enabled much of this expansion, population dispersal, and growth (Erlandson et al. 2007). It is not far-fetched to think that humans have in turn encouraged the expansion and growth of their shelled counterparts.

Niche Construction Theory (NCT) is a useful tool for thinking about anthropogenic landscapes and seascapes in an archaeological context (Cuthrell 2013; Fitzhugh 2000; Smith 2011). Niche construction can be understood in terms of differential responses to selective pressures, whether organisms physically modify, or perturb their environments, or they actively move through space and relocate (Odling-Smee 2003). These responses can be further understood based on whether organisms respond to changing selective pressures or initiate them, in effect counteracting and stabilizing ecological risks (Odling-Smee 2003). NCT, when applied to small-scale societies, can be conceptualized by the modification of vegetation communities, sowing of annuals, transplant of fruit bearing species, encouragement of economically important plants and root crops, and modification of the landscape to increase prey abundance (Smith 2011). Thus, NCT is especially relevant in California, where Indigenous people employed a diverse array of landscape and shoreline resource management strategies (Anderson 2005; Cuthrell 2013; Erlandson 2013; Lightfoot and Luby 2002; Sanchez et al. 2018; Sanchez 2020). Much of the work done using NCT to date has focused on the domestication of plant and animals resources rather than the manipulation and management of ‘wild’ species (Smith 2011), yet the practice of tending clam gardens can be understood as a form of niche construction and maintenance that led to increased productivity and sustainability of intertidal resources (Groesbeck et al. 2014). NCT is especially applicable in examining how people directed the ecological succession of clam stands so they could remain productive and be passed onto future generations.

A significant issue in zooarchaeological studies today is examining whether people harvested specific species in a sustainable manner over time or whether intensive exploitation led to population imbalances of these species and their depletion in local areas (Broughton 1994; Butler and Campbell 2004; Erlandson et al. 2008; Grayson 2001; Sanchez 2020). In order to study changes in shellfish populations in response to intensive harvesting of resources, archaeologists typically look for evidence along three parameters: decrease in mean shell length over time; reduction in modal size of exploited shell species, significantly smaller than unexploited shells of the same species; and finally, species which are more difficult to harvest will increase in number (Claassen 1998). Other factors such as cultural preference can also be employed to provide a good framework or expectations for analyzing demographic shifts in shellfish populations in response to human exploitation (Claassen 1998). Given this framework for assessing the consequences of intensive shellfish exploitation, I expect that evidence of a sustainable and productive fishery in the archaeological record would be characterized by stability in shell length over time, stability in modal size of exploited species, and relative uniformity of taxa breadth over time (i.e. no shift to smaller or harder to harvest lower ranked species).

Estimating Clam Size from Archaeological Samples

Recently, several archaeologists have developed regression-based formulae to predict the size of bivalves from fragmented remains and diagnostic landmarks (Apodaca 2018; Campbell and Braje 2015; Singh and McKechnie 2015), providing researchers a method for estimating the mean size of harvested shellfish remains. For clams, and many other bivalves, umbones (also known as hinges) are the sites for oldest shell growth. Singh and McKechnie (2015) indicate that despite the potential for growth variation between habitats, umbo allometry is a statistically reliable principle in which to base size estimations on. Research on *Mytilus californianus* suggest that morphometric data from umbos can be utilized to create linear regression formulae for extrapolating total length of shell from incomplete shell fragments (Braje and Campbell 2015, Singh and McKechnie 2015). To this end, I developed multiple linear regression for estimating the size of Littleneck clams from umbos and other non-repetitive elements, as outlined in the study below. This study focuses on developing a reliable formula for estimating mean size of Pacific Littleneck clam (*Leukoma staminea*) from archaeological samples. The Littleneck clam was previously classified as *Protothaca staminea*, and is known variously as the common Littleneck, quahog, cherrystone clam, rock cockle, rock clam, meyeki (quahog) by the Bodega Miwok, or meyyechchi (generic name for small clam) by the Coast Miwok (Kelly 1978; Morris et al. 1980). Littlenecks are found from the Aleutian Islands all the way down to Baja California Sur, preferring coarse sand or sandy mud in bay or loose gravel on more exposed, open coastlines (Morris et al. 1980). Their spawning season spans April to September, and sexual maturity is reached at a length of 22-35 mm long, though the time it takes to reach that size varies widely across latitudes (Morris et al. 1980). Littleneck clams have high mortality among young and old members of a population, as conditions must be ideal for larval development and older, senescent clams are more vulnerable to predation and environmental perturbations. As previously noted, California Department of Fish and Wildlife harvest regulations limit the catch of Littlenecks to 50 per day .

It should be noted that it can be difficult to differentiate *Leukoma staminea* from non - native Manila clam (*Venerupis philippinarum).* To address this issue, I acquired a comparative assemblage of Manila clams from Tomales Bay Oyster Company who grows them commercially to insure positive identification.

I then gathered a modern assemblage of 99 Littleneck valves collected at low tide from Heart's Desire beach on the western shore of Tomales Bay with the help of Dr. Gabriel Sanchez and Alec Apodaca. Clams were processed and desiccated, with wet and dry meat weight taken from live individuals, providing an average wet weight of 3.8 grams (standard deviation = 1.02) and dry weight of .598 grams (standard deviation = .18). These clams are indeed a small package, but rich in key macro and micronutrients such as protein and iron (Erlandson 1988). Many of the larger clams found were dead and filled with silt, consistent with high mortality profiles observed amongst older member of these populations but also potentially indicative of local and regional decline of this species (Barber et al. 2012; 2019; Morris et al. 1980)

Following methods from previous studies by Braje and Campbell (2015) and Singh and McKechnie (2015) I took eight measurements of non-repetitive elements (NRE) from each valve, including 1) Total Shell Length, and 2) Total Shell Width, which were both assigned as possible dependent Y variables along with six potential independent X variables: A (Umbo Thickness), B (Umbo to Pallial Sinus), C (Umbo to Hinge Plate), D (Between adductor scars), and E (outside adductor scars). These landmark measurements were assigned to an x-variable, while total shell length and width was assigned to y-variables, as displayed in Figure 4.2 below.

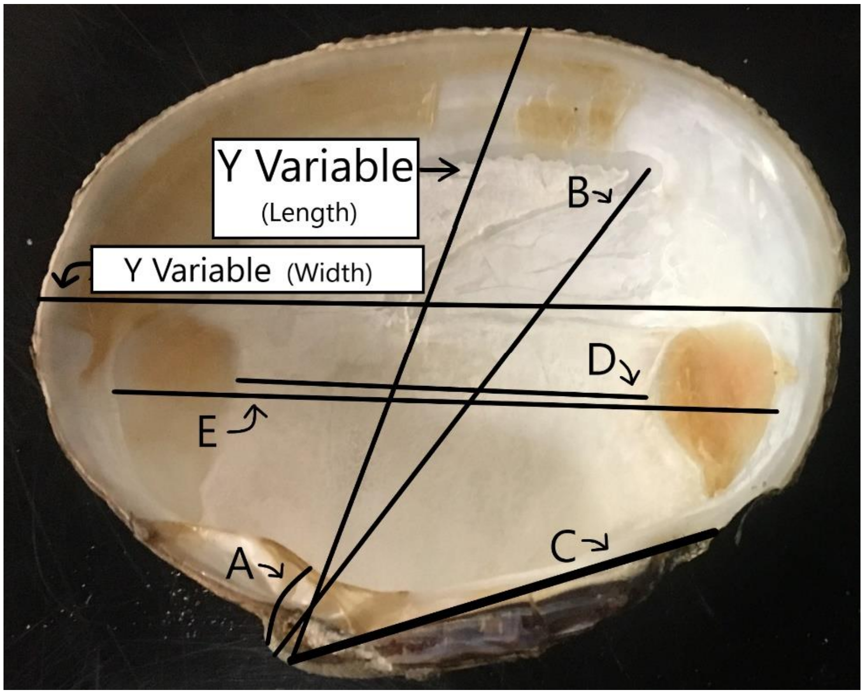


Figure 4.2. Landmark measurements taken to develop predictive formula for fragmented remains

All measurements were obtained using Mitutoyo certified-grade digital calipers. X and Y measurements taken along the same axes (Length/ Width) of the clam shell were more strongly correlated. For example, measurements A and B were more positively correlated with shell length, while measurements E and D were more positively correlated with shell width. After finding statistically significant allometric growth relationships between X values: modern Littleneck clam non-repetitive elements (NRE), and Y values: total shell length or width, I decided to use umbo thickness as the independent as the metric to predict shell length in this study. Umbos are perhaps the most mechanically robust part of a bivalve and therefore preserve well in archaeological samples, making them suitable for archaeometric analysis. Additionally, the formula for estimating Littleneck shell length via umbo thickness had a R-squared value of .88108, as displayed below in Figure 4.3.

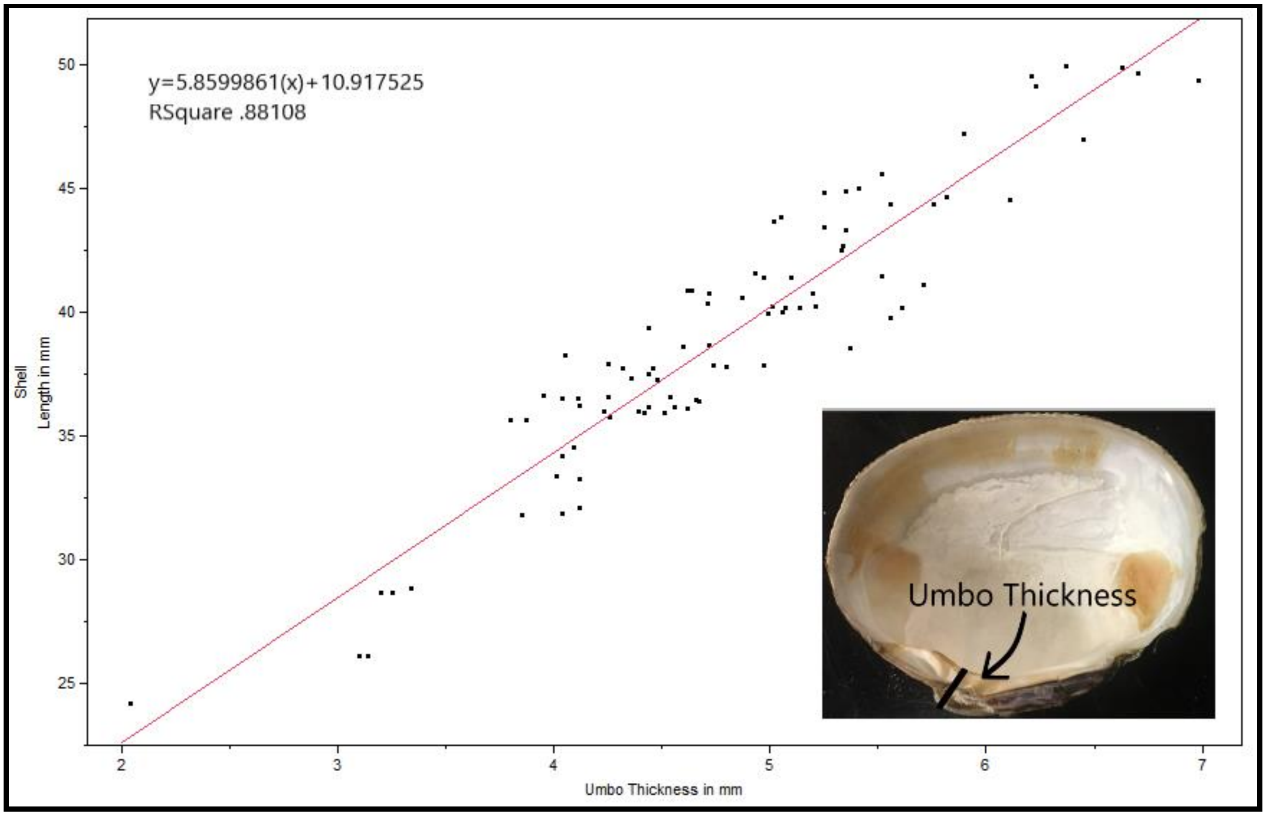


Figure 4.3. Bivariate regression model for estimating overall shell length from umbo thickness. Developed for 99 modern valves collected at Heart's Desire Beach in Tomales Bay

Based on these findings, the analysis of clam umbones provides a statistically reliable method for estimating overall size of Littleneck clam and for quantifying non-repetitive elements within a dataset. This study shows that morphometric analysis of clam hinges can be a quick, effective, and low-cost method to gather more data from invertebrate assemblages, moving interpretations beyond weights and counts (Claassen 1998). Differences in measurements taken from right and left valves were statistically insignificant for developing predictive linear regression formulae, making this formula applicable to all Littleneck clam umbos recovered in archaeological contexts.

The collection and analysis of invertebrate remains from sites in Tomales Bay was carried out as part of the larger HEALPR project (Historical Ecology and Archaeology of Landscapes in Point Reyes) in the summer and fall of 2015, and spring of 2016 as part of an ongoing collaborative research project with The Federated Indians of Graton Rancheria (FIGR), the National Park Service, and the University of California, Berkeley, funded through the National Science Foundation and the Research Institute for Humanity and Nature (RIHN).This project developed and incorporated survey and subsurface sampling strategies which adhere to minimally invasive and ethical approaches in collaborative archaeological field methods (Gonzalez et al. 2006; Gonzalez 2016). As previously mentioned, this began with addressing tribal interests to develop research questions, followed by extensive geophysical survey using Ground Penetrating Radar and

Magnetometry to avoid culturally sensitive materials such as human remains. Extensive surface survey was carried out, using a catch and release method (Gonzalez 2016) to determine artifact densities and site boundaries without removing archaeological materials. Combining data from surface survey and subsurface geophysical testing guided excavation strategies, with augers and opportunistic column samples of exposed and eroding profiles being favored over excavation units for minimal impacts to site integrity and while salvaging data that would soon be washed away by wind, waves, and other erosional forces.

For this study, invertebrate remains from three sites along the western shore of Tomales Bay were analyzed. Sediments from three augers and one column unit taken at 20 cm intervals yielded 24 flotation samples. The flotation samples were processed at the University of California Point Reyes Field Station at PRNS using two SMAP-type flotation tanks constructed by Rob Cuthrell (see Pearsall 2000). Heavy fraction materials were retained in the window screen with ca. 1.0 mm aperture size, while light fraction materials were retained in chiffon with ca. <0.25 mm aperture size. The heavy fraction was then transported to the California Archaeology Laboratory at UC Berkeley where the shellfish remains were sorted and speciated down to >4 mm size class Heavy fraction materials were passed through Tyler sieves to separate materials into the following size classes for ease of analysis: >4 mm, 2-4 mm, 1-2 mm, <1 mm. Invertebrate remains were then separated from the >4 mm size fraction, as smaller fractions were generally composed of highly fragmented shell that would be too time intensive to sample based on the quality of data they might yield. Shell remains were identified with the aid of comparative collections housed in the California Archaeology Lab. Quantitative measures included weight, relative abundance, density (grams of shell/ liter of soil, listed as g/l) and MNI of taxon with non-repetitive elements, counting apices and columella’s for gastropods and dividing the total number of bivalve umbos by two to determine MNI counts. Of the three sites surveyed and sampled along the western shore of Tomales Bay, Pacific Littleneck clam (*Leukoma staminea*) was the most abundant species represented in all samples from each site. Site trinomials are withheld for discretion and with respect to tribal concerns.

Results

The following are brief overviews of the three sites sampled along the western shores of Tomales Bay. Littleneck clam umbos were sorted from these assemblages for morphometric analysis. Further data regarding radiocarbon dates for these contexts are presented in Appendix B.

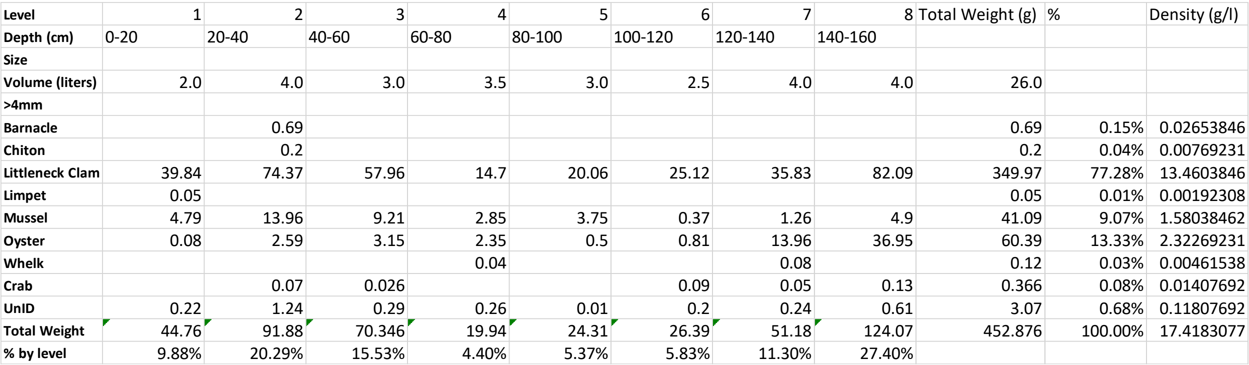
(Site A)

Site	**Level (cm)**	**^{14}C**
A	40-60	1641-1665 CE (0.96)
A	140-160	1035-1059 CE (0.20); 1064-1154 CE (0.80)

Table 4.2. Radiocarbon dates for Site A

Table 4.2 lists the Radiocarbon dates for Site A, which range from 1035 CE to 1665 CE. As outlined below in Table 4.3, the invertebrate assemblage from Auger 1 had a total weight of

452.9 grams and a density of 17.4 grams of shell per liter of soil sampled. Molluscan remains from the auger unit are dominated by Littleneck clam, which were the most abundant species represented within each level, having a relative abundance of 77.3%. Native oyster (*Ostrea lurida*) and California mussel (*Mytilus californianus*) are the next most abundant species, with relative abundance of 13.3% and 9.1%, respectively. There was no notable shift in species density or abundance through time in this assemblage, in keeping with expectations of what resource stability would look like archaeologically.



Level	1	2	3	4	5	6	7	8	Total Weight (g)	%	Density (g/l)
Depth (cm)	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160			
Size											
Volume (liters)	2.0	4.0	3.0	3.5	3.0	2.5	4.0	4.0	26.0		
>4mm											
Barnacle		0.69							0.69	0.15%	0.02653846
Chiton		0.2							0.2	0.04%	0.00769231
Littleneck Clam	39.84	74.37	57.96	14.7	20.06	25.12	35.83	82.09	349.97	77.28%	13.4603846
Limpet	0.05								0.05	0.01%	0.00192308
Mussel	4.79	13.96	9.21	2.85	3.75	0.37	1.26	4.9	41.09	9.07%	1.58038462
Oyster	0.08	2.59	3.15	2.35	0.5	0.81	13.96	36.95	60.39	13.33%	2.32269231
Whelk				0.04			0.08		0.12	0.03%	0.00461538
Crab		0.07	0.026			0.09	0.05	0.13	0.366	0.08%	0.01407692
UnID	0.22	1.24	0.29	0.26	0.01	0.2	0.24	0.61	3.07	0.68%	0.11807692
Total Weight	44.76	91.88	70.346	19.94	24.31	26.39	51.18	124.07	452.876	100.00%	17.4183077
% by level	9.88%	20.29%	15.53%	4.40%	5.37%	5.83%	11.30%	27.40%			

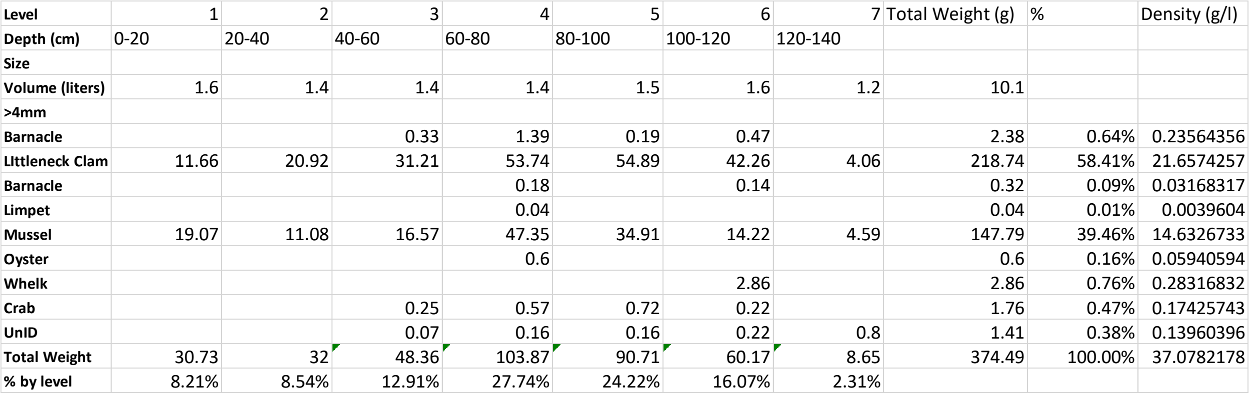
Table 4.3. Invertebrate assemblage from Site A, Auger 1

(Site B)

Site	**Level (cm)**	**^{14}C**
B	60-80	1646-1667 CE (0.70); 1783-1796 CE (0.30)
B	100-120	1652-1677 CE (0.32); 1776-1800 CE (0.53); 1940-1951 CE (0.12)
B	120-140	1271-1294 CE
B	180-200	769-882 CE

Table 4.4. Radiocarbon dates for site B, Column 1

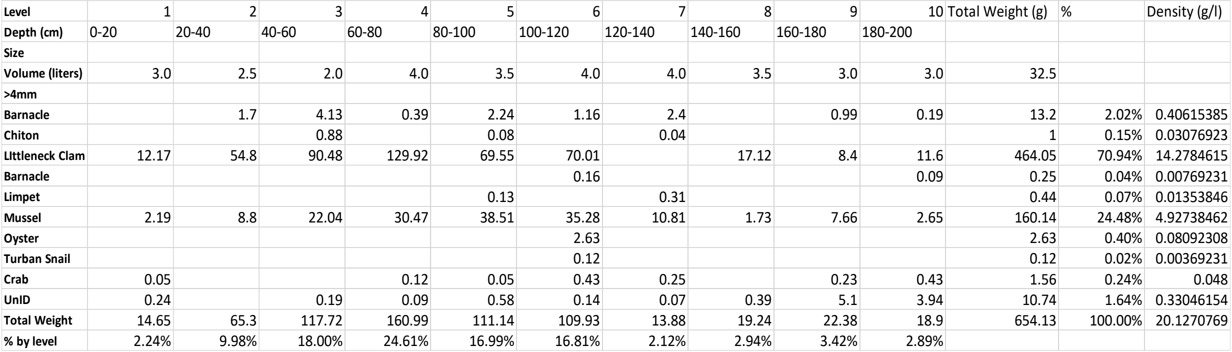
Table 4.4 lists the Radiocarbon dates for Site B, which range from 769 CE- 1951 CE. As displayed in Table 4.5 below, the invertebrate assemblage from Column 1 had a total weight of 374.5 grams and a density of 37.1 grams of shell per liter of soil sampled. Molluscan remains from auger and column samples from Site B are dominated by Littleneck clam and California mussel. Invertebrate abundances from Column 1 was comprised of 58.4% *Leukoma staminea* and 39.5% *Mytilus californianus*, with no other species represented at greater than 1% within each level. There was no notable shift in species density or abundance through time in this assemblage, in keeping with expectations of what resource stability would look like archaeologically.



Level	1	2	3	4	5	6	7	Total Weight (g)	%	Density (g/l)
Depth (cm)	0-20	20-40	40-60	60-80	80-100	100-120	120-140			
Size										
Volume (liters)	1.6	1.4	1.4	1.4	1.5	1.6	1.2	10.1		
>4mm										
Barnacle			0.33	1.39	0.19	0.47		2.38	0.64%	0.23564356
LIttleneck Clam	11.66	20.92	31.21	53.74	54.89	42.26	4.06	218.74	58.41%	21.6574257
Barnacle				0.18		0.14		0.32	0.09%	0.03168317
Limpet				0.04				0.04	0.01%	0.0039604
Mussel	19.07	11.08	16.57	47.35	34.91	14.22	4.59	147.79	39.46%	14.6326733
Oyster				0.6				0.6	0.16%	0.05940594
Whelk						2.86		2.86	0.76%	0.28316832
Crab			0.25	0.57	0.72	0.22		1.76	0.47%	0.17425743
UnID			0.07	0.16	0.16	0.22	0.8	1.41	0.38%	0.13960396
Total Weight	30.73	32	48.36	103.87	90.71	60.17	8.65	374.49	100.00%	37.0782178
% by level	8.21%	8.54%	12.91%	27.74%	24.22%	16.07%	2.31%			

Table 4.5. Invertebrate assemblage from Site B, Column 1

As displayed in Table 4.6 below, the invertebrate assemblage from Auger 1 at Site B had a total weight of 654.1 grams and a density of 20.1 grams of shell per liter of soil sampled. Auger 1 was also dominated by clam and mussel, with both species in every level, Littleneck clam comprising 71% of the invertebrate assemblage and California mussel making up 24.5%. Barnacle was the only other species that made up more than 1% of the assemblage. There was no notable shift in species density or abundance through time in this assemblage, in keeping with expectations of what resource stability would look like archaeologically.



Level	1	2	3	4	5	6	7	8	9	10	Total Weight (g)	%	Density (g/l)
Depth (cm)	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200			
Size													
Volume (liters)	3.0	2.5	2.0	4.0	3.5	4.0	4.0	3.5	3.0	3.0	32.5		
>4mm													
Barnacle		1.7	4.13	0.39	2.24	1.16	2.4		0.99	0.19	13.2	2.02%	0.40615385
Chiton			0.88		0.08		0.04				1	0.15%	0.03076923
LIttleneck Clam	12.17	54.8	90.48	129.92	69.55	70.01		17.12	8.4	11.6	464.05	70.94%	14.2784615
Barnacle						0.16				0.09	0.25	0.04%	0.00769231
Limpet					0.13		0.31				0.44	0.07%	0.01353846
Mussel	2.19	8.8	22.04	30.47	38.51	35.28	10.81	1.73	7.66	2.65	160.14	24.48%	4.92738462
Oyster						2.63					2.63	0.40%	0.08092308
Turban Snail						0.12					0.12	0.02%	0.00369231
Crab	0.05			0.12	0.05	0.43	0.25		0.23	0.43	1.56	0.24%	0.048
UnID	0.24		0.19	0.09	0.58	0.14	0.07	0.39	5.1	3.94	10.74	1.64%	0.33046154
Total Weight	14.65	65.3	117.72	160.99	111.14	109.93	13.88	19.24	22.38	18.9	654.13	100.00%	20.1270769
% by level	2.24%	9.98%	18.00%	24.61%	16.99%	16.81%	2.12%	2.94%	3.42%	2.89%			

Table 4.6. Invertebrate assemblage from Site B, Auger 1

(Site C)

Site	Level (cm)	^{14}C
C	40-60	1663-1682 CE (0.22); 1737-1757 CE (0.11); 1761-1804 CE (0.45); 1936-1951 CE (0.21)
C	60-80	1452-1521 CE (0.70); 1591-1620 CE (0.29)

Table 4.7. Radiocarbon dates for Site C, Auger 1

Table 4.7 lists the Radiocarbon dates for Site C, which range from 1452 CE to 1951 CE. As displayed in Table 4.8 below the invertebrate assemblage from Auger 1 at Site C had a total weight of 391.96 grams and a density of 28.0 grams of shell per liter of soil sampled. *Leukoma staminea* is the most abundant and ubiquitous species in auger 1, present at every level in the greatest abundance and making up 70.7% of the entire assemblage. Native oyster (*Ostrea lurida*) is the second most common species seen, present in every level with a relative abundance of 22.6% of the assemblage for auger 1.

Level	1	2	3	4	5			
Depth (cm)	0-20	20-40	40-60	60-80	80-100			
Size	0.00785	0.00785	0.00785	0.00785	0.00785	Total Weight (	%	Density (g/l)
(liters)	3.0	2.5	3.0	3.0	2.5	14.0		
>4mm								
Barnacle	3.42		1.36			4.78	1.22%	0.341428571
Littneck Clam	5.49	6.68	158.73	63.78	42.48	277.16	70.71%	19.79714286
Limpet			0.07			0.07	0.02%	0.005
Mussel			11.68	3.09	2.5	17.27	4.41%	1.233571429
Oyster	2.58	2.59	47.97	17.44	17.97	88.55	22.59%	6.325
UnID	0.1	0.77	1.32	1.25	0.69	4.13	1.05%	0.295
Total Weight	11.59	10.04	221.13	85.56	63.64	391.96		27.99714286
% by level	2.96%	2.56%	56.42%	21.83%	16.24%			

Table 4.8. Invertebrate assemblage from Site C, Auger 1

The formula outlined in Figure 4.3 was applied to n=151 archaeological clam umbos from 24 contexts from the auger and column samples for the three sites. This data is laid out in box plots with Tukey's Honesty Significance Difference tests to assess statistical significance of variation in size through time in Figures 4.4, 4.5, 4.6, and 4.7. Tukey's HSD tests can be used to compare the differences in the means of values of multiple groups, making them ideal for comparing mean estimated sizes from multiple stratigraphic levels within an archaeological context and determining whether there are statistically significant differences between these means. The circles on the right side of these graphs, labelled All Pairs Tukey-Kramer .05, reflect this variation, with the size of the circles representing relative size of a group of data (i.e. number of umbos measured per level) and the overlap or lack thereof reflecting statistical variation. Simply put, variation is displayed by overlap of the circles, with considerable overlap reflecting no significant differences and little to no overlap reflecting significant difference. Each figure is accompanied by a table that gives provides average size of clams as outlined in Tables 4.9, 4.10, 4.11, 4.12 and 4.13 (below). The results of my study indicate that archaeological clams from all sites average at least 1.5 inches, or 38.1 mm, through time, with an average estimated length of 1.73 inches, or 43.96 mm (std. deviation 7.8 mm) for the entire assemblage of clams (n=151) from all three sites. This is not only larger than modern samples collected from Tomales Bay in the experimental study, but slightly larger than the current size limit of 1.5" imposed by California Department of Fish and Wildlife. In fact, all samples except for a column from site B with a relatively small sample size of clams (n= 24), displayed a trend of clam size increasing through time, suggesting stability and even enhancement of Littleneck clam demographics. These data, considered alongside data from Tables 4.3, 4.5, 4.6, and 4.8 is consistent with expectations of sustainable harvest profiles through time, characterized by 1) stability in shell length over time, 2) stability in modal size of exploited species, 3) and relative uniformity of taxa breadth over time (i.e. no shift to smaller or harder to harvest lower ranked species). I interpret these data as evidence that people were harvesting clams that had reached sexual maturity, enacting practices that maintained a productive, stable fishery for over 1000 years in Tomales Bay.

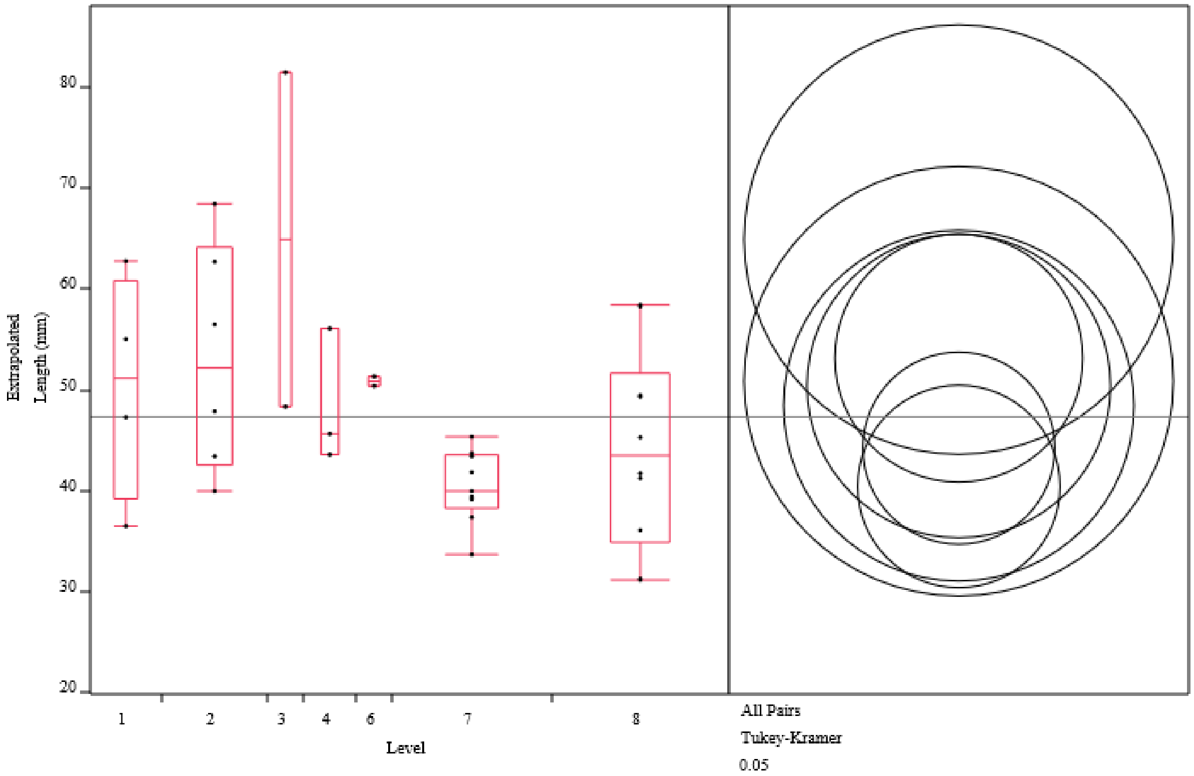


Figure 4.4. Site A Auger 1 boxplots with Tukey’s HSD displaying no statistically significant difference between levels while documenting slight increase in median size through time

Level	Age	N=	Average size	Std. dev.
1	NA	4	50.4 mm	9.7 mm
2	NA	6	53.1 mm	10.3 mm
3	1641-1665 CE (0.96)	2	64.9 mm	16.6 mm
4	NA	3	48.5 mm	5.5 mm
6	NA	2	50.9 mm	.5 mm
7	NA	9	40.5 mm	4.0 mm
8	1035-1059 CE (0.20); 1064-1154 CE (0.80)	10	44.2 mm	9.3 mm

Table 4.9. Average size of clams from Site A, Auger 1

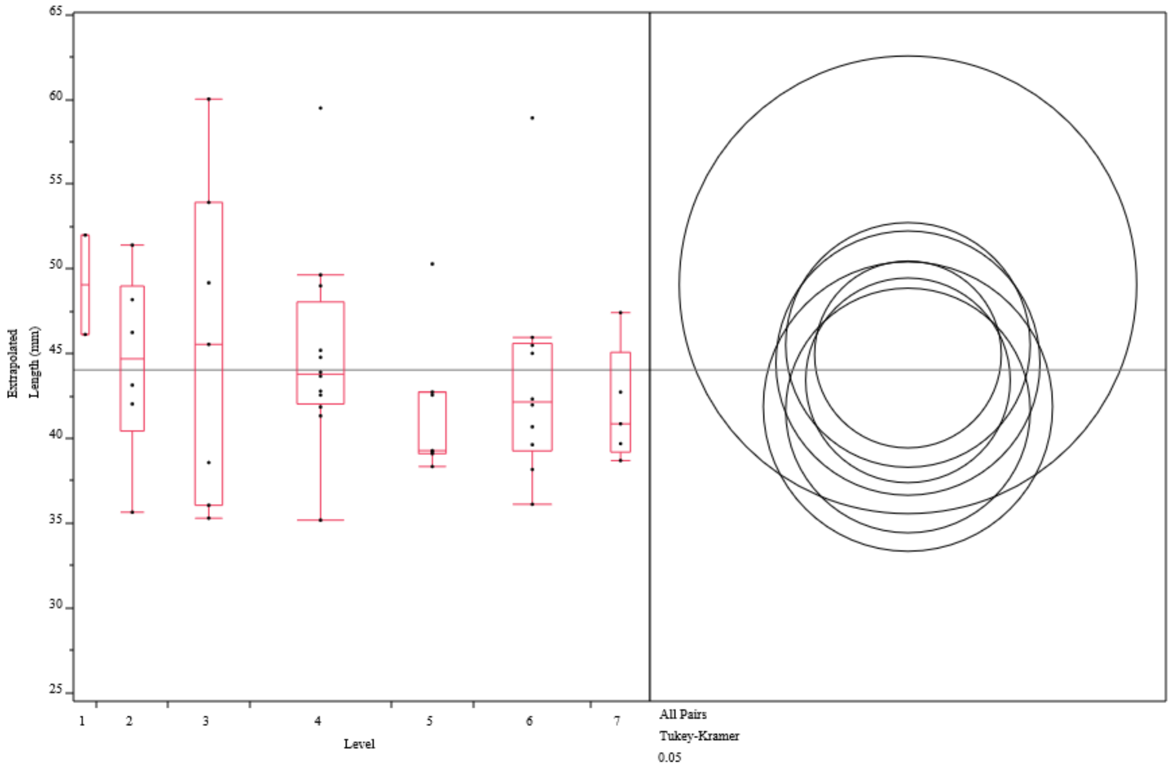


Figure 4.5. Site B Auger 1 boxplots with Tukey's HSD suggesting no statistically significant differences between levels while documenting slight increase in median size through time (Provided there are no stratigraphic reversals)

Level	Age	N=	Average size	Std. dev.
1	NA	2	49.1 mm	2.9 mm
2	NA	6	44.4 mm	5.0 mm
3	NA	7	45.5 mm	8.8 mm
4	NA	12	45.0 mm	5.6 mm
5	NA	7	41.6 mm	3.9 mm
6	NA	10	43.9 mm	6.0 mm
7	NA	5	41.9 mm	3.1 mm

Table 4.10. Average size of clams from Site B, Auger 1

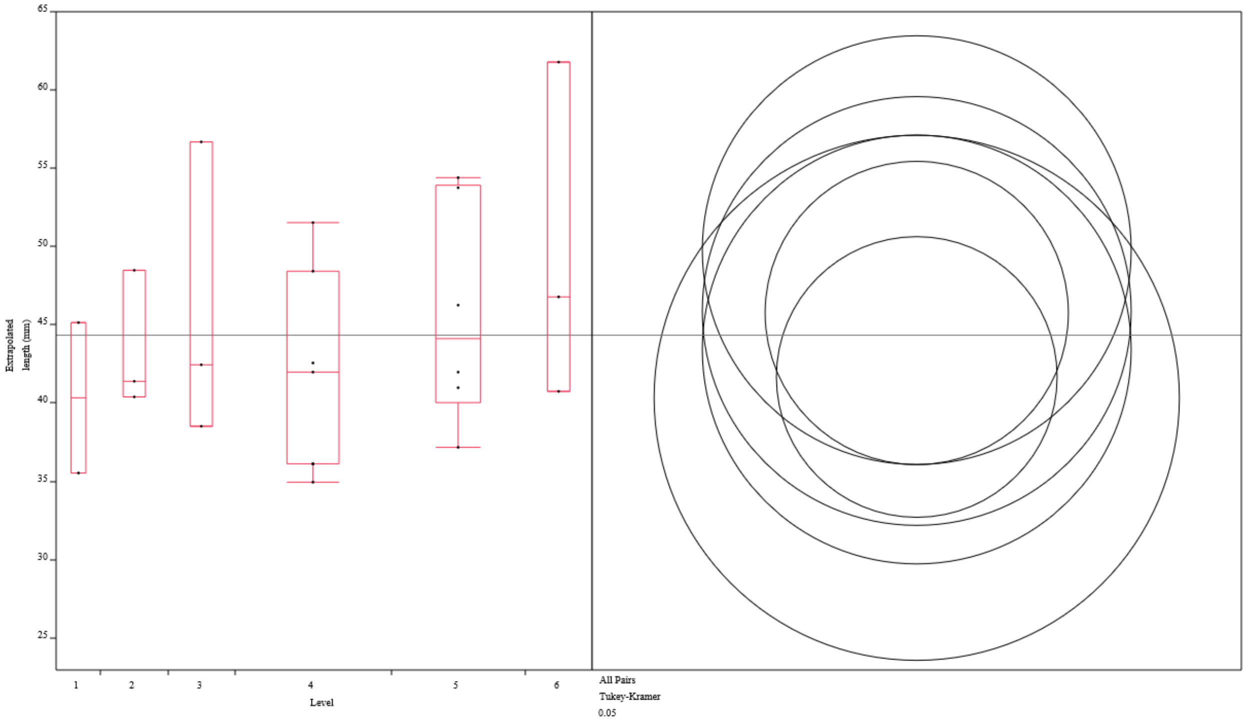


Figure 4.6. Site B Column boxplots with Tukey's HSD suggesting no statistically significant differences between levels while documenting slight decrease in median size through time

Level	Age	N=	Average size	Std. dev.
1	NA	2	40.3 mm	4.8 mm
2	NA	3	43.4 mm	3.6 mm
3	NA	3	45.9 mm	7.8 mm
4	1646-1796 CE	7	41.7 mm	6.0 mm
5	NA	6	45.8 mm	6.5 mm
6	1652-1800 CE	3	49.8 mm	8.8 mm

Table 4.11. Average size of clams from Site B, Column 1

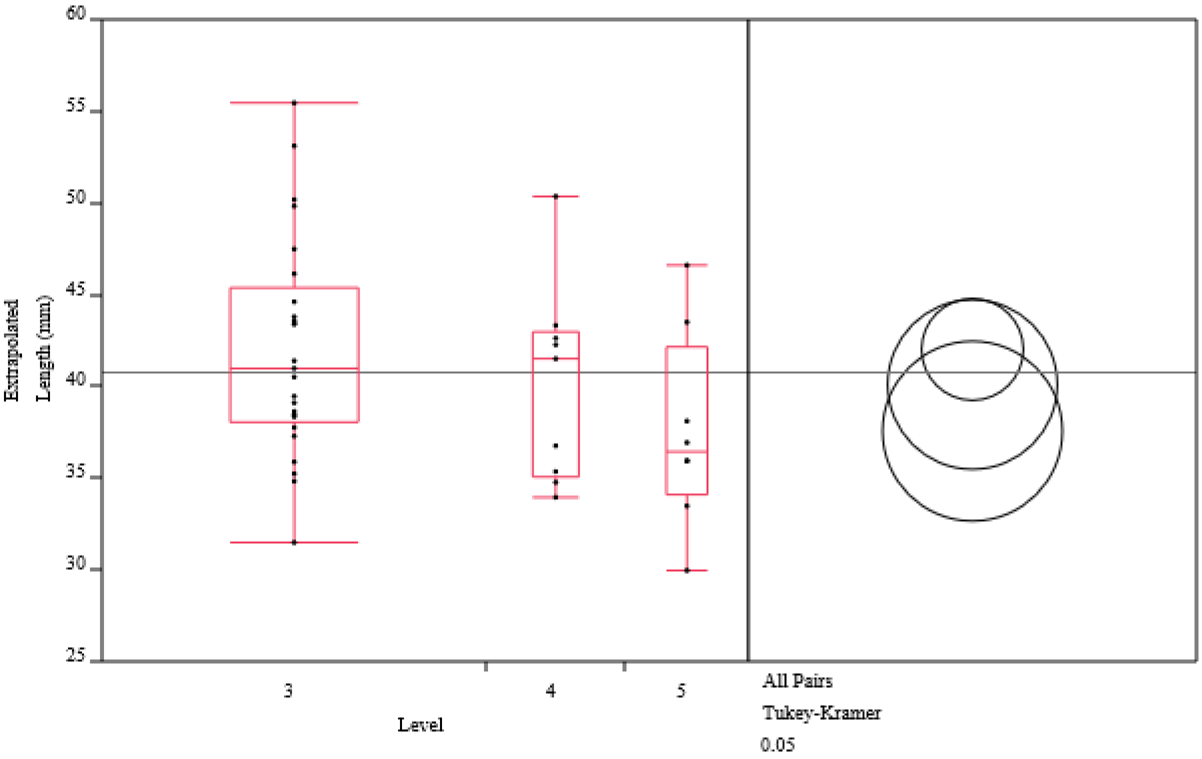


Figure 4.7. Site C Auger 1 box plots with Tukey's HSD suggesting no significant statistical difference between levels while documenting slight increase in median size though time

Level	Age	N=	Average size	Std. dev.
3	1663-1951 CE	25	42.0 mm	5.8 mm
4	1452-1521 CE (0.70); 1591-1620 CE (0.29)	9	40.1 mm	5.0 mm
5	NA	8	37.6 mm	5.0 mm

Table 4.12. Average size of clam from Site C, Auger 1

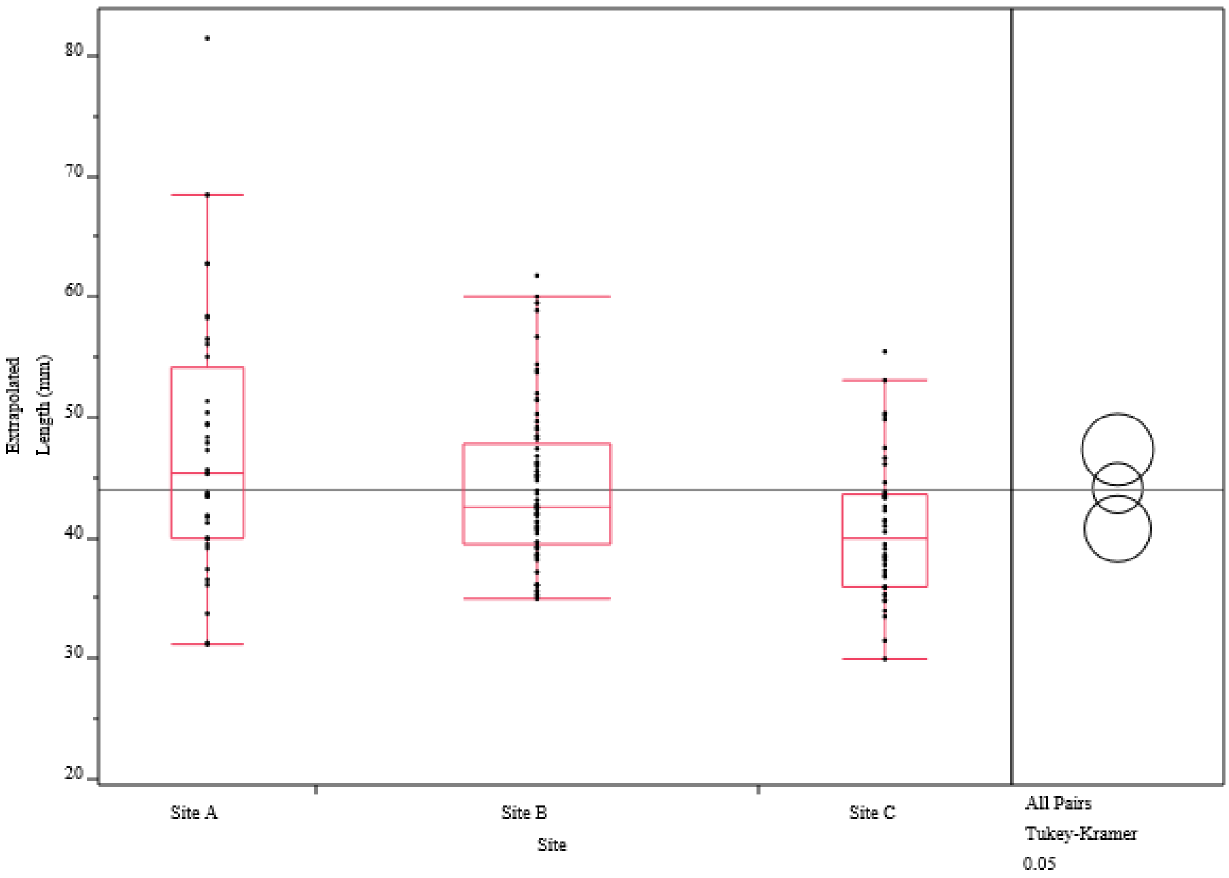


Figure 4.8. Site Comparisons with Tukey's HSD displaying minor statistical significance difference between sites

Site	Dates	n =	Average size
A	1035 CE- 1665 CE	36	45.3 mm
B	769-1951 CE	73	42.6 mm
C	1452-1951CE	42	40.0 mm

Table 4.13. Average size of clams from all sites

Discussion

My diachronic assessment of clam harvesting patterns reflects relative abundances and harvest profiles of Pacific Littleneck (*Leukoma staminea*) over the past 1300 years, suggesting that Native peoples maintained a productive, stable, and sustainable shellfishery for centuries. It could be argued that such a fishery could be the result of low human population and therefore low pressure on shellfish resources, though studies suggest population growth of Native Californians over the last 1000 years (Arnold and Walsh 2010; Beaton 1991; Erlandson et al. 2001; Glassow 2002). Consequently, some might suggest increasing human population in Late Holocene times would increase pressure on clam bed resources that would lead to the overexploitation of shellfish populations. However, increased human population and subsequent resource pressure could also result in the development of stewardship practices such as the selective culling of larger individuals and encouraged proliferation of juvenile clam populations in order to maintain this culturally important resource.

Based on ethnographic accounts and archaeological data, it appears that Coast Miwok people enacted practices that created a sustainable and productive fishery over this time frame. These practices were rooted in traditional resource management practices which display a deep understanding of the life cycle and ecological regimes of clam populations coupled with stewardship protocols which supported Native foodways into the Historic period before bans were put into place, disrupting a once well-tended and regulated system. Baker (1992) has raised concern about the disappearance of Coast Miwok clam "gardens" and research along the Pacific coast of North America has documented declines in native species of clam (Barber et al. 2012; 2019). This concern has also been echoed by land managers and clammers such as Willie Lawson, stating that native varieties of clam are becoming hard to find and recreational harvesting of them in the area is often fueling black market trading of favored varieties such as Washington and Gaper clam.

In order to further understand the Historical Ecology of clam populations dynamics in response to varied human predation strategies, I suggest that future studies integrate several approaches in addition to archaeometry and ethnography. These approaches should include 1) the development of and use of stable isotopes geochemistry to assess seasonality of harvest, 2) the incorporation of other sites and clam species into this research program, 3) geophysical survey of the shorelines of the bay at low tide to assess presence of relict management features of "clam gardens", and 4) the integration of comparative archaeological and modern data sets from other regions along the Pacific Coast (Barber et al. 2012; 2019)

Conclusion

My study demonstrates archaeological evidence of traditional resource management practices of clam bed tending in Tomales Bay in keeping with expectations laid out by ethnographic and ethnohistoric sources, as well as living memory and traditional ecological knowledge of Coast Miwok tribal elders. This approach provides a time and cost-effective method to drawing broader and deeper interpretations from archaeological invertebrate assemblages. The integration of Ancient data sets and traditional ecological knowledges of Indigenous stakeholders is critical for improving management of marine resources which face pressures ranging from ocean acidification, habitat loss, pollution and eutrophication, to overharvesting and contemporary mismanagement. Public land management agencies, the National Parks Service in this case, can incorporate this information into the coastal management plans for intertidal protection and restoration, allowing best available science to include Indigenous knowledge and long-term archaeological perspectives. Such a long-term perspective reifies the wisdom and utility of Indigenous knowledge and is especially useful for informing tribal efforts to reincorporate TEK and TREM in restoration and management efforts within their traditional homelands, providing empirical data to confirm thousands of years of ancestral knowledge.

Chapter 5:

Conclusion: The Archaeology of Shellfish and Shoreline Stewardship

The results of the three case studies presented in chapter 2, 3, and 4 are outlined below in terms of how they addressed the following three research questions:

Research Question 1

> Changes in invertebrate species diversity, ubiquity, and size in archaeological assemblages through time can reflect paleoenvironmental fluctuations, sustained management, or overexploitation. Is there evidence of sustained management of shellfish on the central coast of California?

Research Question 2

> “Non-dietary” or “incidental” marine invertebrates associated with marine macroalgae in archaeological assemblages can be analyzed to infer kelp and seagrass harvesting in the past. To what extent are these practices evidenced in these sites, how far back do they date, and what can they t tell us about past human relationships with shoreline resources on the central coast of California?

Research Question 3

> How can eco-archaeological research be applied to contemporary resource management policies and be mobilized to revitalize “dormant” traditional ecological knowledge lost or suppressed during colonization?

I begin by assessing how Case Study One addressed questions two and three. Secondly, I assess how Case Study Two addressed questions one and three. Thirdly, I assess how Case Study 3 addressed questions one and three. Finally, I conclude with a discussion of the broader impacts of this research and future directions to build upon these approaches

Case Study One:

Archaeological Signatures of Ancient Seaweed Harvesting Practices: A Case Study from the Central California Coast.

Seaweed and kelp provide critical ecosystem services and are important resources for humans throughout the world. However, kelp and seaweed harvesting practices have been understudied archaeologically due to their poor preservation in most archaeological contexts. My research suggests the analysis of smaller size fractions (<4mm) are required to detect the presence of shellfish species often considered incidental or non-dietary, which may have used kelp and seagrass as substrate and therefore serve as a proxy for kelp and seagrass harvesting. My study focused on analyses of invertebrate assemblages from several sites along the Santa Cruz coast spanning the Mid-Holocene to the Historic era. This study evidenced the presence of kelp and seaweed associated gastropods at several sites in Santa Cruz and San Mateo Counties spanning nearly 7000 years, displaying tightly woven relationships between Indigenous people and the sea in this region for millennia. This study developed improved laboratory methodologies for detecting the presence of kelp and seaweed associated gastropods, providing suggestions and protocols for increasing the resolution of archaeological invertebrate assemblages and their utility as a proxy for detecting Ancient marine macrophyte harvesting practices. This study also contributed to community outreach efforts, providing key information for the Amah Mutsun Land Trust Coastal Stewardship Program, which was disseminated through curriculum developed for coastal field trips during the summers of 2018, 2019, and 2020 with the AMLT youth Summer Camp and Stewardship Corps led by myself. These field trips focused on applying Ancient archaeological data of kelp and seaweed harvesting practices to restore and revitalize TEK and TREM of marine resources which may have been suppressed during successive waves of colonization but have cultural significance to the Amah Mutsun Tribal Band. I have led groups of 15-20 campers and Native Stewards on multiple field trips each summer, breaking them into smaller groups and guiding them through an intertidal tour of tidepools, sandy shores, rocky intertidal zones, and surfgrass beds. I provided them with a field guide I made with marine resources evidenced in the archeological record to help them find and identify different species in their habitats, when and how to harvest them sustainably, what their Mutsun names are, and why they are important components of healthy oceans. We identified different types of seaweed and kelps and discussed how to prepare them. We even caught and cooked an elusive monkeyfaced prickleback, a fish found in the archaeological record which proved to be quite tasty. During all this we emphasized ocean safety, respect, and the responsibility of seascape stewardship. Such a research project weaves together zooarchaeological data, improved laboratory methods for detecting kelp and seaweed harvesting practices, and community-based approaches in archaeology to aid in cultural revitalization and restoration of traditional resource management. As a continuation of this collaborative endeavor, I am currently working with the Amah Mutsun Land Trust as a consultant to continue developing curriculum and programs for the Coastal Stewardship Program, integrating archaeological data, TEK, and marine ecology to inform and guide cultural revitalization efforts and contemporary stewardship of the sea in Amah Mutsun territory.

Case Study Two:

Ancient Mussel Bed Harvesting: Implications for the Revitalization of Indigenous Stewardship Practices on the Central California Coast

In this study, I assessed Indigenous resource harvesting practices through the analysis of invertebrate remains from three archaeological sites on the northern Santa Cruz and southern San Mateo coasts. My purpose was to assess changes in shellfish populations in response to human exploitation through time from 6500 cal BP to 100 cal BP. Of interest was the possibility that Indigenous people may have employed shellfish harvesting practices that were geared towards enhancing the long-term productivity of mussel beds. To this end, this study employed a Historical Ecological approach to examine broader regional trends in shellfish harvesting practices through time, incorporating stable isotope analysis and experimental morphometrics to assess changes in seasonality and mussel size through a multi-site, diachronic framework. My study suggests that Native practices of marine resource harvesting changed throughout the Holocene, and that Native people may have been using a stripping method of harvesting in the early fall to manage and sustain mussel beds. This study built upon approaches for assessing instances of resource depression and sustained management of shellfish populations, incorporating multiple lines of evidence including experimental morphometrics, stable isotope geochemistry, and zooarchaeological analysis with a comparative, diachronic scope. These analyses suggest a trend of resource depression of California mussel from the Middle Holocene to the Late Holocene, as evidenced by a decreased average size of mussels in archaeological assemblages from three sites in Santa Cruz and San Mateo Counties. However, the data from Late Holocene sites suggests resource stability of mussel populations that is consistent with expectations of a stripping method of harvest and stewardship of mussel beds that may mirror the management of terrestrial resources in the region during this time period. Like Case Study One, this study also contributed to community outreach efforts with the Amah Mutsun Land Trust Coastal Stewardship Program, which was disseminated through curriculum developed for coastal field trips with the AMLT youth Summer Camp and Stewardship Corps led by the author. These field trips focused on applying Ancient archaeological data of shellfish harvesting practices to restore and revitalize TEK and TREM of shoreline stewardship. Despite mussels being under quarantine during these summer months, Tribal members learned about the diversity of intertidal resources in their traditional homelands, as well as their traditional Mutsun names and sustainable harvest practices, gathering seaweed and catching and preparing fish evidenced in archaeological sites in the area. We plan to return in the fall to harvest mussels, guided by ethnographic and archaeological data from this study.

<u>Case Study Three:</u>

Coast Miwok Stewardship of Clam Beds in Tomales Bay: An Eco-Archaeological Investigation

Accounts from Coast Miwok tribal elders and ethnographic sources suggest the presence and maintenance of clam beds in Tomales Bay in Central California, maintained by Indigenous practices which may have improved the productivity of native clam species through selective harvesting and habitat enhancement. My study synthesized extant tribal information and archaeological data to identify clam management practices in Tomales Bay in Ancient and Historic times. By developing a morphometric equation for extrapolating shell length of fragmented archaeological shell remains, applying this formula to archaeological clams from three sites in Tomales Bay, and conducting interviews with tribal elder Gilbert Zoppi regarding traditional clam harvesting practices, this study presented a research program that is integrative, diachronic, holistic, and can be used a model for detecting shoreline stewardship of clams resources through time. This collaborative research project with the Federated Indians of Graton Rancheria (FIGR), The National Parks Service, and UC Berkeley displayed a trend of stability and enhancement of Littleneck clams in Tomales Bay over more than 1000 years resulting from Coast Miwok stewardship practices. This information is being shared with FIGR and we continue to collaborate on how to use this information to incorporate Traditional Resource Management of clam beds in Tomales Bay for contemporary fisheries policy and regulations.

Broader Impacts

This dissertation increases the scope of our knowledge regarding shoreline management along the Central Coast of California, contributing a focus on marine resource harvesting and management practices to complement a pre-existing body of archaeological work dealing with terrestrial resource management and the use of fire to modify biotic communities in this region. This work provides a model for assessing Indigenous people's interactions with coastal resources that may have created productive and sustainable relationships through time. This stands in contrast to much archaeological research which treats coastal resources as marginally important and often frames indigenous relationships with these resources in terms of resource intensification which inevitably leads to resource depression and depletion. By investigating human interactions with shoreline ecosystems from a diachronic perspective we are more thoroughly informed when assessing the extent and degree of human impacts on Ancient seascapes. In addition. we can provide important baseline data regarding long-term human interactions with the marine ecosystems that can inform wildlife and fisheries management and guide more sustainable policy decisions. This work is especially timely, as the dramatic coastal environment of Central California is in dire need of archaeological inquiry due to climate change, sea level rise, rapid coastal erosion and subsequent destruction of archaeological sites. My work has and continues to involve the survey and study of these endangered sites to preserve valuable information regarding coastal management practices.

These case studies serve as a model for community-based research with local tribes and stakeholders that can have important applications to our contemporary world in the management of both coastal and terrestrial resources on public lands, acknowledging and affirming Ancient Indigenous wisdom regarding that lands and shorelines they called home long before European arrived and instituted often short sighted and destructive management practices. This collaborative, interdisciplinary approach can also serve to restore and revitalize the traditional ecological knowledge of Indigenous stakeholders and tribal collaborators that may have been affected during colonization. This dissertation provides cultural and ecological data that will be employed by the Amah Mutsun Tribal Band, the Federated Indians of Graton Rancheria, the National Parks Service, and California State Parks in developing contemporary strategies for shoreline restoration and stewardship.

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Appendix A: Site, Material, and Context information for radiocarbon dates from HEALPR project sites from Santa Cruz and San Mateo Counties.

Site	**Unit**	**Level**	**Material Type**	**AMS Lab #**	**AMS Lab Sample Name**	**14C Age**	**14C Age Error**	**Calib Age 2-sig (<0.05 Intervals Omitted)**
CA-SCR-7	Col #1	2	Bark	182836	F132-1	3820	15	2,300-2,202 BCE (0.99)
CA-SCR-7	Col #1	4	Bark	197217	F122-1	3790	15	2,286-2,246 BCE (0.43); 2,235-2,195 BCE (0.36); 2,173-2,145 BCE (0.19)
CA-SCR-7	Col #1	6	Bark	197215	F117-1	4030	15	2,579-2,488 BCE
CA-SCR-7	Col #1	8	Twig	197216	F120-1	4765	15	3,635-3,621 BCE (0.13); 3,606-3,522 BCE (0.87)
CA-SCR-7	Col #1	10	Twig	197214	F115-1	4955	15	3,776-3,694 BCE (0.97)
CA-SCR-7	Col #1	11	Parenchyma	182847	F85-1	4995	15	3,798-3,710 BCE (0.99)
CA-SCR-7	Col #2	2	Bark	182849	F97-1	3785	15	2,285-2,247 BCE (0.36); 2,234-2,192 BCE (0.33); 2,178-2,143 BCE (0.30)
CA-SCR-7	Col #2	4	Bark	197248	F99-1	3855	15	2,457-2,418 BCE (0.09); 2,407-2,374 BCE (0.14); 2,351-2,279 BCE (0.67); 2,250-2,230 BCE (0.06)
CA-SCR-7	Col #2	6	Bark	197210	F103-1	3890	15	2,463-2,335 BCE (0.93); 2,324-2,303 BCE (0.07)
CA-SCR-7	Col #2	8	Bark	197244	F78-1	5025	15	3,939-3,869 BCE (0.61); 3,813-3,765 BCE (0.38)
CA-SCR-7	Col #2	9	Bark	182846	F8301	4050	15	2,623-2,562 BCE (0.55); 2,534-2,493 BCE (0.45)
CA-SCR-7	Col #7	2	Parenchyma	182841	F66-1	5770	15	4,686-4,577 BCE (0.90); 4,575-4,555 BCE (0.10)
CA-SCR-7	Col #7	3	Bark	197246	F92-1	5855	15	4,780-4,694 BCE
CA-SCR-7	Col #7	4	Notholithocarpus	182842	F68-1	5875	15	4,787-4,713 BCE
CA-SCR-14	Exc #1	2	Parenchyma	197221	F143-1	100	15	1,693-1,727 CE (0.29); 1,812-1,897 CE (0.58); 1,902-1,919 CE (0.13)

CA-SCR-14	Exc #1	4	Bark	197222	F145-1	895	20	1,044-1,099 CE (0.43); 1,119-1,143 CE (0.13); 1,146-1,210 CE (0.44)
CA-SCR-14	Exc #1	5	Bark	197223	F146-1	985	15	1,016-1,046 CE (0.82); 1,093-1,121 CE (0.16)
CA-SCR-14	Exc #1	5	Mytilus	197224	F146-2	1095	20	1,309-1,651 CE
CA-SCR-14	Exc #2	2	Twig	197225	F148-1	85	15	1,695-1,726 CE (0.27); 1,813-1,838 CE (0.20); 1,868-1,918 CE (0.49)
CA-SCR-14	Exc #2	3	Bark	197226	F149-1	385	15	1,449-1,511 CE (0.86); 1,601-1,616 CE (0.14)
CA-SCR-14	Exc #2	5	Bark	197231	F159-1	650	60	1,267-1,411 CE
CA-SCR-14	Exc #2	6	Bark	197232	F160-1	865	15	1,159-1,212 CE
CA-SMA-216	A	NA	Charred Ephemeral Veg.	157883	SMA-216 ST4B	575	30	1,302-1,366CE (0.64); 1,383-1,420 (0.36)
CA-SMA-216	CA	NA	Charred botanical	NA	NA	345	40	1,460-1,640CE
CA-SMA-216	CB	NA	Charred botanical	NA	NA	350	35	1,457-1,534CE (0.43); 1,536-1,635CE (0.57)

Appendix B: Site, Material, and Context information for radiocarbon dates from three HEALPR project sites from Tomales Bay.

Catalog #	Site	Context	Material Type	AMS Lab #	AMS Lab Sample name	14C Age	14C Age Error	Cal Age 2-sig
222-0008-04-AMS-1	A	140-160 cm; Flot #53	Bark	169142	F53-1	935	15	1,035-1,059 AD (0.20); 1,064-1,154 AD (0.80)
222-0003-04-AMS-1	A	40-60 cm; Flot #48	Bark	169143	F48-1	255	15	1,641-1,665 AD (0.96)
224-0006-04-AMS-1	B	100-120 cm; Flot #20	Twig	169137	F24-1	210	15	1,652-1,677 AD (0.32); 1,776-1,800 AD (0.53); 1,940-1,951 AD (0.12)
224-0017-04-AMS-1	B	120-140 cm; Flot #31	Twig	169147	F20-1	705	15	1,271-1,294 AD
224-0010-04-AMS-1	B	180-200 cm; Flot #24	Bark	169136	F28-1	1210	15	769-882 AD
224-0014-04-AMS-1	B	60-80 cm; Flot #28	Bark	169146	F31-1	235	15	1,646-1,667 AD (0.70); 1,783-1,796 AD (0.30)
249-0003-04-AMS-1	C	40-60 cm; Flot #12	Bark	169134	F12-1	190	15	1,663-1,682 AD (0.22); 1,737-1,757 AD (0.11); 1,761-1,804 AD (0.45); 1,936-1,951 AD (0.21)
249-0004-04-AMS-1	C	60-80 cm; Flot #13	Bark	169135	F13-1	370	15	1,452-1,521 AD (0.70); 1,591-1,620 AD (0.29)