LOCALIZED HISTORIES OF CALUSA ECOLOGY AND ECONOMY, SOUTHWESTERN FLORIDA, AD 1000 – 1500

by

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(Under the Direction of Victor D. Thompson)

ABSTRACT

Humans experience climate effects on scales that directly affect the availability of resources. This is especially true for those populations that reside near and depend upon estuarine ecosystems where sea level change can act as a primary driving force in the distribution and configuration of these ecosystems. The research that follows explores the local manifestations of global climate trends related to the Little Ice Age from AD 1000 – 1500 within two distinct estuarine systems in Florida, Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay in Southwest Florida. It also combines this with an examination of the consequences of environmental change on economic strategies that in turn influence Indigenous sociopolitical and socioeconomic organization among the Calusa. This research utilizes high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate and invertebrate refuse at Mound Key (8LL2) and the Pineland Site Complex (8LL33, etc.), AD 1000 – 1450, to examine local environmental conditions and evidence for deeply rooted ecological knowledge that supported complex socio-economic organization. Lastly, this research examines evidence for the organization of non-subsistence based economies through a unique assemblage of toxic burrfishes remains recovered from archaeological deposits at Mound Key.

INDEX WORDS: Zooarchaeology, Stable Isotopes, Environmental Archaeology, Economics, Southwestern Florida

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DEDICATION

For Jake and Julie.

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CHAPTER 1

INTRODUCTION

Humans experience climate effects on scales that directly affect the availability of resources. This is especially true for those populations that reside near and depend upon shallow estuarine ecosystems where sea-level change can act as a primary driving force in the distribution and configuration of these ecosystems. Many archaeological studies focus on long-term, multi-century adaptations to climate change as they relate to changes in the availability of resources (e.g., Anderson et al. 2006; Anderson et al. 2007; Beresford-Jones et al. 2018; Caramanica et al. 2018; Clarke et al. 2016; D'Anjou et al. 2012; Jefferies et al. 2005). While important, such work only provides a partial perspective which often lacks information on two accounts. First, it accepts to some extent that global climatic trends affected regional and local environmental conditions in broadly similar ways. Second, it lacks information on exactly how specific economic changes articulated with local environmental change. The research that follows builds on these previous studies by exploring the local manifestations of global climate trends within two distinct estuarine systems in Florida, Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay in Southwest Florida (Figure 1.1). It also combines this with an examination of the consequences of environmental change on economic strategies that in turn influence Indigenous sociopolitical and socioeconomic organization. Through the

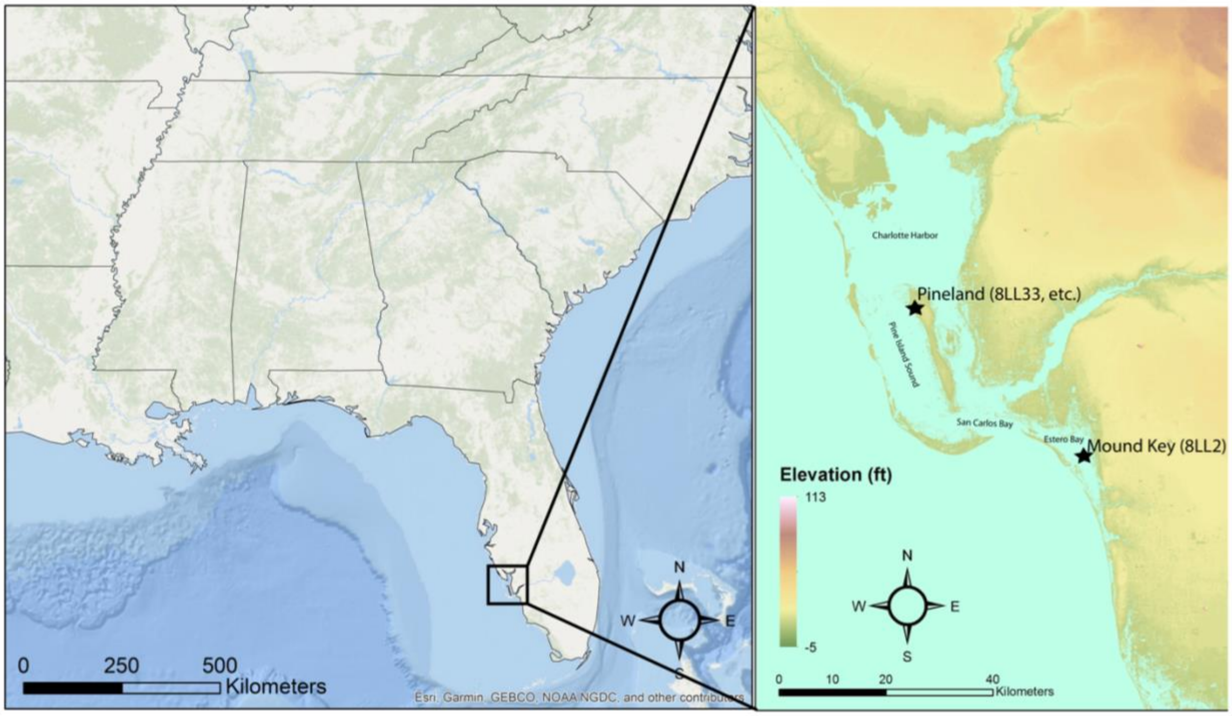

Figure 1.1. Location of Pineland Site Complex (8LL33, etc.) and Mound Key (8LL2), Southwestern Florida, USA within their respective estuarine systems. Panel on right is a Digital Elevation Model.

first case study presented here, I examine the local characteristics of global climatic change associated with the onset of the Little Ice Age, ca. AD 1200, through high-resolution Bayesian chronological modeling, and zooarchaeological analyses at the Pineland Site Complex (8LL33, etc.) in southwestern Florida (Chapter 2). The second cases study employs high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate refuse at Mound Key (8LL2), AD 1000 – 1450, to examine local environmental conditions and evidence for deeply rooted ecological knowledge that supported complex socio-economic organization (Chapter 3). Finally, I examine evidence for the organization of non-subsistence economies through a unique assemblage of toxic burrfishes remains recovered from archaeological deposits at Mound Key (Chapter 4).

Previous work, most notably at the Pineland Site Complex, along the southwestern Florida Gulf Coast, documents varying relationships between climate change, animals and plants, and human economic practices (deFrance and Walker 2013; Marquardt and Walker 2013; Walker 1992, 2013) over a span of about 1,500 years starting around the first century AD through European contact. Substantial evidence, on a 50-year timescale, has been advanced to explore these relationships for the first 1,000 years of this timespan (Marquardt and Walker 2013). The dynamics of these socioecological relationships, to date, however, remain far less understood for the final 500 years of the timespan (ca. AD 1000 – 1500). Of paramount importance, this is the period during which a warmer/wetter climate episode transitioned into a cooler/dryer one, known as the transition from the Medieval Warm Period to the Little Ice Age (Lund and

Curry 2006; Richey et al. 2007), and during which the Calusa emerged as a powerful complex society (Marquardt 1988; Thompson et al. 2018). This research proposes to re-examine these 500 years, AD 1000 – 1500, at two sites, one in Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay, Pineland (8LL33, etc.) and one at Mound Key (8LL2), through the lens of hyper-local ecological and social change.

Using the conceptual frameworks of Historical Ecology and Resilience Theory, this research merges high-resolution radiocarbon dating, zooarchaeological analyses of vertebrate and invertebrate faunal remains, and high-resolution, incremental isotope analyses on hard clam remains from recent excavations at both Mound Key and Pineland. Specifically, this research contributes to developing understandings of how people living in the coastal regions of southwestern Florida mediated the local manifestations of global environmental changes between AD 1000 and 1500. Using data from the Pineland Site Complex, a major Calusa settlement in southwestern Florida, and Mound Key, the capital of the Calusa at the time of Spanish contact in southwestern Florida, I examine the dynamic paleoenvironmental settings within which the Calusa navigated changing socio-political and socio-economic institutions in the context of the climatic period known as the Little Ice Age (ca. AD 1200-1850).

Broadly, this research explores relationships between local-scale environmental change and economic practices among complex, fisher-gatherer-hunters at spatial and temporal resolutions not often recognizable in the archaeological record. It also provides an opportunity to examine these relationships as they manifest at two different Calusa settlements within two unique estuarine systems. The ability to mediate local changes in environment likely contributed to the overall resiliency of these coastal groups. The data employed here allow for resolutions that are amenable to examining resiliency at multiple temporal scales (e.g., events, generational timelines, and multi-centennial trends). Bayesian analyses of radiocarbon dates from excavations of well-stratified shell midden deposits, from which the data considered here were collected, provide estimates for the Pineland deposits to have accumulated between *cal AD 940-1015* (*68% probability*) and *cal AD 1430-1495* (*68% probability*) (Chapter 2) and estimates for the Mound Key deposits from *cal AD 1000 – 1120* (*68% probability*) (Chapter 3) through Spanish contact in the 16th century. Specifically, the phenomena to be investigated here include local environmental changes, changes to subsistence economies, changes in the diversity of resources exploited, and the economic use of animals beyond subsistence. Thus, these data are used to investigate the following research questions:

1. *Do there exist local signatures of the onset of the Little Ice Age and if so, are they congruent with the global signature (e.g., significant cooling and drying trends)?(Chapter 2, 3)*
2. *Did large scale climate change alter localized resource utilization across the estuarine systems of southwestern Florida? (Chapter 2, 3)*

Historical Ecology and Resilience Theory

This research views social and natural systems as coupled, bound entities that do not change linearly or deterministically and thus uses the socioecological perspectives offered by Resilience Theory and Historical Ecology. This combination of perspectives allows for an understanding of human-environmental interactions but recognizes the challenges of living in climatically sensitive environments and the notion that humans possess extensive ecological knowledge of the places they live and the ability to actively manipulate the environment to mitigate changing conditions that affect the location and availability of resources. Additionally, it also provides a mechanism with which to further explore the intersection between socio-ecological and socio-political facets of these coastal communities. It is only when Historical Ecology is contextualized within Resilience Theory that the nature of these trajectories and interactions can be empirically informed.

Historical Ecology (Balée 2006; Crumley 2009), a research program that investigates the dynamic relationship between humans and their environment, situates the intersection between socio-ecological and socio-political realms of complex fisher-gatherer-hunter communities within both macro-scale (e.g., 500 years) and meso-scale (e.g., generational) trajectories of human occupation. Anthropologists, geographers, and historians use this approach to conceptualize historically informed environmental analyses and develop more comprehensive regional studies of landscapes over time (Balée 2006; Balée and Erickson 2006; Crumley 1994; Crumley 2009). It is through this study of landscapes over time that archaeologists address questions pertaining to human-environmental interactions, human impacts on their environments, human management of past ecosystems, and the development of baselines for contemporary ecosystems (Crumley 2009; Thompson 2013, 2014). Historical Ecology facilitates the integration of multiple disciplines in order to employ a time depth necessary for the analysis of long-term ecological changes as well for the analysis of the interconnectedness of humans and their environments (Crumley 2009). Interactions between humans and their environments are not viewed as environmentally deterministic, but rather as dialectical through an emphasis on humans as co-producers of their environment as opposed to emphasizing human adaptation to their environment (Crumley 2009; Marquardt 1992; Thompson 2014). This research program has been the driving framework for much of the previous work in southwestern Florida (Marquardt and Walker 2012; 2013).

Historical Ecology does not presume inherent separation between humans and ecosystems, but rather that humans are part of their ecosystems, socially and biologically. In fact, Historical Ecology centers the idea that most, if not the entirety, of the biosphere has been affected by human activity (Balée 2006; Crumley 2009). Different human activities, especially with regards to intentionality, are developed through time through the accumulation of distinct and historically defined ways of knowing local landscapes (Balée and Erikson 2006; Marquardt 1992). Humans as a species are not genetically programmed to promote or destroy biodiversity, but the way in which they enculturate their environment into the socio-political and socio-economic structures of their societies can have profound effects on overall diversity (Balée 2006). Humans do not serve as passive respondents to ecological change but are active agents in changes that occur within ecosystems for the landscape functions as a representation or material manifestation of this agency (Balée 2006; Balée and Erickson 2006; Crumley 2009; Thompson 2014).

Historical Ecology provides a theoretical perspective that allows and advocates for the examination of past changes in human-environment relationships while continuing to acknowledge and incorporate the non-human agents of change (Thompson 2014). It also provides a mechanism with which to address questions at various scales within the domains, of space, time, and the particular phenomena in question. Indeed, some such work has been undertaken in southwestern Florida through an explicitly historical ecological lens (Marquardt and Walker 2013; Walker 2013; Wang et al. 2013); however, understandings of the diversity of past human responses to climate change, especially across local contexts, remain either generalized and/or ambiguous for the time period AD 1000 – 1500. Thus, the research proposed here uses the guiding postulates of Historical Ecology to identify and explain the long-term and short-term trajectories of human-environmental interactions and how this articulates with trajectories of social and political complexity among the Calusa. The combination of Historical Ecology and Resilience Theory promotes investigation into the empirical nature of these trajectories and interactions.

Resilience Theory is used to explain how local populations persist through environmental hardship and localized environmental transformations. Resilience Theory offers a perspective on landscape continuity and change using the adaptive cycle metaphor (Holling and Gunderson 2002; Redman 2005; Redman and Kinzig 2003). It is used to explain how socioecological systems respond to change while maintaining basic form and/or function (Walker and Salt 2006). The adaptive cycle acts as a metaphor for understanding the stages of exploration, conservation, release, and reorganization within socioecological systems (Holling and Gunderson 2002). For archaeologists, Resilience Theory is a tool for understanding how behavior relates to local environmental conditions (e.g., Fitzhugh et al. 2016; Thompson and Turck 2009). Resilience is most often defined as the ability of a system to respond to disturbance by maintaining or returning to a state similar to the basic properties of the previous system without experiencing a wholesale shift to a different state or organization (Holling 1986). Specifically, in this research, I use it as a means with which to examine the stability of the economic systems of coastal southwestern Florida rooted in estuarine and marine resource use. While Historical Ecology provides a perspective, Resilience Theory provides the mechanics; the whys and the hows of the social and environmental circumstances considered within a historical perspective.

Global Climatic Trends and Their Local Manifestations

The manifestations of global climatic trends at local scales continue to be largely understudied from an archaeological perspective. This inhibits our ability to understand the nature of local species distributions and reproduction and our ability to assess how people experienced and navigated environmental change over shorter time spans. Studies often extrapolate local environmental characteristics from global climatic trends. The issue arises in archaeology when these named global trends are developed in areas far removed from the archaeological site or area of interest. Understanding the relationship between different patterns of resource use and environmental change requires the use of empirical data rooted in archaeological contexts. Studies seeking to answer questions related to this relationship often emphasize general climatic patterns as drivers of social change, including shifts in resource use. This approach is problematic because global climatic trends and local shifts in patterns of resource use operate at vastly different temporal and spatial scales. Additionally, many archaeologists use climatic records to understand social patterns without tying data to the paleoenvironmental records that either come directly from associated archaeological sites or even surrounding areas. Ultimately, this leads to problems with our understanding of the exact context under which coastal groups altered their exploitations of resources. However, works by Rick and Erlandson (2008) and Thompson and Waggoner (2013) demonstrate the interconnectedness of fisher-gatherer-hunter societies with the landscapes they inhabited and the resiliency of human and marine ecosystem interactions through time and space. Investigating the relationship between climatic change, local environmental conditions, and economic practices through the combined perspective offered by Historical Ecology and Resilience Theory provides a solution to these problems.

Much emphasis has been placed on analyzing how general, regional and global patterns of climate change correlated with social change in the past (e.g., Ames and Marshall 1980; Brown and Vierra 1983; Brown 1985; Habu and Hall 2013). Less work, however, has been undertaken to understand how global changes (e.g., Medieval Warm Period, Little Ice Age) were manifest and experienced at local levels in an explicit fashion outside of the areas in which they were constructed. While the use of these broad climatic trends may allow archaeologists to address global and regional trends, tying the archaeological record to the paleoenvironmental data directly from archaeological sites provides a more precise reconstruction of paleoenvironmental conditions and allows human-environmental relations to be investigated at much smaller scales (Crumley 2009; Kennett and Kennett 2004; Predergast and Stevens 2014).

Southwestern Florida harbors a record of long-term, coupled socio-ecological systems, as both ecological and cultural variables are responsive to each other during times of change and stasis in these systems (see Marquardt and Walker 2013). Estuarine systems trap nutrients and have year-round photosynthesis, making them extremely productive ecosystems (Odum 2005). When at lower levels of salinity, they also provide an ecological barrier that protects developing fisheries and shellfish from offshore predators (Weinstein 1979). However, minor fluctuations in sea level can dramatically compound changes along the shoreline for this area, which is characterized by a small tidal range, a series of shallow estuarine systems, and a long continental shelf making this area vulnerable to even minor fluctuations in environmental characteristics (Geselbracht et al. 2015; Passeri et al. 2016). Local ecosystem changes can result in changes to local communities and population structures including their distribution, population abundance and locations, and inter- and intra-species behavior. Ray et al. (1992) demonstrate that, at least in the twenty-first century, broad scale extinctions are unlikely to occur during a warming climate in coastal estuarine and marine systems. They point out that what should be expected is change to the distribution and composition of communities within an ecosystem. The rapidity and success of marine and estuarine ecosystems to respond and adapt to these changes depends on the pace of climate change. The climatic period known as the Little Ice Age, beginning ca. AD 1200, is roughly categorized as a time of cooler global temperatures with a Gulf of Mexico sea-level record (Tanner 1991, 1992) indicating a general, overall lower relative sea level starting sometime ca. AD 1200 with variations throughout its duration (Walker 2013; Walker and Surge 2006; Wang et al. 2013)

The residues of past economies provide insights into the spatial and temporal distribution of preferred resources. Preferred resources provide insights into the paleoecological conditions because organisms occupy distinct geographic distributions (Brown and Lomolino 1998) both spatially and through time as environmental conditions change (Lyman 2017). When environmental conditions change, whether these changes are manifest through changes in temperature, relative sea level, or other factors, organisms can respond to these changes via relocation, reproduction, or altering other aspects of behavior to adapt to the new environmental conditions (Gauthreaux 1980; Gienapp et al. 2008). However, while these resources respond to a changing environment, humans also alter their economic strategies to either follow these resources when they relocate, adopt alternative types of resources, or adapt and alter their collection practices to best fit new environmental conditions. This research seeks to identify environmental changes and explore how populations altered their economic practices to foster resiliency. Indeed, economic strategies across southwestern Florida likely articulated with the composition and distribution of local resources (Walker 2013).

Fisher-Gatherer-Hunters of Southwestern Florida, AD 1000-1500

This research focuses on two sites in southwestern Florida located along the Gulf Coast, the Pineland Site Complex (8LL33, etc.) and Mound Key (8LL2). The Pineland Site Complex, a major Calusa center (Figure 1.2) is located on Pine Island and Mound Key, the capital of the Calusa at the time of Spanish contact in the 16th century, is located within Estero Bay to the south of Pine Island. The Calusa were a non-agricultural, complex chiefdom or weak tributary state (Hutchison et al. 2016; Marquardt 2014; Thompson et al. 2018; Thompson et al. 2013), which exacted control over the lower third of peninsular Florida at the time of European contact in the sixteenth century. While the exact timing for the emergence of the kind of political complexity seen at the time of European contact in southern Florida is unclear, such organizational complexity was likely realized by at least AD 800 (Thompson and Worth 2011). In the absence of maize (Hutchison et al. 2016), the Calusa relied on aquatic resources, wild plant foods, and cultivated home gardens that provided species such as chili peppers, papaya, gourds, and squash (Marquardt 2014; Newsom and Scarry 2013; Newsom et al. 1993). Environmental conditions undoubtedly played a key role in both sociopolitical and socioeconomic structuring and restructuring of Calusa communities given their reliance on fishing, gathering, and hunting. Marquardt and Walker (2013) propose that an erratic sea-level regression associated with the Vandal Minimum global climatic episode ca. AD 550 – 850 created conditions that reduced the availability of stable fish used by the Calusa. Thompson and colleagues (2014) propose a restructuring of household organization, kin relations, and labor roles at Pineland during beginning at the onset of the episode. These trends likely set in motion historical shifts that would result in the large complex polity encountered by Spanish explorers in the sixteenth century (Thompson et al. 2018).

While the resiliency of the Calusa at Pineland during the climatically tumultuous time of the Vandal Minimum is relatively well understood, the environmental history and economic strategies characterizing the period between AD 1000-1500 remain less well understood. This period encompasses the shift from the Medieval Warm period (ca. AD 850-1200) to the onset of the Little Ice Age (ca. AD 1200-1850) (Walker 2013). This kind of high-resolution data set of human-environmental relationships has most intensively been explored at Pineland while little other data of this expanse exists for other Calusa sites. Pineland was occupied by the Calusa both well before and well after the period from AD 1000 – 1500 (Marquardt and Walker 2013). The timing of occupation at Mound Key is less clear but current data suggests the intensive occupation occurred prior to AD 1000 and persisted through European contact (Thompson et al. 2016; Thompson et al. 2020a). Both sites contain large midden-mound complexes with a

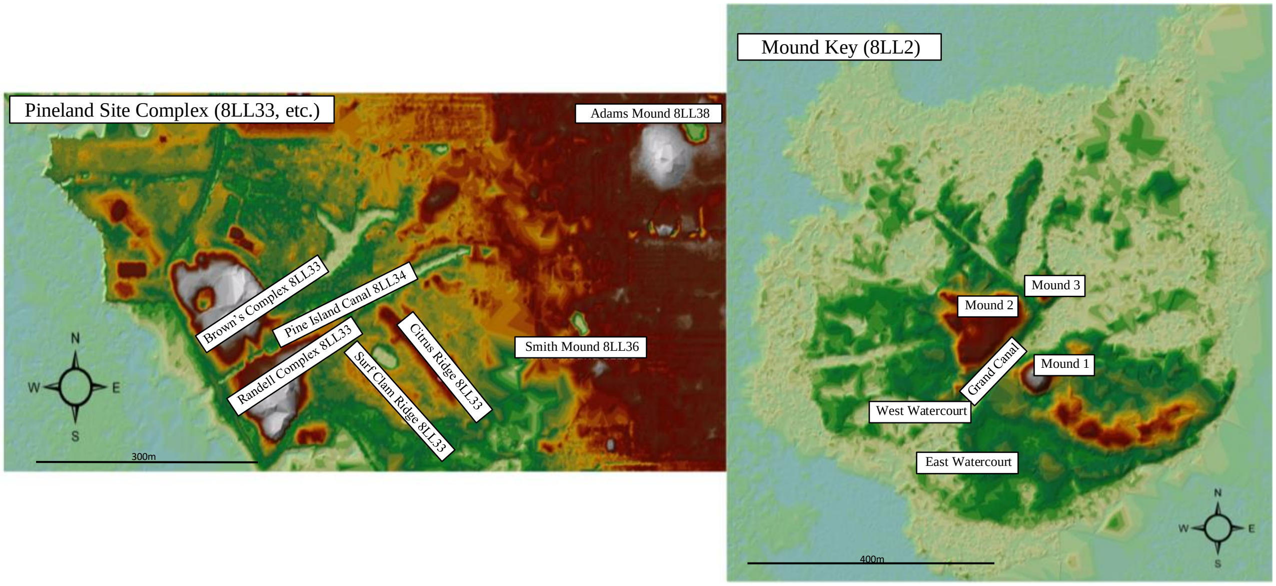

Figure 1.2. LiDAR digital elevation models of Pineland Site Complex (8LL33, etc.) (left) and Mound Key (8LL33) (right) showing prominent features.

central canal and are located within estuarine systems with distinct ecological and hydrological characteristics that would have been impacted by climatic fluctuations, including relative sea level rise, changes to sea surface temperature, and shifting salinity gradients.

The Pineland Site Complex is a group of related sites with a wide variety of archaeological features. Brown's Complex and Randell Complex, the most prominent midden-mound complexes, are bisected by the Pine Island Canal (Marquardt and Walker 2013). Along this canal there are other anthropogenic water features including several water courts, canals, numerous ridges and mounds, and lakes that surround two sand burial mounds. These features are a product of a roughly 1700-year history providing a detailed record of the relationship between Calusa culture and environmental change. During the Caloosahatchee I-late period (AD 1-500), the southwestern portion of the site complex saw major domestic occupations along an old shoreline including the Old Mound, Surf Clam Ride, Citrus Ridge, and Low Mound areas of the site and year-round settlement is indicated, as evidenced by faunal analysis (Marquardt and Walker 2013), with inhabitants living in small (ca. 3.5 m diameter) round structures (Worth 2007; Thompson et al. 2014). During the Caloosahatchee IIA period (AD 500-800), settlement shifted to the areas of Old Mound and Brown's Complex with the initial construction of the Central Canal (Marquardt and Walker 2013). This period aligns with the climatic period known as the Vandal Minimum (ca. AD 550-850) during which conditions were generally cool and dry but with erratic changes to temperature, precipitation patterns, and relative sea level. Settlement was still year-round with household organization shifting from small family units to large multifamily households (Marquardt and Walker 2013;

Thompson et al. 2014). It is also during this time that fisheries productivity diminished and evidence for long-distance exchange increased (Marquardt and Walker 2013).

At the onset of the Warm Medieval Period and the beginning of the Caloosahatchee IIB period (AD 800-1200), site structure shifted from a pattern of paralleling the shoreline to mound complexes situated perpendicular to the shoreline (Marquardt and Walker 2013). It is also likely that during this time, as relative sea levels rose, additional water-control features such as lakes, water impoundment features, and canals, including the Pine Island Canal, were constructed. During the Little Ice Age, coeval with the Caloosahatchee III and IV periods (AD 1200-1350 and AD 1350-1500, respectively), accumulation continued on midden-mounds, canals were maintained, people likely lived on the flat-topped mounds to either side of the Pine Island Canal, and populations across the region coalesced into larger villages. No undisturbed Caloosahatchee V (AD 1500-1700) deposits have been identified but isolated objects such as glass beads and other European trade goods were recovered (Marquardt and Walker 2013:109-110; Worth 2014). While the resiliency of the Calusa at Pineland during the climatically tumultuous time between ca. AD 550 and 850 (Vandal Minimum) was explored in depth by Marquardt and Walker (2013), the environmental history and economic strategies of the Calusa at Pineland are not as well-known between ca. AD 1000 and 1500. The period between ca. AD 1000 and 1500 captures the decline of global climatic conditions from the Medieval Warm period and beginning of the Little Ice Age.

Mound Key, a 51-hectare anthropogenic island composed primarily of shell midden (Thompson et al. 2016), is located in Estero Bay, Florida and is a complex arrangement of midden-mounds, canals, watercourts, and many other features (Figure

1.2). By AD 1000, the two largest mounds, Mounds 1 and 2, reached their pinnacle heights of 10m and 6m, respectively (Thompson et al. 2016). Mound 1 contains a mound-top structure with at least 3 phases of construction and repair beginning around AD 1000 (Thompson et al. 2016). A large canal, termed the Grand Canal, bisects the area between Mounds 1 and 2 and extends across the entire island at 365m long and averages 28m wide (Thompson et al. 2019) much like the Pine Island Canal. At the canal's southern end, at the base of Mounds 1 and 2, exist two watercourts that mirror each other on either side of the canal. Recent research by the PI and colleagues demonstrates final construction phases, and likely peak use of, the watercourts to date to *cal. AD 1385—1450* (68% probability) (Thompson et al. 2020b). They argue these watercourts functioned as large areas of surplus fish storage that supported the increasing Calusa political structure (Thompson et al. 2020b).

In the absence of maize (Hutchison et al. 2016), the Calusa relied on aquatic resources, wild plant foods, and cultivated home gardens that provided species such as chili peppers, papaya, gourds, and squash (Marquardt 2014; Newsom and Scarry 2013). The Calusa consumed a wide variety of invertebrates and vertebrates, leaving behind numerous shell middens which provide a laboratory through which archaeologists can explore local temporalities of socio-environmental change. Many vertebrate and invertebrate species in the region are available and were utilized both seasonally and year-round (deFrance and Walker 2013; Russo 1998; Quitmyer 2013). Some mollusks and vertebrates are effective proxies for paleoclimate reconstructions (Andrus 2012; Wang et al. 2013; Quitmyer 2013). The complexity of structural elements to control water at both Mound Key and Pineland demonstrates Calusa communities embedded estuarine resource control into their lifeways and likely used this manipulation of the environment to support a level of socio-political complexity usually only seen in societies who rely on agricultural production. At Pineland, the more intensively studied of the two sites, and likely also at Mound Key, these features are a product of a roughly 1700-year history providing a detailed record of the relationship between Calusa culture and environmental change (Marquardt and Walker 2013). Both sites were occupied well before and well after the period AD 1000 – 1500 and are located within estuarine systems with distinct ecological and hydrological characteristics that would have been impacted by climatic fluctuations, including relative sea level rise and fall, changes to sea surface temperature, and shifting salinity gradients. The combination of the rich contextual history provided by previous researchers at Pineland and the new research from Mound Key provides an opportunity to contribute to our understanding of the trajectory of fisher-gatherer-hunters and increasing socio-political complexity.

Hypotheses

Macro-scale Hypotheses

Previous research at Pineland demonstrates that from the Roman Warm Period (350 BC – AD 550) to the Vandal Minimum (AD 550 – AD 850) economic practices likely changed in response to a cooler climate and lowered sea levels (Marquardt and Walker 2013). The research presented here examines the period beyond AD 850 to study the transition between the Warm Medieval Period (AD 850 – 1200) and the Little Ice Age (AD 1200 – 1850). For southwestern Florida generally, there is a paucity of archaeological data associated with the Little Ice Age. Available data correspond to the early onset of the Little Ice Age, and thus may not represent the full effects of and response to cooler climatic conditions that persisted through AD 1500. Recent data on global fisheries in relation to climatic indices suggests a causal link in the extra-tropical Pacific between climatic variability and fishery productivity, which reflects climatic changes within the previous one to two years (Castro-Ortiz and Lluch-Beldaa 2007). Fisheries, both invertebrate and vertebrate, are sensitive enough to reflect change at the annual, decadal, and multi-centennial scale and thus may be reflect in the various economic strategies of the Calusa.

The proposed research evaluates the following hypotheses concerning macro-scale patterns:

1. *There is an onset of cooler temperatures, lower sea levels, and decreased salinities locally in the Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay areas beginning ca. AD 1200 and lasting through ca. AD 1500 that corresponds with the onset of the global cooling event known as the Little Ice Age. (Chapters 2 and 3)*
2. *The onset of these associated trends is associated with a multi-centennial change in the diversity and equitability of species that formed the basis of coastal economies. (Chapters 2 and 3)*
3. *The economic strategies of the Calusa were resilient to changing environmental conditions. (Chapters 2, 3, and 4)*

Meso-scale Hypotheses

The Little Ice Age was a time of great climatic variability. The Haeberli and Holzahauser (2003:14) alpine glacial record documents three sub-cooling episodes that were likely global occurrences: AD 1250-1350, AD 1500-1650, and AD 1750-1850.

Eddy (1994:29-31) demonstrates that periods of low solar activity, associated with cooler global temperatures, characterized the Little Ice Age with the Wolf Minimum (ca. AD 1280-1340), Spoerer Minimum (ca. AD 1410-1510), and Maunder Minimum (ca. AD 1640-1710). Other records supporting this variability include, but are not limited to, a Sargasso Sea record (Keigwin 1996), a Puerto Rico record (Nyberg et al. 2002), and a Chesapeake Bay record (Cronin et al. 2003). Rapidly changing environmental conditions resulting from global climatic changes could have affected the location and availability of key resources to the people at Pineland. How well people and their prey adapt to changing conditions depends on the rapidity at which these changes take place. Given local records demonstrating decadal and centennial-scale environmental variability elsewhere across the globe, the environments around Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay also likely experienced perturbations throughout this overall cooling trend with punctuated periods of even cooler conditions. This likely had severe impacts on the local estuarine ecosystems, for many of the species found in shallow-water ecosystems are highly susceptible to freeze damage. The reliance on geographically distant, long-term climatic records and the vulnerability of the low-lying, shallow-water, subtropical ecosystems of the Florida Gulf Coast contribute to the need to investigate the impacts of these variations on environmental conditions surrounding Charlotte Harbor/Pine Island Sound/San Carlos Bay and Estero Bay.

The proposed research evaluates the following hypotheses concerning meso-scale patterns:

1. *Minor variations in temperature and salinity, proxies for climate and sea-level, during the Little Ice Age are measurable in the archaeological records from*

Pineland and Mound Key and are comparably different between their respective estuarine systems. (Chapter 2 and 3)

2. *During periods of minor variation, changes in faunal diversity fluctuated with variations in temperature and salinity. (Chapter 2 and 3)*

Research Design

This research uses zooarchaeological, archaeobotanical, and isotopic data from both Mound Key and Pineland that were excavated as a part of research programs lead by Victor Thompson, William Marquardt, and Karen Walker during the summers of 2013 and 2015 and the spring of 2017. I participated in the excavations and recovery of the materials used in this research at Pineland and Mound Key conducted during the spring of 2017. This research required extensive analysis of stratigraphy, zooarchaeological faunal samples, Bayesian modeling of radiocarbon dates, and collecting and analyzing samples for stable oxygen isotope analysis at the Georgia Museum of Natural History, Laboratory of Archaeology, and Center for Applied Isotope studies, all at the University of Georgia.

Zooarchaeological Analysis

I analyzed all vertebrate and invertebrate remains presented in this research (Chapters 2, 3, and 4) at the Georgia Museum of Natural History, University of Georgia and the Florida Museum of Natural History, University of Florida following the basic zooarchaeological methods outlined in Reitz and Wing (2008) under the advisement of dissertation committee member Elizabeth Reitz. Identifications for each specimen are made to the lowest possible taxon primarily using the comparative collection at the University of Georgia and, when necessary, the comparative collection at the Florida

Museum of Natural History in consultation with Karen Walker. A series of primary data classes were collected including the Number of Identified Specimens (NISP), weight (g), modifications, and measurements where appropriate. I estimated minimum number of individuals (MNI) by pairing elements and separating individuals by age structure and size classes when possible (Reitz and Wing 2008). After the species lists for the samples were created, diversity and equitability were estimated. Equitability examines the degree to which species are equally abundant (Reitz and Wing 2008). Diversity, estimated via the Shannon-Weaver Function, provides a way to measure species presence and abundance to classify the heterogeneity of the given analytical unit (Reitz and Wing 2008). The vertebrate and invertebrate analysis contributed to the both sets of hypotheses (Walker 1992; deFrance and Walker 2013).

The faunal analyses were conducted on representative samples from appropriate strata at Pineland excavated in both 2015 and 2017 (Chapter 2). Radiocarbon analyses demonstrate these deposits represents an approximately 500-year time span. These deposits were chosen for analysis for several reasons. Based on context, stratigraphy, and their relationship to other contexts across the larger site complex, these deposits likely do not represent an idiosyncratic deposit but represent broad-scale, continuous activity. When compared to other Calusa middens and mound/mound-top contexts, this deposit is comparable to other long-term midden deposits in terms of the shell tool assemblage and the faunal assemblage. Faunal examinations, as well as comparisons to other faunal assemblages south of Pine Island, demonstrated that the faunal assemblage analyzed was consistent with other Calusa faunal assemblages in the area. As the emergence of sociopolitical complexity was likely in place at least two centuries before the earliest date associated with these deposits, changes represented within this deposit likely represent changes spurred by factors beyond critical sociopolitical shifts. All material was water-screened through a series of nested screens with the smallest mesh at approximately 1/16-inch. Vertebrate faunal material was analyzed to the 1/8-inch size fraction and mollusk faunal material was analyzed to the 1/16-inch size fraction.

Materials from Mound Key were excavated during 2013 and 2017 (Chapters 3 and 4). Examining materials from these locations provides contexts that capture the targeted time range for this research, AD 1000 to AD 1500, and situates increasing political complexity among the Calusa and the role of Mound Key as a seat of political and economic power in the environmental context of southwestern Florida for the first few hundred years of the Little Ice Age. Ultimately, these deposits provide a medium through which to investigate Calusa economic strategies across the shift to the Little Ice age. The material excavated as part of the 2013 season targets the time after ca. AD 1300. These excavations were chosen based on location and associated AMS radiocarbon dates (see Thompson et al. 2016; Thompson et al. 2018; Thompson et al. 2020b). The 2013 excavations targeted the tops of both Mound 1 and Mound 2 while the material excavated during the 2017 season targeted the watercourt locations at the base of Mound 1 and Mound 2. AMS radiocarbon dates from the watercourt excavations place these deposits ca. AD 1000 to AD 1300 (Thompson et al. 2020b). All faunal material was recovered in the field using 1/4-inch screen.

Radiocarbon Chronological Modelling

All AMS dates were run at the Center for Applied Isotope Studies at the University of Georgia and all botanical samples were transported to Flagler College for identification by Lee Newsom. A series of 19 AMS radiocarbon dates establishes the chronology of the Pineland deposits. This allowed for zooarchaeological data to be understood on a high-resolution temporal scale elucidating the nature of these deposits and clarifying the impact of time averaging on these analyses. These dates were calibrated and modeled via Bayesian statistical modeling using OxCal 4.4.1 (Bronk Ramsey 2009) and IntCal 20 calibration curve (Reimer et al. 2020) (Chapter 2). Bayesian statistical modeling of radiocarbon dates and site data provides researchers with a better understanding of site chronologies by enabling date estimates on the generational scale (Bayliss et al. 2007; Bayliss 2009). The benefits of this method include avoiding overestimates of time, establishing a temporal trend for the activities recorded in the midden, and the overall temporality of the depositional sequence. The model generated estimates date ranges for each 10cm level at no longer than 25 years providing generational temporal contexts necessary to evaluate the meso-scale hypotheses. This constructed model demonstrates that the deposits selected for further analysis capture the onset of the Little Ice Age (ca. AD 1200) and approximately the first 200-300 years of its duration.

While many radiocarbon dates have been obtained at Mound Key to evaluate the timing and temporality of mound construction, nine additional AMS radiocarbon dates from Mound Key are presented here. I selected these dates from 3 *Mercenaria campechiensis* shells collected from three different deposits at Mound Key (Chapter 3). These shells represent the time period of ca. AD 1175 – 1450. Three dates were selected from each shell: one date from the most recent growth of the shell, one date from approximately half-way through the organism's lifespan, and a third date from one of the earliest growth stages, following the methodology outlined in Kennett and Culleton (2012). Counts of annual growth rings between samples selected for AMS radiocarbon dating were incorporated into a Bayesian model using OxCal 4.4.1 with the Marine20 curve (Heaton et al. 2020) and a local marine reservoir correction of -44 ±49 (Chapter 3) (Bronk Ramsey 2001). The *D_Sequence* command was used to evaluate dates with the known age separation between the selected samples within each shell. This model provides a temporal framework to evaluate the stable oxygen isotope analyses outlined in following sections.

Stable Isotope Geochemistry

The same clams used for the radiocarbon dating discussed above were sampled for stable oxygen isotope analyses. Each shell was sampled with even distribution through time by collecting a series of approximately 70 samples per shell, through the increments representing the developmental growth history (ontogeny) of the organism through its life. These samples were drilled along the axis of maximum growth of each left valve shell to gain a thorough representation of the environmental conditions during the hard clam's lifetime (situated in absolute time through the Bayesian modeling described above). Resulting samples of shell powder were submitted to the Center for Applied Isotope Studies at the University of Georgia.

Hard clams precipitate their shells near the oxygen isotopic equilibrium with the ambient conditions of growth (Elliot et al. 2003; Epstein et al. 1951; Jones and Quitmeyer 1996; Mook and Vogel 1968) with the composition and temperature of the water acting as the controlling factor on oxygen isotope fractionation between the shell and environment. Water temperature and the isotopic composition of shell material display an inverse relationship. Thus, analysis of oxygen isotopic composition of the shell correlates with past changes in temperature. Additionally, oxygen isotopic composition of water has a positive correlation with the oxygen isotopic composition of shells as a function of evaporation, precipitation, terrestrial run-off, and the mixing of salt and fresh-water inputs (Bemis and Geary 1996; Dansgaard 1964; Eagle et al. 2013; Grossman and Ku 1986; Shackleton 1969). Evaporation and increased input of marine waters not only increase salinity but also increase the oxygen isotopic composition of the water. This research recognizes that multiple variables, such as temperature, rainfall patterns, freshwater input, etc., contribute to the oxygen isotopic signatures recovered from marine shell. The interpretation of the data will be instrumental in addressing the research questions and hypotheses put forth here. These stable isotope analyses contribute to both the macro- and meso-scale hypotheses but will be key in addressing meso-scale variations in environmental change.

Dissertation Outline

In Chapter 2, my coauthors and I combine extant archaeological research from the Pineland Site (8LL33, etc.) with high-resolution chronological and vertebrate and invertebrate (shellfish) zooarchaeological analyses to investigate the local manifestations of the Little Ice Age and to provide new insight into the relationship between Indigenous peoples of southwestern Florida and local environmental changes. In this chapter, we finely track changes to trends in habitat exploitation and correlate these changes with shifting local ecological and environmental conditions. Through these efforts, we resolve, at a high-resolution, the specific local manifestations, and the tangible effects, of the global climatic trend known as the Little Ice Age

In Chapter 3, my coauthors and I employ high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate refuse from Mound Key. The isotopic and chronological data re used to reconstruct past environmental and climatic conditions over the course of the Little Ice Age. Through zooarchaeological investigations, we identify the particular species that were likely kept as surplus in the watercourts beyond what has already been discussed (Thompson et al. 2020b). While we have previously discussed the engineering of these watercourts (Thompson et al. 2020b), here we explore the ecological and biological knowledge deployed by the Calusa to make effective use of these engineered features.

In Chapter 4, I investigate a case of an unusually high number of burrfishes recovered from particular deposits at Mound Key. I analyze the kinds of burrfishes skeletal elements recovered from these deposits and discuss their potential role in the economic institutions of the Calusa through a discussion of the use of animals beyond their role in subsistence economies. This case study is presented as a useful comparative case for the role of zooarchaeological analyses in informing broader understandings of non-food and non-subsistence economies.

Chapter 5 presents conclusions and a synthesis of the results outlined in Chapters 2, 3, and 4. The themes of these papers, collectively, demonstrate the complex human-environmental relationships of southwestern Florida and the need for understanding how local environmental conditions relate to the global climatic trends. By employing a combination of high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate and invertebrate research refuse my coauthors and I demonstrate that the localized environmental conditions of southwestern Florida were not necessarily congruent with larger climatic trends and that the Calusa possessed deeply rooted ecological knowledge that supported a complex socio-economic organization.

In the attached appendices, I present the habitat designations, oyster measurements, OxCal Bayesian code, and stable oxygen isotope measurements utilized in Chapters 2 and 3. All habitat designations for the vertebrates and invertebrates used in Chapter 2 are presented in Appendix A and B, respectively. Appendix C presents the oyster measurements used in Chapter 2. Appendix D and E present the OxCal code for the Bayesian analysis presented in Chapter 2 and 3, respectively. The stable carbon and oxygen isotope measurements used in Chapter 3 are presented in Appendix F. All primary zooarchaeological data are housed at the Georgia Museum of Natural History, Zooarchaeology Laboratory.

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CHAPTER 2

CALUSA SOCIOECOLOGICAL HISTORIES AND ZOOARCHAEOLOGICAL INDICATORS OF ENVIRONMENTAL CHANGE DURING THE LITTLE ICE AGE IN SOUTHWESTERN FLORIDA, USA[1]

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Abstract

The Pineland Site Complex, 8LL1902, is a large archaeological complex of middens, mounds, and other topographic features located in coastal, southwestern Florida. It was occupied from approximately AD 50 and was a major Calusa town at European contact. We combine extant research from this well-preserved and well-studied archaeological site with chronological and zooarchaeological analyses to provide new insight into the relationship between fisher-gatherer-hunter subsistence economies and small scale but impactful, critical climatic change. Specifically, we identify and record a shift from the Warm Medieval Period (AD 850 – 1200) to the Little Ice Age (AD 1200-1850), evident in a lowering of local sea level, ca. AD 1250, inferred from changes in faunal assemblages. By combining Bayesian statistical analyses of radiocarbon dates with zooarchaeological analyses of a water-logged, shoreline midden we generate a high-resolution, localized view of socioecological interactions prior to and through the first two centuries of the Little Ice Age. Such micro-scale temporal perspectives are necessary to achieve high-resolution, localized histories of human-climate dynamics.

Introduction

Reconstructing the temporal scales relative to the human experience has been difficult to achieve through archaeological research. Generational temporalities are often difficult to explore alongside longer-term climatic trends, despite the drastic effects on resource availability that can occur within a lifetime. This is especially true for populations that depend upon shallow estuarine ecosystems where sea level change, temperature, and external inputs such as rainfall or riverine discharge can act as driving forces in the distribution of resources. Many archaeological studies focus on changes to these resources at coarse and long-term temporal resolutions of hundreds of years. Such changes, however, need to be resolved at a scale relative to the human experience that allows for the identification of both natural and cultural mechanisms that structured resource availability. This article combines Bayesian statistical analyses of radiocarbon dates with zooarchaeological analyses from a waterlogged shell midden at the Pineland Site Complex on the Gulf Coast of Florida to provide a high-resolution view of socio-ecological changes that occurred during the transition from the Warm Medieval Period (AD 850 – 1200) to and through the first few centuries of the Little Ice Age (AD 1200 – 1850). This case study illustrates the flexibility in the coupled natural and social systems at Pineland that buffered socioecological systems against environmental change as evidenced by high-resolution chronology building in combination with zooarchaeological analyses.

Using zooarchaeological assemblages to contribute to paleoecological models is not new (see Lyman 2017). Without a high degree of temporal control, it remains difficult to understand how discrete deposits relate to the broader scope of archaeological sites and to regional histories. Coarse-grain temporal resolutions hinder our ability to understand how quickly local species distributions respond to changes, how the structure of species distributions relates to cultural phenomena, and how people experienced and navigated environmental change over shorter time spans. In practice, archaeologists often extrapolate local environmental characteristics from global climatic trends, thus creating a disconnect between temporal and spatial scales of analysis. Recently, however, there has been a trend to incorporate more regional proxies of environmental conditions but there is still a need for local and site specific proxies (Birch and Linden 2018; Rivera-

Araya et al. 2019). The issue is that most global models are developed in areas far removed from the archaeological area of interest. Studies seeking to answer questions related to human-environment relationships often over-emphasize general climatic patterns and their effects on social and ecological change. Understanding the relationship between different patterns of resource use and environmental change requires the use of local, empirical data from archaeological contexts. All paleoenvironmental records, whether they be ice cores, lake sediments, or archaeological deposits, respond to formation processes whether they be anthropogenic, natural, or some combination of the two (Sandweiss 2017).

Previous work, most notably at the Pineland Site Complex (8LL1902) along the southwestern Florida Gulf Coast (Figures 2.1 and 2.2), has documented varying relationships between climate change, animals and plants, and socioeconomic practices over a span of about 1,350 years from the first century AD on (deFrance and Walker 2013; Marquardt and Walker 2013a; Thompson et al. 2014; Walker 1992, 2013) (Table 2.1). For much of this span, these relationships have been resolved to a timescale with a resolution of roughly 50 years using a combination of radiocarbon dating, ceramic seriations, and detailed stratigraphic analyses (Marquardt and Walker 2013b). The span from AD 1000 up to European contact, however, during which there occurred a transition from generally warmer/wetter conditions to generally cooler/drier conditions (Lund and Curry 2004; Richey et al. 2007), lacks the resolution needed to explore the dynamics of socioecological changes associated with such climatic change. It was also during this time, ca. AD 1000-1500, that the Calusa emerged as a powerful complex society of

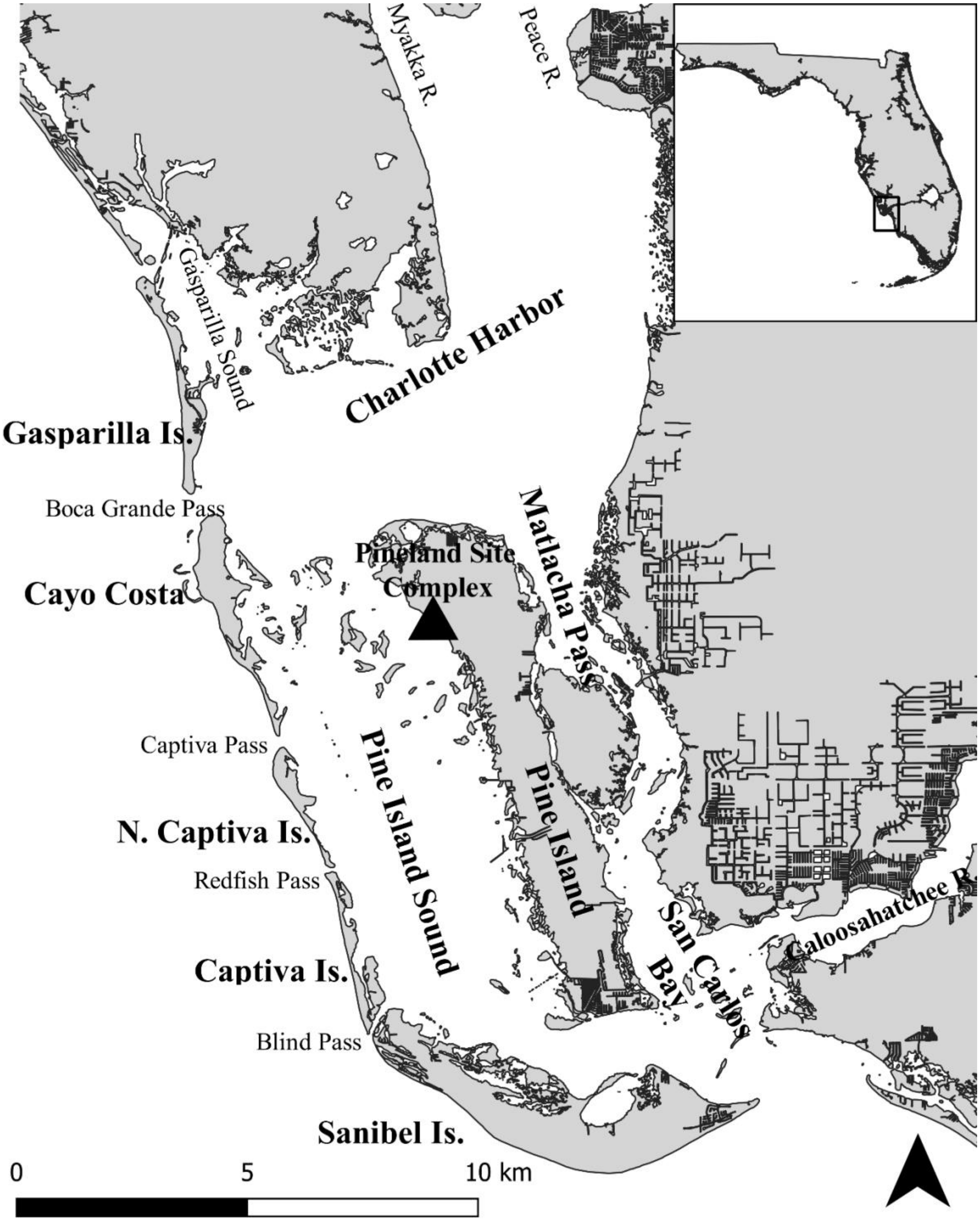


Figure 2.1. Map of Pine Island Sound and Charlotte Harbor region.

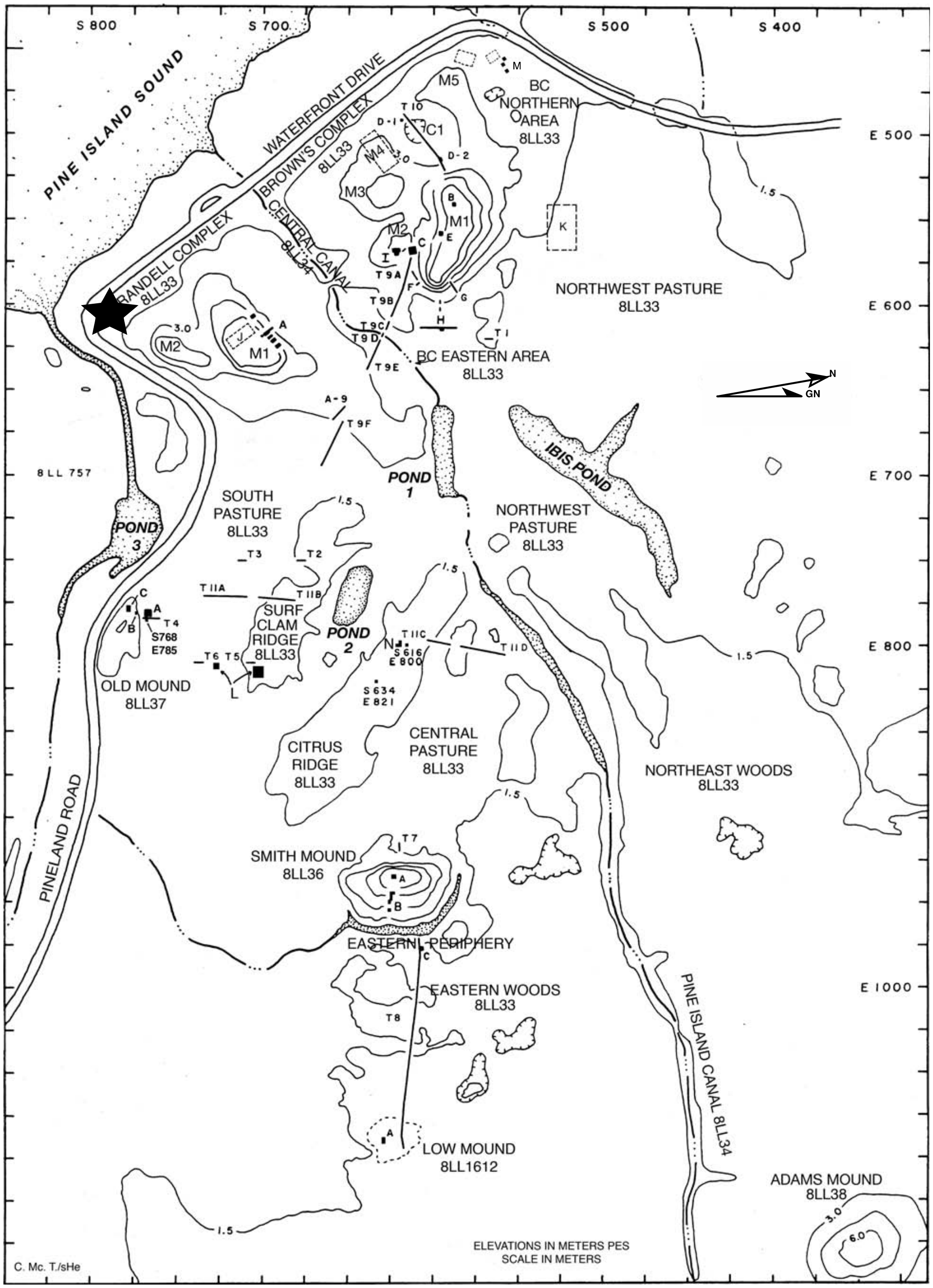
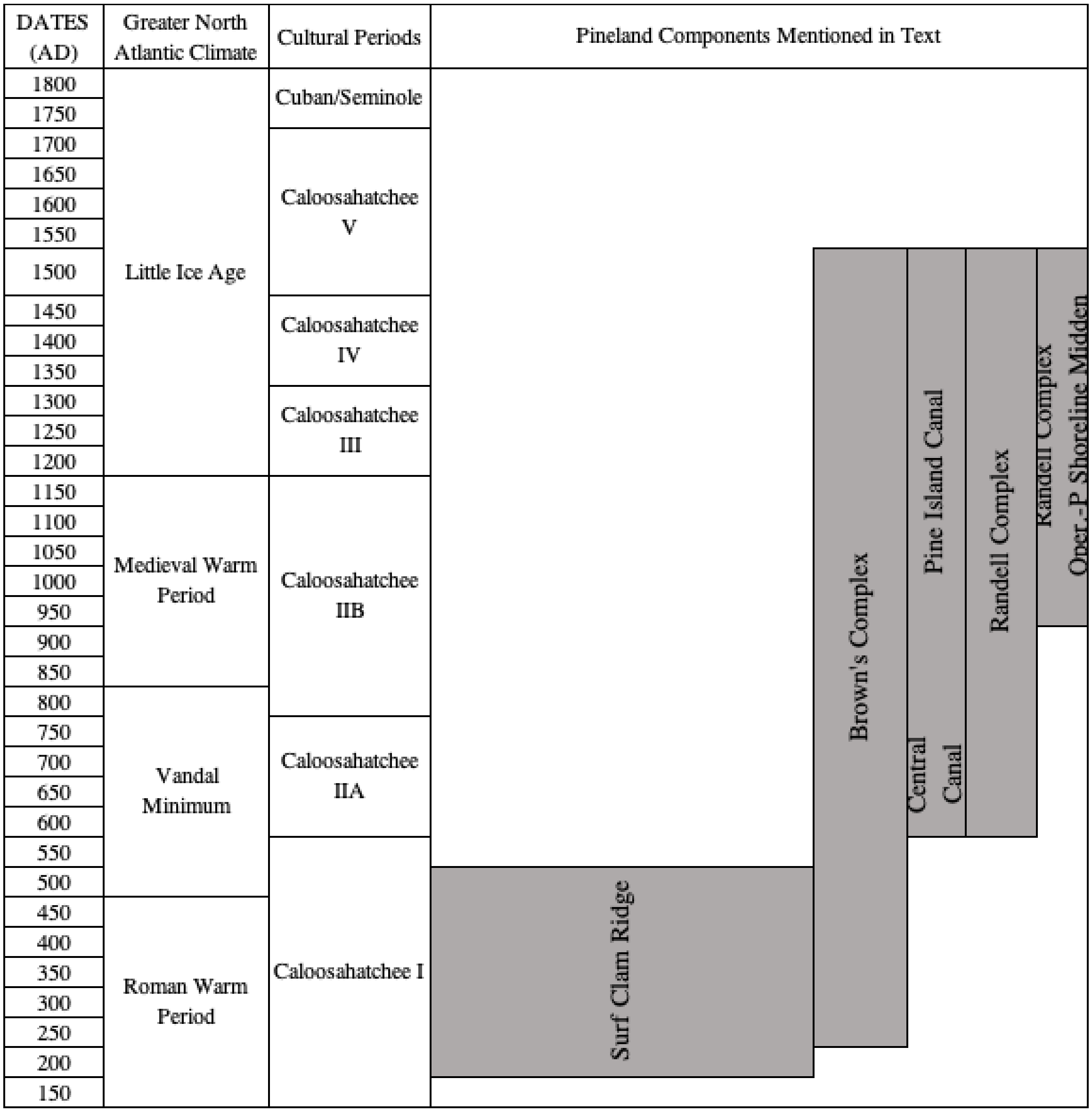


Figure 2.2. Map of the Pineland Site Complex showing locations of major components, previous excavations, and Operation P (black star). Adapted from Marquardt and Walker (2013:799 Figure 1).

Table 2.1 Generalized chronologies of climate, cultural periods, and the timeline of the Pineland Site Complex. This chart is generalized and does not capture the more nuanced variation in any of the columns.



DATES (AD)	Greater North Atlantic Climate	Cultural Periods	Pineland Components Mentioned in Text				
1800	Little Ice Age	Cuban/Seminole					
1750							
1700		Caloosahatchee V					
1650							
1600							
1550							
1500				Brown's Complex	Pine Island Canal Central Canal	Randell Complex	Randell Complex Oper.-P Shoreline Midden
1450		Caloosahatchee IV		▨	▨	▨	▨
1400				▨	▨	▨	▨
1350				▨	▨	▨	▨
1300		Caloosahatchee III		▨	▨	▨	▨
1250				▨	▨	▨	▨
1200				▨	▨	▨	▨
1150	Medieval Warm Period	Caloosahatchee IIB		▨	▨	▨	▨
1100				▨	▨	▨	▨
1050				▨	▨	▨	▨
1000				▨	▨	▨	▨
950				▨	▨	▨	▨
900				▨	▨	▨	
850				▨	▨	▨	
800	Vandal Minimum			▨	▨	▨	
750		Caloosahatchee IIA		▨	▨	▨	
700				▨	▨	▨	
650				▨	▨	▨	
600				▨	▨	▨	
550		Caloosahatchee I		▨			
500			Surf Clam Ridge	▨			
450	Roman Warm Period		▨	▨			
400			▨	▨			
350			▨	▨			
300			▨	▨			
250			▨	▨			
200			▨				
150							

fisher-gatherer-hunters, dominating the political and economic landscape of the lower half of the Florida peninsula (Marquardt 1988; Thompson et al. 2018, 2020a,b). This article re-examines this critical period through a detailed study of socioecological change as encoded at the Pineland Site Complex in southwestern Florida.

Warm Medieval Period, Little Ice Age, and Pine Island Sound

The Warm Medieval Period (AD 850 – 1200, hereafter WMP) is generally characterized as a time of relatively warm temperatures and wet episodes, (Ljungqvist 2010; Mann et al. 2009; Solomon et al. 2007). A more through summary of these records can be found in Walker (2013), but we highlight here that the WMP is highly contested in terms of started and end dates which emphasizes its incongruity of effects across the globe. The variety of records available for this time period generally demonstrate a period of warmer temperatures punctuated with relatively shorter and cooler events (Cronin et al. 2003; Keigwin 1996; Nyberg et al. 2002). A Sargasso Sea record suggests a period of warming temperatures beginning ca. AD 850 and reaching a peak at AD 1000 followed by a cooling until AD 1050 and subsequent warming until AD 1150 (Keigwin 1996). The variability of this time frame has not been fully established for this time period but this Sargasso Sea record, being the nearest suggests a period of warmer temperatures compared to the following global climatic trend, the Little Ice Age.

The Little Ice Age (AD 1200 – 1850, hereafter LIA) is generally characterized as a time of relatively cool temperatures, glacial advances, and drying episodes (Jones et al. 2001; Mann 2002; Mann et al. 2009). As previously and more thoroughly summarized in Walker (2013), the LIA included variability indicated in a variety of records, based on a variety of proxies, scales, dating methods, etc. and thus produced varied results.

Beginning as early as 1228, multiple volcanic eruptions contributed to cooler temperatures during the thirteenth century (Gao et al. 2008). Haeberli and Holzahauser's (2003:14) alpine glacial records document three sub-cooling episodes that were likely global occurrences: AD 1250-1350; AD 1500-1650; and AD 1750-1850. Eddy (1994:29-31) demonstrates that periods of low solar activity, associated with cooler global temperatures, divided the LIA into three episodes called the Wolf Minimum (ca. AD 1280-1340), Spoerer Minimum (ca. AD 1410-1510), and Maunder Minimum (ca. AD 1640-1710). Other records supporting this variability include, but are not limited to, a Sargasso Sea record (Keigwin 1996), a Puerto Rico record (Nyberg et al. 2002), and a Chesapeake Bay record (Cronin et al. 2003). The Sargasso Sea record indicates that a cooling episode began by approximately AD 1150 and continued until AD 1400 when a period of warmer sea surface temperature lasted until AD 1550 (Keigwin 1996). Similar trends are recorded in the Chesapeake Bay and Puerto Rico records. Across the southeastern United States, it is likely that conditions would have become, generally, cooler and drier with lower relative sea levels. While the larger scale effects of these climate shifts provide a starting point for understanding human behavior, their manifestations at the local scale, as relevant to the scale of anthropological inquires, require multiple detailed studies.

Paleoclimatic records from across the world demonstrate that climate change can occur rapidly over the course of only a few years (National Research Council 2001:153). Rapidly changing environmental conditions resulting from global climatic changes could have affected the location and availability of key resources to populations residing along coastlines, including those along the Gulf Coast of Florida. How well people and prey adapt to changing conditions in part depends on the rapidity at which these changes take place. Given local records demonstrating decadal and centennial-scale environmental variability elsewhere across the globe, the environments in the Charlotte Harbor/Pine Island Sound region also likely experienced variations throughout these overall cooling trends associated with the LIA, with punctuated periods of even cooler conditions. Walker and colleagues (Marquardt and Walker 2013b; Walker 1992, 2000a; Walker et al. 1994, 1995; Wang et al. 2011, 2013) have documented the relationship between the region's residents, their subsistence practices, and shifts in climate change during the impactful Vandal Minimum. Although likely to be less severe, we address these relationships during the transition from the WMP to the LIA. This shift likely had local impacts on the local estuarine ecosystems because many of the species found in these shallow-water ecosystems are highly susceptible to changes in temperature, water depth, and salinity. The vulnerability of the low-lying, shallow-water inshore bays of the Florida Gulf Coast necessitates an investigation into the ecological impacts of minor variations in the climatic and environmental conditions around Pine Island.

The Pineland Site Complex (hereafter Pineland) is located on the western portion of Pine Island along the eastern shores of Pine Island Sound (Figure 2.1). Pine Island is located within a complex estuarine system comprised of Charlotte Harbor, Pine Island Sound, and San Carlos Bay. Fresh water input into this estuarine system comes from the Myakka, Peace, and Caloosahatchee rivers combined with freshwater runoff. The shape, long and linear from north to south, and location of Pine Island restricts the amount of freshwater runoff from the mainland that reaches Pine Island Sound. Pine Island Sound is an oceanic bay with its inshore waters exhibiting high salinities often near marine values of ca. 32 ppt (Wang and Raney 1971:18). The sound is located between Pine Island and a series of barrier islands to the west that protect it from open ocean conditions (Figure 2.1). Its shallow depths typically only range from 0.3 m to 0.6 m. Mangroves, primarily red mangrove (*Rhizophora mangle*) and black mangrove (*Avicennia germinans*), cover the shorelines and the shallow waters contain extensive seagrass meadows comprised primarily of turtle grass (*Thalassia testudinum* and *Halophila engelmann*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*). Mangrove swamps and seagrass beds are extremely productive ecosystems, even rivaling the net primary productivity of agriculture (Odum et al. 1982:19, Zieman 1982). The Calusa took advantage of these highly productive ecosystems, centering their economies on the resources found within these environments.

The Calusa and the Pineland Site Complex

The Calusa were a large non-farming polity that exacted control over the southern third of peninsular Florida at the time of European contact in the sixteenth century (Marquardt 1988, 2014; Thompson et al. 2018; Widmer 1988). Complex polities arose across southern Florida by approximately AD 800 and eventually coalesced into a large political entity with central authority and hereditary leadership as documented by the Spanish in the sixteenth century (Marquardt 2014; Thompson and Worth 2011; Thompson et al. 2018). The timing of this political consolidation remains uncertain but was likely built upon the emergence of collective action and communal buy-in at multiple social and spatial scales across Calusa communities (Thompson et al. 2018).

In the absence of maize (Hutchison et al. 2016), Calusa peoples relied extensively on aquatic animal resources, wild plant foods, and cultivated home gardens that provided species such as chili peppers, papaya, gourds, and squash (deFrance and Walker 2013; Marquardt 2014; Newsom and Scarry 2013; Thompson et al. 2020a; Walker 1992). Early Spanish accounts note a lack of widespread, row crop farming and reliance on wild fruits and rootstock (Hann 1986, 1991; Smith 1944). The Calusa used pine and black mangrove as the most common fuel woods (Scarry 1985, 1993; Scarry and Newsom 1992; Newsom and Scarry 2013). Saw palmetto (*Serenoa repens*), false mastic (*Sideroxylon foetidissimum*), sea-grape (C*occoloba uvifera*), and prickly pear (*Opuntia* sp.) were some of the most commonly used native edible pulpy fruits and other vegetation used by Indigenous communities of southwestern Florida (Newsom and Scarry 2013). Along with a variety of plant remains, southwestern Florida middens also contain abundant animals remains, both invertebrate and vertebrate with a heavy reliance on estuarine fauna (deFrance and Walker 2013; Walker 1992). Walker (1992) demonstrates that Calusa middens in the Charlotte Harbor/Pine Island Sound area are dominated by resources that could have been collected within immediate proximity to communities. These results indicate that zooarchaeological assemblages of both finfish and invertebrates from sites in this region can be used to model local paleoecological (Walker 1992:289-290). Fisheries, both invertebrate and vertebrate, are sensitive enough to reflect change at the annual, decadal, and multi-centennial scale making the Charlotte Harbor/Pine Island Sound region a prime locale to explore the potential impact of the LIA episodes on local resource regimes from a multi-scalar perspective.

The Pineland complex contains two prominent midden-mound complexes, bisected by the Central Canal (Marquardt and Walker 2013a) (Figure 2.2). Along this canal, there are or were other anthropogenic water features including several water courts, secondary canals, numerous other ridges and mounds, and water features that surround two sand burial mounds. Altogether, these features are a product of a roughly 1,700-year occupational history.

Previous research at Pineland indicates that the shift from the Roman Warm Period (350 BC – AD 550) to the Vandal Minimum (AD 550 – AD 850) changed economic practices likely changed in response to a period of cascading cooler-climate and lowered sea-level events (Marquardt and Walker 2013). If this episodic, relative sea-level regression was as significant as the data suggests, large portions of the Charlotte Harbor/Pine Island Sound region would have been dry, especially during the final event centered on AD 850 (Tanner 1991, 2000), severely impacting the location and availability of key estuarine resources.

Around the onset of the WMP (ca. AD 850 – 900), early in the Caloosahatchee IIB period (AD 800-1200) (Table 2.1), site structure shifted from the traditional pattern of paralleling the shoreline to mound complexes situated perpendicular to the shoreline (Marquardt and Walker 2013b; Thompson et al. 2014). It is also likely that during this time, as sea level rose, additional water-control features such as water impoundments, and secondary canals were constructed, including the formalization of the Central Canal. Additionally, the much longer eastward extension of the Central Canal known as the Pine Island Canal was engineered. Previous research on the WMP also indicates that as a result of the La Costa High rising sea levels (also AD 850 – 1200), shallow areas of the Pine Island Sound, etc. previously reduced to sand or mud flats during relative sea level lows were inundated and seagrass communities were likely reestablished as indicated by an increase in the use of fish and shell fish that inhabit seagrass communities (deFrance and Walker 2013; Marquardt and Walker 2013b; Stapor et al. 1991; Walker 1992). A zooarchaeological assemblage from nearby Josslyn Island that also dates to the end of the WMP and beginning of the LIA ca. AD 1200, and a Pineland assemblage dating to AD 1350 – 1400 display similarly high species richness with species primarily coming from seagrass meadow environments (deFrance and Walker 2013:324).

During the LIA, roughly coeval with the Caloosahatchee III and IV periods (AD 1200-1350 and AD 1350-1500, respectively) (Table 2.1), house construction/habitation and accumulation of midden continued on the mounds with Mound 1 in Brown's Mound Complex providing evidence for raising its summit to at least 9 m through redeposition of old midden, a process also documented at Mound Key, another prominent Calusa site (Thompson et al. 2016). Canals continued to be maintained and residents lived on the flat-topped mounds surrounding the Central Canal. Throughout this period in southwestern Florida, populations coalesced into larger towns such as Pineland.

While the socio-economic situation of the Calusahatchee IIA people at Pineland during the climatically tumultuous Vandal Minimum (AD 500-850) has been explored, environmental histories and economic strategies are not well understood between AD 1000 and 1500, when climate and sea-level records indicate that in the middle of the WMP an abrupt cooling/sea-level event centered on ca AD 1100 (Oort Minimum). Because environmental conditions played a key role in both sociopolitical and socioeconomic restructuring of Calusa communities in the region and throughout Pineland's history (Marquardt and Walker 2013b; Thompson et al. 2014), the investigation of this period remains critical for understanding the trajectory of Calusa complexity. The climate of southwestern Florida can generally be characterized as subtropical with warm winters that allow for the year-around availability of resources such as fish and shellfish. Pineland along the shoreline of a shallow bay system with distinct ecological and hydrological characteristics that were surely impacted by small-scale, climatic fluctuations. These fluctuations likely relative sea-level fluctuations, changes in sea-surface temperatures, and shifting salinity gradients. For southwestern Florida generally, there is a paucity of coupled archaeological and paleoenvironmental data associated with the MWP and LIA periods. Available data may not represent the full effects of and responses to these climatic conditions. However, Walker (1992) demonstrates changes in the compositions of invertebrate and vertebrate species with different salinity tolerances over time. Walker suggests that local estuarine conditions fluctuated between being more marine or more freshwater as related in large part to changes in relative sea level. A lowering of waters adjacent to Pine Island restricts the extent of the saltwater wedge into the embayment and causes the nearby waters to become less saline. As relative sea-level rises, the location of the saltwater wedge moves further into the embayment, increasing the salinity and expanding marine conditions further into the embayment. All of which is further complicated by inlet/barrier island dynamics. Beyond these very initial stages of the Little Ice Age as defined in extant categorical terms, little is understood about how this global climatic event manifested in local environmental change or how the Calusa mediated such changes. This study investigates the local environmental conditions at Pineland within the timeframe AD 1000 – 1500 through a detailed study using zooarchaeological and radiocarbon analyses.

Methods

Excavations

Excavations of the material used in this study were designated Operation P and conducted in two short field seasons, 2015 and 2017. The 2015 excavations (Walker et al. 2019) were conducted as part of mitigation for the installation of a new septic tank for a modern-day home that sits along the southwestern portion of the Randell Complex (8LL33) (Figure 2.2). The 2017 field excavations revisited the same deposits but about a meter to the west. These excavations revealed a water-logged, anaerobic shell midden that contains well preserved stratification indicating primary deposits. Water-logged materials not often recovered at dry sites include strands of knots and cordage, and in two cases, combinations of strand and knots, surely fragments of a fishing nets. Also recovered are abundant non-burned and burned plant remains, and unburned wood debris, likely debitage as a result of canoe manufacturing (see Newsom 1987; Newsom and Purdy 1990, Newsom and Scarry 2013). Excavation units, 1-m-x-1-m, were excavated to approximately 1.3 m in depth. Units P-1 and P-7 through P-10 were hand excavated in 10-cm arbitrary levels with change in strata being accounted for by use of a level-locus system, which is referenced to a site-wide datum (Walker and Marquardt 2013:54).

The profiles of the excavations indicate intact shell midden deposits; Figure 2.3 presents the east profiles of the adjoined P-7 through P-10 units and their descriptions. The deposition patterns are of shells relatively flat-lying, no discernable disturbances, and no features such as floors, postmolds, pits, etc. Approximately three quarters of the excavated portion of these deposits are submerged under the water with the base of the midden at -65 cm below March's 2017's water table. At the top of Level 106 was white sand and a cessation of any cultural or biological materials (Stratum 6). Visually the most notable difference between the earliest midden deposit, Stratum 5, and the Stratum 4

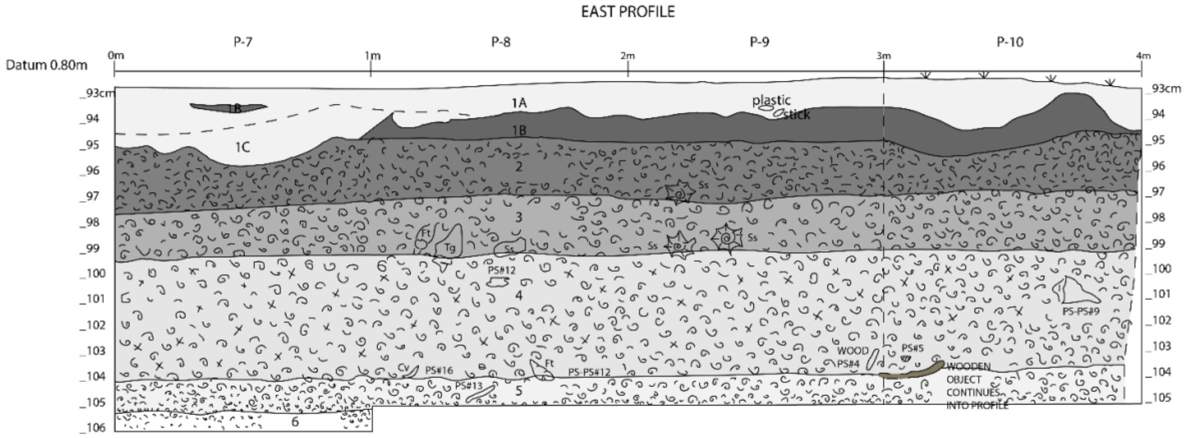


Figure 2.3. Eastern profile of Operation P, Excavations P-7 through P-10
Strata descriptions below include Munsell color designation, deposit description, and related notes. Large shells were plotted and sketched as landmark shells. Curled and present symbols represent gastropod and bivalve shells, respectively. Specimens labels PS# were plotted specimens (indicated above are: 5, a pottery rimsherd; 4, 12, 13, and 105/14 are waterlogged wood specimens; 16 is a large left valve of eastern oyster). Specimens labelled PS PS# were collected for palynological analyses. Digitized from field drawing by Karen Walker.

1A, 1B, 1C: imported to site August 2015

2: 10YR 3/1 very dark gray to 10YR 2/1 black silty sand with highly fragmented and dense shell midden; visible shells are mostly of whelks and conchs, but oyster shells also are notable in quantity; midden is compacted.

3: 10YR 3/1 very dark gray to 10YR 2/1 black silty sand with dense shell midden with whole and broken shells; visible shells are mostly of whelks, conchs, and oysters, with secondary taxa; in situ wrack-like vegetation is interspersed within the midden but limited to Level 98 in the southern portion of the excavation, recorded specifically in P-10's west profile, not shown.

4: 10YR 3/1 very dark gray, silty sand transitioning to 10YR 6/1 gray coarse sand; dense shell midden with whole and broken shells; visible shells are mostly whelks and conchs with secondary taxa; abundant wrack-like vegetation throughout Stratum 4; the lower half of the stratum exhibits a few remains of pen shell, surf clam, tulip/horse mussel, kitten's paw, stone crab, sea urchin, sea turtle, and bottle-nosed dolphin and there is a noticeable increase in numbers of small, intertidal clam (some with valves still articulated) and gastropod shells; also in the lower half, charred wood is noticeably present and waterlogged, uncharred-wood debris and gastropod operculae are abundant and cordage (including knotted cord) and seeds are present.

5: 10YR 6/1 gray coarse sand; decreasing numbers of large mollusk shells, still mostly whelks and conchs, but as with Stratum 4, the pen shell, et al. assemblage is present with specimens in small numbers; abundant shells of small, intertidal clams (some with valves still articulated) and gastropods.

6: 10YR 6/1 gray coarse sand; many shells of small, intertidal mollusks in first few centimeters then stratum 6 transitions to mostly sand with a few small fragments of shell.

midden is the change in sediment type. An abundance of uncharred plant material, possibly representing seagrass wrack, occurs throughout Stratum 4 and continues into Stratum 3 in one small area of P-10 (Figure 2.3). These materials likely consist of seagrass blades, roots, and rhizomes, although no formal paleoethnobotanical study has yet been conducted on them. Stratum 4, generally, contains faunal and plant remains that display high degrees of preservation due to the anaerobic environments created by uninterrupted submersion under water. The strata 3 and 2 middens, with darker sediments, are also undisturbed deposits except for the preservation impacts of fluctuating water levels.

Radiocarbon Dating

In order to establish the temporality of a depositional sequence that represents a timeframe suitable for generational-scale analyses between AD 1000 and 1500, a series of 19 radiocarbon dates was obtained from the stratified midden deposit within unit P-10 (Table 2.2). The radiocarbon samples were selected from levels 97 through 105 (Figure 2.4). A total of 31 specimens of charred botanical remains were identified to the lowest possible taxon, including the number of rings present in the wood samples, by Lee Newsom at Flagler College. From these, nine samples of charred wood and one charred seed were selected for analysis. Seven of the charred wood specimens were identified as *Avicennia germinans*, black mangrove, and two as Pinaceae samples, the

pine family. The charred seed was of *Serenoa repens*, saw palmetto seed. The nine specimens of wood were chosen for radiocarbon analysis based on a few parameters: the specimen had to have more than five growth rings; the specimen must come from either a

Table 2.2. Table of Radiocarbon Dates for Pineland RCM1, Operation P. Calibrated and modelled using OxCal 4.4.1, IntCal20 curve. Dates for Level P-10-99 were not included in the Bayesian model due to uncertainty in sample representation of the tree at age of death.

Site	**Unit**	**Level**	**Species**	**Characteristics of original sample**	**RC Sample ID**	**Number of Years between Samples**	**UGAMS**	**δ^{13}C,‰**	**^{14}C age years, BP**	**±**	**pMC**	**±**	***Modelled Date Range***	
													68% probability	*98% probability*
8LL33	P-10	97	*Avicennia germinians*	10 rings with pith	8LL33P1097AA	8 years	37389	-23.74	480	20	94.19	0.22	*1430-1445*	*1425-1455*
					8LL33P1097AB		37390	-24.72	470	20	94.33	0.22	*1420-1440*	*1415-1445*
8LL33	P-10	98	*Avicennia germinians*	13 growth rings with pith, no bark	8LL33P1098BA	11 years	37391	-24.41	590	20	92.89	0.22	*1390-1405*	*1345-1410*
					8LL33P1098BB		37392	-23.14	620	20	92.60	0.22	*1375-1395*	*1330-1400*
8LL33	P-10COL	99	Pinaceae	13 rings, mature	8LL33P1099COLCA	10 years	37393	-25.91	710	20	91.54	0.22	**modelled level to cal AD 1345-1390 (68% probability) and cal AD 1335-1400 (98% probability)*	
					8LL33P1099COLCB		37394	-22.28	760	20	90.92	0.21		
8LL33	P-10COL	100	*Avicennia germinians*	7 rings	8LL33P10100COLBA	5 years	37395	-26.14	570	20	93.16	0.22	*1330-1350*	*1325-1360*
					8LL33P10100COLBB		37396	-22.52	560	20	93.25	0.22	*1325-1345*	*1320-1355*
8LL33	P-10COL	101	*Avicennia germinians*	10 years old near pith, possibly some bark	8LL33P10101COLBA	8 years	37397	-22.81	510	20	93.86	0.22	*1300-1330*	*1290-1345*
					8LL33P10101COLBB		37398	-22.71	620	20	92.61	0.22	*1305-1335*	*1300-1350*
8LL33	P-10COL	102	*Avicennia germinians*	Pith plus 10 years of growth	8LL33P10102COLAA	8 years	37399	-22.71	770	20	90.84	0.21	*1240-1265*	*1230-1270*
					8LL33P10102COLAB		37400	-22.42	860	20	89.85	0.22	*1250-1275*	*1240-1280*
8LL33	P-10COL	103	Pinaceae	9 years of growth with mature rings	8LL33P10103COLAA	10 years	37401	-23.72	760	20	90.98	0.22	*1230-1255*	*1225-1270*
					8LL33P10103COLAB		37402	-23.58	800	20	90.50	0.22	*1220-1250*	*1220-1260*
8LL33	P-10COL	103	*Serenoa repens*	Seed	8LL33P10103COLF		37403	-26.92	800	20	90.55	0.22	*1225-1255*	*1225-1265*
8LL33	P-10COL	104	*Avicennia germinians*	10 years of growth, pith and bark	8LL33P10104COLAA	8 years	37404	-23.85	780	20	90.72	0.22	*1220-1235*	*1215-1245*
					8LL33P10104COLAB		37405	-23.54	850	20	90.01	0.21	*1210-1225*	*1205-1235*
8LL33	P-10COL	105	*Avicennia germinians*	12 years of growth	8LL33P10105COLCA	10 years	37406	-25.57	1050	20	87.77	0.21	*1000-1025*	*990-1030*
					8LL33P10105COLCB		37407	-23.53	1060	20	87.68	0.21	*990-1015*	*980-1020*

short-lived species, a branch/twig, likely be close to the outermost ring, or contain adhering bark; and the specimen's rings must be easily identifiable.

After these nine wood specimens were chosen, two radiocarbon samples were selected from each specimen with a known number of rings between the two samples. Each ring sample was cut away from the wood specimen using a razor blade under a handheld microscope at 10x magnification. All samples were submitted to the Center for Applied Isotope Studies at the University of Georgia for analysis. Then, these dates and the one from the seed were calibrated and modeled using Bayesian statistical analyses producing posterior estimates for the radiocarbon age (Bayliss 2009; Bayliss et al. 2007). These posterior estimates are produced through modeling and thus, are not absolute, but are interpretive estimates with the flexibility to change as more data become available and as other researchers may choose to model the existing data from different perspectives (Lulewicz 2018). This allows for a known age gap to be incorporated into the Bayesian analysis of these radiocarbon dates. For example, if the two samples were taken with 10 rings separating them, we know those two radiocarbon dates must be 10 years apart from one another. Radiocarbon determinations from individual wood samples were modeled using the D_sequence function in OxCal v. 4.4.1 within which the number of rings could be incorporated into the interpretation of the radiocarbon determinations using the IntCal 20 calibration curve (Bronk Ramsey 2007, 2009; Reimer et al. 2020). These D_sequences were then incorporated into a larger P_sequence (Bronk Ramsey 2007) whereby individual wood samples were modeled based on their stratigraphic relationships. The resulting models were used to produce high-resolution age estimates for each stratigraphic layer within the midden deposits.

Zooarchaeology

After Bayesian analysis of the radiocarbon dates provided a timeframe for the depositional sequence, four zooarchaeological samples, P-10-99, P-10-101, P-1-103, and P-10-105, were analyzed to represent the AD 1000 – 1500 timeframe. All four were collected as bulk 50-cm-x-50-cm x-10-cm column samples in either P-1 or P-10. Vertebrate remains were screened to 3.35mm (approx. 1/8") while invertebrate remains were screened to 1mm (approx. 1/16"). We used a smaller screen size for the invertebrate remains to capture the smaller taxa that are more sensitive to immediate environmental conditions. Identifications were made to the lowest possible taxon using the comparative collections at the University of Georgia Museum of Natural History and the Florida Museum of Natural History. Scientific and common names used in this study follow Felder and Camp, eds. (2009). For the purposes of this study, we used the following quantitative measurements to assess both invertebrate and vertebrate remains: number of identifiable specimens (NISP), Minimum Number of Individuals (MNI), and bone or shell weight (Reitz and Wing 2008). We rely on MNI for purposes of comparison and model creation so a brief discussion of MNI and its purposes and pitfalls are discussed more in depth below. The taxa identified here are also summarized into faunal categories based on vertebrate class which include Sharks and Rays, Bony Fishes, Turtles and Snakes, Birds, Deer, Other Wild Mammals, Gastropods, and Bivalves.

The minimum number of individuals (MNI) was estimated by pairing elements and separating individuals by age structure and size classes when possible using the minimum distinction method whereby estimations were made to each arbitrary 10 cm level (Grayson 1978; Reitz and Wing 2008). The MNI for the invertebrates was estimated based on symmetry of shells and their size for bivalves, and shell completeness for gastropods. For the bivalves analyzed here, both whole valves and valve fragments containing the hinge/chondrophore portion of the shell were used in MNI estimations. For the gastropods analyzed here, whole shells, columellae with apices, and apices of the shells were used in MNI estimations. Normally for both vertebrates and invertebrates, MNI is estimated at the lowest possible taxonomic level, usually for species. However, when specimens cannot be identified beyond family or genus, MNI may be estimated at a higher level.

In addition to these primary biases, MNI is also subject to secondary bias introduced by the way samples are collected during excavation, processing, and by the way they are aggregated during analysis. The use of 3.35 mm screen for the vertebrate assemblages here does not capture the very smallest remains like those from small sized fishes of the Clupeidae family. The use of 2mm screen does capture many small invertebrates that are good indicators of environmental conditions. Some of these small invertebrates are collected as bycatch along with the intended harvest of larger organisms that are restricted in the mobility throughout their lifetime. The MNI of certain species, such as eastern oyster, crested oyster, crown conch, pointed venus, and slippersnails are examined for trends in time following Walker (1992).

After the species lists for the samples were created, diversity was estimated via the Shannon-Weaver Function, providing a way to measure species presence and abundance to classify the heterogeneity of the given analytical unit (Reitz and Wing 2008). The diversity of each sample was then compared through time which facilitates our modelling of past environmental conditions that existed at the time of resource collection. In addition to diversity, equitability for each sample was measured where values closer to 1.0 indicate an even distribution of taxa and lower values suggest a dominance of one or a few taxa (Reitz and Wing 2008).

Because Pineland is a large, site complex that likely served purposes beyond solely habitation, this paper takes precaution when using faunal remains to determine shifts in local paleoecological conditions at the onset of the Little Ice Age. However, we interpret the deposits revealed in Operation P in question as midden deposits unrelated to feasting events, but rather as midden resulting gradual accumulation of midden debris. In order to investigate a model of environmental change based on the assemblages analyzed here, all identified taxa were given environment (habitat) designations similar to methods reported in Walker (1992) by roughly segmenting the Charlotte Harbor/Pine Island Sound region into different salinity regimes as they are present today. Salinity, a measure of the amount of dissolved inorganic salt content of water, is influenced by rainfall patterns and freshwater runoff, which can both be affected by major and minor climatic fluctuation. Typical ocean salinities measure 35 ppt. Here we treat salinity as the primary limiting factor in an aquatic animal's presence/absence and abundance across the estuarine ecological gradient (Boesch 1977). While there are many factors that contribute to the location and distribution of species within ecological regimes, salinity provides a useful analytic factor within estuarine systems because it is usually reflected in zooarchaeological assemblages, especially invertebrate ones. Both vertebrate and invertebrate taxa were categorized into one of seven types of habitat categories which roughly follow the estuarine gradient from fresh to oceanic water (Table 2.3; Appendices A and B).

To designate the habitat types for the vertebrates and invertebrates, we follow the methods outlined in Walker (1992), as noted, who modified mangrove/fish community designations from Odum et al. (1982:50-51) (Table 2.3). We also include references from Felder and Camp, eds. (2009) to ensure most of the identified taxa were classified. For the vertebrates, the habitat types are as follows (I) terrestrial, (II) freshwater, (III) mangrove basin, (IV) mangrove-fringed stream (V) mangrove-fringed estuarine bays and lagoons, (VI) mangrove-fringed oceanic bays and lagoons, and (VII) the littoral zone and Gulf of Mexico waters. Types V and VI are associated with seagrass meadows and are the aquatic habitats most closely located to the Pineland site. Types I and II were added to complete the gradient. For the invertebrates, the habitat types are as follows (I) tidal stream, (II) estuarine mangrove edge, (III) oyster bed, (IV) seagrass meadow, and (V) littoral zone and Gulf of Mexico waters. To identify potential changes in local environmental conditions the total MNI and total number of taxa are compared between these classifications (Appendices A and B). Some taxa are found in multiple habitats. However, unlike the method used for examining the vertebrate trends, those taxa that could be found in multiple categories were removed from the comparison, leaving only those invertebrates associated with a single habitat type.

A separate analysis was included to examine only those organisms associated with oyster bar communities that serve as reliable indicators of changes in salinity (Felder and Camp, eds. 2009; Walker 1992). We first compare the ratio of eastern oyster (*Crassostrea virginica*) to crested oysters (*Ostreola equestris)*. Crested oysters, of the same family, Ostreidae, live in more restricted habitat ranges as compared to eastern oysters. They prefer subtidal, stenohaline environments with minimum salinities of 20-25

Table 2.3. Regional Habitat Types for Vertebrate and Invertebrate Taxa

VERTEBRATES

Type Designation	*Title*	*Description*	*Modern Example Geographic Locales Near Pineland Site*
Type I	Terrestrial	Salt marshes, mangrove forests, coastal strands, woodlands	e.g., Pine Island, mainland Florida
Type II	Freshwater	Freshwater streams, rivers, ponds, lakes	e.g., Caloosahatchee, Mayakka, Peace Rivers and landlocked freshwater bodies
Type III	Mangrove Basin	Backwater areas with marginal saltwater influence	North of Big Mound Key
Type IV	Mangrove-Fringed Stream	Tidally influenced streams	e.g., Myakka, Peace, and Caloosahatchee Rivers; Whidden Creek, Alligator Creek
Type V	Mangrove-Fringed Estuarine Bays and Lagoons	Mangrove shorelines and seagrass meadows; less saline than Type VI	Turtle Bay, Bull Bay, Matlacha Pass and east of Pine Island
Type VI	Mangrove-Fringed Oceanic Bays and Lagoons	Mangrove shorelines and seagrass meadows; more saline than Type V	San Carlos Bay, Gasparilla Sound, inshore lagoons of Pine Island Sound
Type VII	Littoral Zone and Gulf of Mexico Waters	Littoral zones surrounding barrier islands, oceanic passes, and open ocean waters	Shores of Gasparilla, Cayo Costa, Captiva and Sanibel Islands; oceanic passes of Gasparilla, Boca Grande, Captive, Redfish, and Blind; Gulf of Mexico

INVERTEBRATES

Type Designation	*Title*	*Description*	*Example Modern Geographic Locales Near Pineland Site*
Type I	Tidal Stream	Riverine environments with some tidal influence	Tidal Streams, Myakka and Peace Rivers
Type II	Estuarine Mangrove Edge	Edges of mangrove forests, among the red mangrove prop roots and clack mangrove pneumataphores in lower tidal streams and estuarine locations, associated intertidal mud flats; soft and hard substrates	Shorelines across the Charlotte Harbor and Pine Island Sound region
Type III	Oyster Bed	Oyster bed communities which includes a variety of fauna using these bars or reefs as refuge and food resource; hard substrate; increase in diversity with increase in salinity (Wells 1961)	Turtle Bay, Matlacha Pass, San Carlos Bay
Type IV	Seagrass Meadow	Organisms found among the shallow-water seagrass beds; soft substrate; abundant invertebrates	Pine Island Sound
Type V	Littoral Zone and Gulf of Mexico Waters	Organisms found in the beach zone and open ocean waters, mostly soft substrates	Western beaches of Cayo Costa, Captiva Island, Sanibel Island, and Gasparilla Island

practical salinity units (ppt) (Galtsoff and Merrill 1962; Gunter 1951; Menzel 1955). Where preservation allowed, measurements of eastern oyster shells followed standard measurements outlined by Claassen (1998) (Figure 2.4) (Appendix C). Eastern oysters can tolerate 0-42 ppt but reach optimal conditions for growth and reproduction between 15 to 30 ppt and their size and shape are largely dependent on environmental constraints of their growth environment (Bartol et al. 1999:171-172; Classen 1998; Shumway 1996:648). Those growing on hard substrates and/or at low-population density grow equally in length and height while those growing on soft substrates and/or at high-population density grow straighter and longer (Gunter 1938). Measurements were on all whole left valves and on broken left valves where missing parts did not preclude measurements (Appendix C). We focused on measurements of valve height (VH) and valve length (VL) because these are most directly tied to the growth environment (Gunter 1938). Comparisons of valve height and the ratio between valve height and valve length are made for the assemblages and are compared through time.

Results

Bayesian Modeling

The posterior density estimates from OxCal are presented in calendar years and in *italics* and probability ranges with endpoints are rounded outward to 5 years. OxCal code is included as Appendix D. The model for the Pineand midden sequence shows good overall agreement between the ^{14}C dates and the model assumptions ($A_{model} = 89.8$; $A_{overall}=94$) (Figure 2.5). The depositional sequence begins ca. *cal AD 950 – 1020* (68% probability) and ends ca. *cal AD 1430 – 1500* (68% probability). For each 10cm level in between the beginning and end of the deposition sequence, the model estimates date

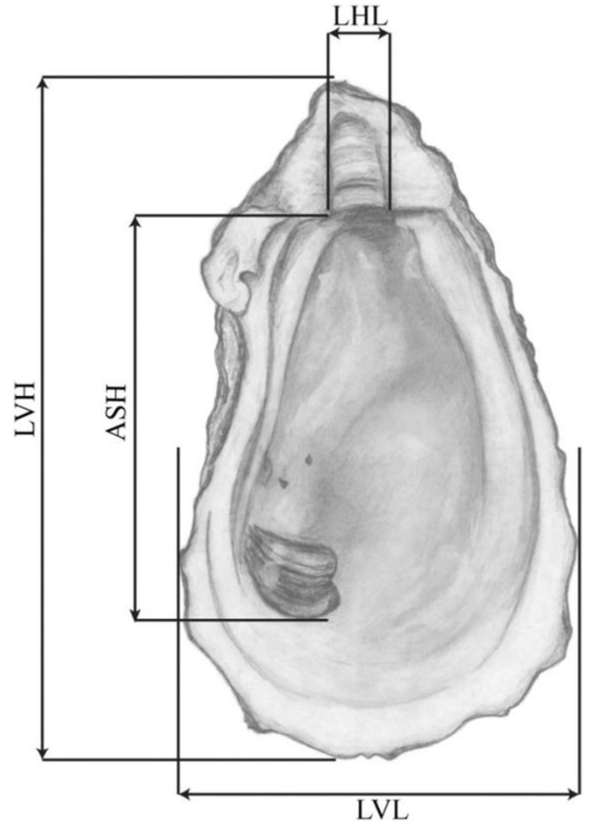


Figure 2.4 Standard measurements taken on left valve of eastern oyster (*Crassostrea virginica*). (From Lulewicz et al. (2017)).

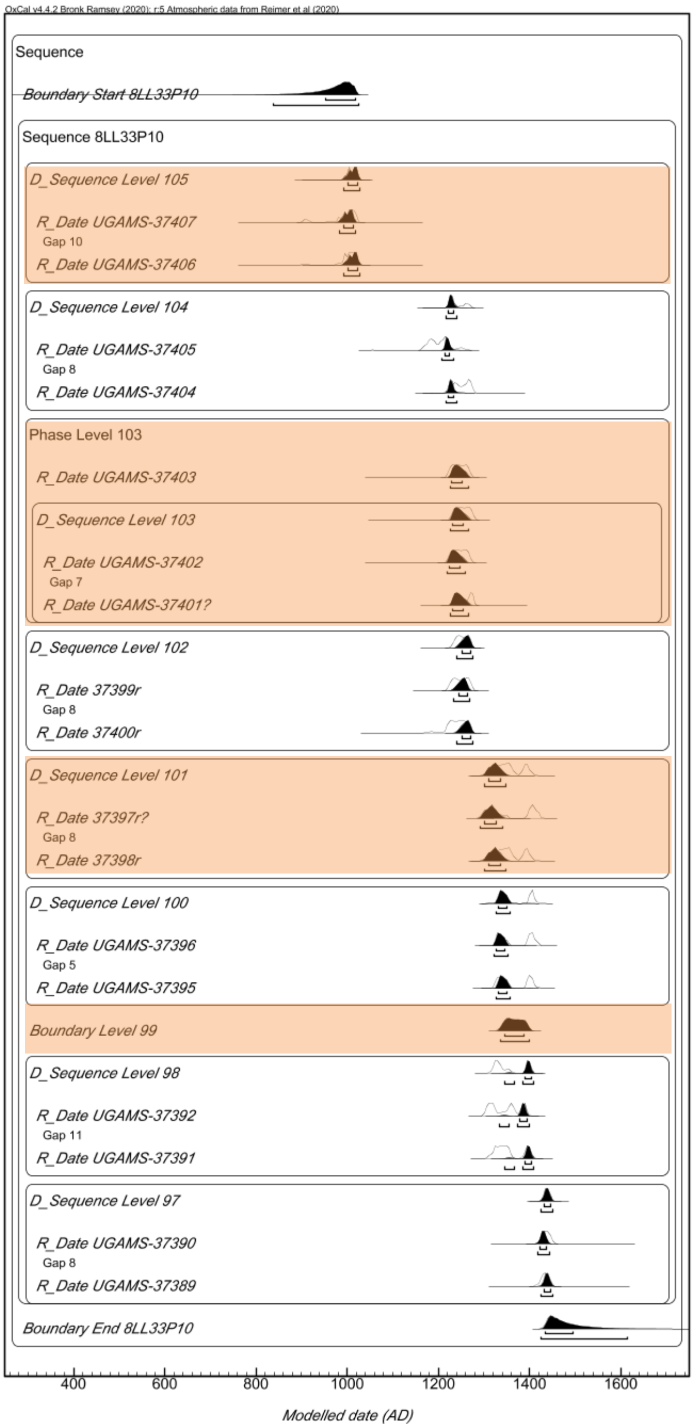


Figure 2.5. Bayesian model of radiocarbon dates from Pineland RCM1, Operation P, Excavation P-10, levels 97 through 105. Strata from which zooarchaeological samples were analyzed are highlighted.

ranges to periods of no more than 30 years each. For the selected zooarchaeological samples, the model estimates level P-10-105 to date to *cal AD 1000 – 1025*, level P-1-103 to date to *cal AD 1230 – 1255*, level P-10-101 to date to *cal AD 1305 – 1335,* and level P-10-99 to date to *cal AD 1345-1390* (all at 68 percent probability). The modelled date ranges for levels P-10-105 and P-10-104 display the widest gap in time for midden accumulation. We interpret this to likely be a product of this date coming from the basal deposits and initial stages of midden accumulation as opposed to a gap in shoreline occupations. Certainly, this midden deposit accumulated during the WMP but cannot be used as a representative sample of the WMP which is needed for a robust comparison to the transitional deposits of the LIA overlying it. More data is needed to test investigate models of shoreline occupation for the area. Therefore, we do not use these deposits as necessarily representative of the conditions and variability of the WMP but instead focus on general trends and data acquired from the overlying layers to discuss the early stages of the LIA. In regard to extant global climate episodes, the deposits chosen for zooarchaeological analysis span the complete transition between the WMP and the LIA.

Zooarchaeology - Vertebrates

The four samples analyzed for this research produced a total of 1,547 vertebrate bones and bone fragments (NISP identified at least to Class) with 136 vertebrate MNI (Table 2.4). Specimens were identified to a total of 42 taxa or distinct families. The majority of vertebrate remains are from Bony Fishes (Table 2.5) ranging from 78 percent to 90 percent of MNI in each level. The diversity measurements for the vertebrate samples estimated here demonstrate a trend that rises, falls, and rises again through time (Figure 2.6). The equitability measures demonstrate a relatively even distribution of taxa

Table 2.4. Vertebrate and invertebrate taxa lists for zooarchaeological assemblages from Pineland RCM1, Operation P. (Vertebrate remains were screened to 3.35 mm and Invertebrate remains to 2 mm)

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Sphyrnidae	Hammerhead sharks													1	1	2.2	0.64
Carcharhinus spp.	Requium sharks									1	1	2.56	0.03				
Rajiformes	Rays, skates	1	1	5.00	0.02					6	1	2.56	0.36	1	1	2.2	0.06
Dasyatidae	Whiptail stingrays									1	1	2.56	0.03	1	1	2.2	0.03
Myliobatidae	Eagle rays									1	1	2.56	0.09				
Chondrichthyes	Cartilagenous fishes	10	x		0.30	3	1	3.70	0.38	11	x		3.33	8	x		1.68
Amia calva	Bowfin													1	1	2.2	0.09
Clupeidae	Herring									1	1	2.56	0.05				
Ariopsis felis	Hardhead catfish	5	x		0.37	7	x		0.74	19	4	10.26	2.72	1	x		0.21
Bagre marinus	Gafftopsail catfish	1	x		0.09									15	x		2.05
Ariidae	Sea catfish	29	6	30.00	4.28	20	13	48.15	5.73	8	x		1.45	45	9	19.6	4.4
Siluriformes	Catfish	6	x		0.14	3	x		0.14	20	x		0.69	3	x		0.07
Opsanus spp.	Toadfish	2	1	5.00	0.26					3	1	2.56	0.16	5	2	4.3	1.17
Mugil spp.	Mullet	7	1	5.00	0.94	6	1	3.70	0.88	14	3	7.69	3.55	10	3	6.5	2.73
Epinephelus sp.	Grouper									1	1	2.56	1.62				
Serranidae	Sea basses and grouper													4	2	4.3	3.4
Caranx latus	Horse-eye jack									2	2	5.13	0.09				
Carangidae	Jacks									1	x		0.09				
Lutjanus spp.	Snapper									4	2	5.13	0.23				
Lutjanidae	Snapper									1	x		0.04	1	1	2.2	0.02
Gerreidae	Mojarra, jenny									1	1	2.56	0.01				
Haemulon spp.	Grunt	1	1	5.00	0.03					10	3	7.69	0.34				
Orthopristis chrysoptera	Pigfish													5	1	2.2	0.09
Archosargus probatocephalus	Sheepshead													1	1	2.2	0.2
Diplodus holbrookii	Spottail pinfish									1	1	2.56	0.01				
Lagodon rhomboides	Pinfish									1	1	2.56	0.03	14	3	6.5	0.2
Pagrus pagrus	Red porgy									1	1	2.56	0.05				
Sparidae	Sea breams and porgies	2	2	10.00	0.64												
Bairdiella chrysoura	Silver perch	1	1	5.00	0.08					2	2	5.13	0.16	1	1	2.2	0.01
Cynoscion nebulosus	Spotted seatrout	1	1	5.00	0.51	1	1	3.70	0.03	3	x		1.17	10	7	15.2	3.64
Cynoscion spp.	Seatrout	1	1	5.00	0.03	10	5	18.52	4.32	2	2	5.13	1.24				

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Menticirrhus saxatilis	Northern kingfish													1	1	2.2	0.01
Pogonias cromis	Black drum									1	1	2.56	0.21				
Sciaenops ocellatus	Red drum	1	1	5.00	1.39	7	2	7.41	5.11	1	1	2.56	0.26	8	2	4.3	3.49
Sciaenidae	Drum fishes									1	x		14.06				
Lactophrys sp.	Trunk fish									2	1	2.56	0.03				
Bothidae	Lefteye flounder					1	1	3.70	0.41								
Paralichthys sp.	Large tooth flounder									1	1	2.56	0.42				
Chilomycterus schoepfi	Striped burrfish	2	2	10.00	3.15												
Diodon spp.	Porcuepinefish	2	1	5.00	0.81	1	1	3.70	0.25	2	2	5.13	0.25				
Diodontidae	Burr and porcupine fish									2	x		0.43	3	1	2.2	0.07
Actinopterygii	Bony Fish	253	x		18.63	81	x		15.42	170	x		18.12	591	x		20.7
Colubridae	Nonpoisonous snake									1	1	2.56	0.03				
Chelydridae	Snapping Turtles													5	1	2.2	10.55
Gopherus polyphemus	Gopher tortoise									1	1	2.56	5.5	2	1	2.2	5.56
Malaclemys terrapin	Diamondback terrapin					1	1	3.70	3.32								
Trachemys sp. /*Pseudemys* sp.	Sliders, cooters													1	1	2.2	8.75
Testudines	Turtles					1	x		0.21	8	x		4.58	6	x		3.63
Aves	Bird	6	1	5.00	0.33					7	1	2.56	0.27	1	1	2.2	0.08
Rodentia	Rodent													1	1	2.2	0.03
Procyon lotor	Raccoon									1	1	2.56	0.55	1	1	2.2	3.49
Odocoileus virginianus	Whitetail deer													1	1	2.2	17.4
Cetacean	Aquatic mammals													3	1	2.2	26.73
Mammalia	Mammals					2	1	3.70	0.71	4	x		2.83	4	x		14.11
Vertebrata	Vertebrate								0.35			0.00	1.36				5.56
TOTAL VERTEBRATES		**331**	**20**	**100**	**32**	**144**	**27**	**100**	**37.65**	**317**	**39**	**100**	**65.08**	**755**	**46**	**100**	**135.29**
Diodora cayenensis	Cayene keyhole limpet									1	1	0.04	0.10	4	3	0.0	0.65
Littoridinops sp.	Hydrobe									2	2	0.07	0.10				
Tryonia aequicostata	Smooth-rib hydrobe									1	1	0.04	0.10				
Schwartziella catesbyana	Catesby's Risso	1	1	0.02	0.10												

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Assiminea succinea	Atlantic assiminea	13	13	0.26	0.10												
Calliostoma sp.	Topsnail													1	1	0.0	0.02
Littoraria angulifera	Mangrove periwinkle					1	1	0.09	0.33								
Littorina sp.	Periwinkle													2	2	0.0	0.14
Turritella exoleta	Eastern turretsnail	1	1	0.02	0.10												
Turritellidae	Turretsnail									2	2	0.07	0.10	9	6	0.1	1.01
Vermetidae	Wormsnail													2	1	0.0	0.43
Modulus modulus	Buttonsnail	11	11	0.22	1.00	3	3	0.26	1.15	38	35	1.30	7.60	107	102	1.0	14.47
Cerithidea costata	Costate hornsnail									14	14	0.52	0.40	40	40	0.4	0.47
Cerithidea scalariformis	Ladder hornsnail	26	24	0.48	1.40	5	5	0.44	0.36	10	8	0.30	0.9	64	44	0.4	4.13
Cerithiopsis academicorum	Common miniature cerith	1	x		0.10												
Bittiolum varium	Grass cerith	2	2	0.04	0.10												
Cerithium eburneum	Ivory cerith	2	2	0.04	0.30					3	3	0.11	1.00	4	3	0.0	1.49
Cerithium lutosum	Variable cerith	85	80	1.59	3.10					16	16	0.59	0.90	16	15	0.2	1.58
Cerithium muscarum	Flyspeck cerith	144	137	2.73	6.10	92	92	8.10	6.53	190	190	7.03	17.60	4067	4067	40.9	275.60
Cerithium spp.	Cerith	123	x		3.50					97	x		5.70				
Bittiinae (subfamily)	Bittium									2	x		0.40				
Cerithidae	Ceriths					2	x		0.04								
Seila adamsii	Adams miniature cerith	1	1	0.02	0.10					4	4	0.15	0.10	2	2	0.0	0.03
Cerithopsidae	Common miniature cerith									2	2	0.07	0.10	1	1	0.0	0.01
Eulimidae	Eulimid													2	2	0.0	0.04
Strombus alatus	Florida fighting conch									15	13	0.48	544.70	8	8	0.1	418.44
Crepidula aculeata	Spiny slippersnail					1	1	0.09	0.23	1	1	0.04	0.10	1	x		0.09
Crepidula fornicata	Common Atlantic slippersnail	10	10	0.20	1.30	2	2	0.18	0.07	33	33	1.22	1.50	19	x		2.52
Crepidula maculosa	Spotted slippersnail									16	16	0.59	0.20	17	x		0.80
Crepidula plana	Eastern white slippersnail	4	4	0.08	0.20	6	6	0.53	0.96	19	19	0.70	1.20	20	x		1.10
Crepidula spp.	Slippersnail					3	x		0.09					74	74	0.7	1.24
Cerodrillia thea	Tea drillia	1	1	0.02	0.10									2	2	0.0	0.11
Cerodrillia (cf.) thea	Tea drilla									1	1	0.04	0.10				
Neverita duplicata	Shark eye	3	2	0.04	3.20	2	2	0.18	34.65	6	3	0.11	12.30				
Eupleura sulcidentata	Sharp-rib drill					2	2	0.18	0.12	2	2	0.07	0.10	8	8	0.1	0.70
Urosalpinx cinerea	Atlantic oyster drill	4	4	0.08	0.10	2	2	0.18	0.33	5	5	0.19	0.60	27	25	0.3	3.02
Urosalpinx perrugata	Gulf oyster drill	6	6	0.12	0.50	4	4	0.35	1.52	9	9	0.33	2.20	25	25	0.3	4.10

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Urosalpinx tampaensis	Tampa drill									1	1	0.04	0.10	7	7	0.1	0.02
Muricidae	Rock snails	1	x		0.10					1	x		0.10				
Columbellidae species A	Dovesnail									1	1	0.04	0.10				
Columbellidae species B	Dovesnail									1	1	0.04	0.10				
Columbellidae species C	Dovesnail									1	1	0.04	0.10				
Costoanachis semiplicata	Gulf dovesnail	1	1	0.02	0.10	1	1	0.09	0.08	17	17	0.63	1.50	80	79	0.8	7.94
Costoanachis sparsa	Sparse dovesnail									6	6	0.22	0.20				
Costoanachis spp.	Dovesnail	1	x		0.10									1	x		0.01
Nitidella nitida	Glossy dovesnail									2	2	0.07	0.50	2	2	0.0	0.75
Suturoglypta iontha	Lineate dovesnail									1	1	0.04	0.10	1	1	0.0	0.02
Busycon sinistrum	Lightning whelk	621	206	4.10	2347.00	355	316	27.82	2841.76	631	228	8.44	2510.70	211	205	2.1	533.06
Busycotypus spiratus	Pearwhelk	50	30	0.60	170.70	94	88	7.75	579.49	181	117	4.33	544.80	52	36	0.4	124.03
Geomphus tinctus	Tinted cantharus									2	2	0.07	0.70	1	1	0.0	0.13
Hesperisternia multangulus	Ribbed cantharus									1	1	0.04	0.30				
Solenosteria cancellaria	Cancellate cantharus									2	2	0.07	0.10				
Buccinidae	Cantharus									1	x		0.30	22	x		3.50
Melongena corona	Crown conch	18	8	0.16	31.60	102	50	4.40	258.76	216	126	4.66	407.70	93	50	0.5	97.87
Nassarius vibex	Bruised nassa	18	18	0.36	1.80	5	5	0.44	0.52	70	70	2.59	9.50	259	243	2.4	34.79
Fasciolaria lilium	Banded tulip	12	9	0.18	16.20	4	4	0.35	26.59	38	18	0.67	39.90	22	9	0.1	16.20
Fasciolaria tulipa	True tulip	12	7	0.14	51.00	4	3	0.26	70.18	42	17	0.63	437.40	3	3	0.0	22.13
Triplogusus giganteus	Horse conch					1	1	0.09	46.90	3	3	0.11	192.40				
Fasciolariidae	Tulip snails	4	x		9.30	13	x		7.24	89	x		103.70	24	x		34.40
Olivella floralia	Common rice olive	14	14	0.28	0.60					8	8	0.30	0.20	22	22	0.2	0.63
Olivella pusilla	Tiny dwarf olive	12	12	0.24	0.40												
Olividae	Olive									1	x		0.10				
Granulina hadria	Hadria marginella	4	4	0.08	0.10												
Prunum apicinum	Common Atlantic marginella	27	27	0.54	0.70	2	2	0.18	0.13	36	36	1.33	1.70	101	101	1.0	8.57
Prunum succinea	Velie marginella									1	1	0.04	0.10				
Conus anabathrum	Florida cone									4	4	0.15	0.10				
Conus (cf.) anabathrum	Florida cone	1	1	0.02	0.10												
Conus spp.	Cone	1	x		0.10					5	x		0.10	5	5	0.1	0.19
Pyrgospira tampaensis	Tampa turrid									1	1	0.04	0.10				
Pilsbryspira leucocyma	White-knob drilla	3	3	0.06	0.10					21	21	0.78	0.80	20	20	0.2	1.20

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Agathotoma candidissima	Sugar mangelia	7	7	0.14	0.10					6	6	0.22	0.10	22	22	0.2	0.19
Mangeliidae	Mangelia									1	x		0.10				
Boonea impressa	Impressed odostome	5	5	0.10	0.10					2	2	0.07	0.10	5	5	0.1	0.03
Eulimastoma canaliculatum	Channeled odostome	1	1	0.02	0.10												
Odostomia laevigata	Ovoid odostome									2	2	0.07	0.10				
Odostomia sp.	Odostome	4	4	0.08	0.10									4	4	0.0	0.02
Sayella fusca	Brown sayella	1	1	0.02	0.10												
Bulla striata	Striate bubble	3	3	0.06	0.10					1	1	0.04	0.10				
Turbonilla species A	Turbonille									2	2	0.07	0.10				
Turbonilla species B	Turbonille									3	3	0.11	0.10				
Turbonilla spp.	Turbonille	140	x		1.10									2	2	0.0	0.09
Pyramidellidae species A	Pyramid shells													1	1	0.0	0.01
Pyramidellidae species B	Pyramid shells													1	1	0.0	0.08
Pyramidellidae	Pyramid shells									1	x		0.10				
Bulla striata	Striate bubble													25	25	0.3	1.07
Acteocina canaliculata	Channeled barrel-bubble	96	96	1.91	0.80	1	1	0.09	0.01	108	108	4.00	1.30	186	186	1.9	2.38
Blauneria heteroclita	Left-hand melampus	1	1	0.02	0.10												
Ellobium sp.	White melampus									1	1	0.04	0.10				
Melampus bidentatus	Eastern melampus	63	33	0.66	4.60	13	13	1.14	2.26	55	55	2.04	3.80	46	46	0.5	5.87
Melampus bullaoides	Bubble melampus	1	1	0.02	0.10												
Melampus coffeus	Coffee melampus					11	9	0.79	1.14	1	1	0.04	0.20	47	47	0.5	9.04
Melampus spp.	Melampus					20	x		1.65	1	x		0.10				
Pedipes mirabilis	Miraculous pedipes									1	1	0.04	0.10				
Microtralia occidentalis	Tiny melampus	1	1	0.02	0.10												
Ellobiidae	Melampus													95	x		5.52
Polygyra cereolus	Southern flatcoil	76	45	0.90	0.70	1	1	0.09	0.02	3	3	0.11	0.10				
Gastropoda	UID Gastropods	279	x		15.80	391	x		413.77	145	x		4.50		x		423.38
Brachidontes exustus	Scorched mussel					2	1	0.09	0.76	27	5	0.19	1.40	59	34	0.3	3.13
Geukensia granosissima	Southern ribbed-mussel	2	2	0.04	0.10	48	23	2.02	9.46	213	30	1.11	37.10	17	10	0.1	6.22
Modiolus americanus	American horsemussel					1	1	0.09	0.06	30	1	0.04	8.60	413	16	0.2	57.87
Mytilidae species A	Mussel	27	12	0.24	5.70					1	1	0.04	0.10				
Mytilidae species B	Mussel	5	1	0.02	0.10					3	1	0.04	1.00				
Mytilidae	Mussel					38	x		4.54					318	x		16.30

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Anadara transversa	Transverse ark	1	1	0.02	0.10	2	2	0.18	0.55	7	4	0.15	4.30	11	6	0.1	1.66
Arcidae	Ark shells	1	x		5.30					1	x		0.20				
Noetia ponderosa	Ponderous ark	1	1	0.02	6.30	1	1	0.09	0.37	4	2	0.07	40.20	4	4	0.0	2.02
Atrina sp.	Pen shell					4	1	0.09	0.75	273	2	0.07	14.20	97	1	0.0	16.84
Argopecten gibbus	Atlantic calico scallop									1	1	0.04	0.60				
Argopecten irradians	Bay Scallop					1	1	0.09	1.55	52	3	0.11	53.90	5	3	0.0	4.50
Pectinidae	Scallop													2	x		0.64
Plicatula gibbosa	Atlantic kittenpaw													13	7	0.1	9.95
Anomia simplex	Common jingle					3	3	0.26	0.37	35	29	1.07	9.60	245	60	0.6	35.10
Crassostrea virginica	Eastern oyster	911	462	9.20	2774.80	1196	312	27.46	2225.00	460	236	8.73	1659.80	212	118	1.2	708.95
Ostreola equestris	Crested oyster	38	25	0.50	14.00	73	34	2.99	26.52	83	42	1.55	16.60	331	170	1.7	62.12
Ostreidae	Oyster									434	x		476.00	209	x		205.78
Lucinisca nassula	Woven lucine					3	2	0.18	0.20	2	2	0.07	2.10	2	2	0.0	0.14
Radiolucina amianta	Miniature lucine	1	1	0.02	0.10												
Stewartia floridana	Florida lucine	1	1	0.02	0.10												
Lucinidae	Lucine									2	x		0.10	4	3	0.0	8.56
Carditamera floridana	Broad-ribbed carditid	1	1	0.02	0.10	6	4	0.35	3.31	16	x		5.10	34	18	0.2	12.68
Carditidae	Carditid									1	x		0.30				
Crassinella (cf.) lunulata	Lunate crassinella	2	2	0.04	0.10									8	4	0.0	0.20
Dinocardium robustum	Atlantic giant cockle					1	1	0.09	0.76	4	1	0.04	2.90	2	1	0.0	23.11
Trachycardium egmontianum	Florida pricklycockle													2	1	0.0	0.76
Trachycardium muricatum	Yellow pricklycockle													2	1	0.0	0.55
Cardiidae	Cockle					1	x		3.27					1	x		0.61
Spisula raveneli	Atlantic surf clam	2	2	0.04	2.10					13	5	0.19	10.50	4	2	0.0	7.59
Spisula sp.	Surf clam					4	1	0.09	2.27								
Tampaella tampaensis	Tampa tellin	11	8	0.16	1.30	13	12	1.06	4.47					285	155	1.6	15.41
Tellina spp.	Tellin									2	2	0.07	0.20				
Donax variabilis	Variable coquina					1	1	0.09	0.11	2	2	0.07	0.20	2	2	0.0	0.50
Tagelus sp.	Tagelus													10	6	0.1	1.00
Cumingia coarctata	Contracted semele									1	1	0.04	0.10				
Semele proficua	Atlantic semele									1	1	0.04	0.10				
Polymesoda floridana	Southern marshclam	101	57	1.14	11.90	56	29	2.55	10.02	545	232	8.59	99.40	1827	945	9.5	361.67

Taxon	Common Name	P-10-99				P-10-101				P-1-103				P-10-105			
		NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Arcinella cornuta	Florida spiny jewelbox													1	1	0.0	0.99
Diplodonta sp.	Diplodonta									1	1	0.04	0.10				
Anomalocardia auberiana	Pointed venus	149	63	1.25	20.50	170	47	4.14	24.67	447	184	6.81	57.90	4553	1740	17.5	789.50
Chione cancellata	Cross-barred venus					2	1	0.09	0.54	5	2	0.07	2.50	26	12	0.1	27.76
(cf) Macrocallista nimbosa	Sunray venus									1	1	0.04	1.90	4	1	0.0	6.56
Mercenaria campechiensis	Southern quahog									16	1	0.04	316.00	94	5	0.1	1033.25
Parastarte triquetra	Brown gemclam	689	345	6.87	2.10	7	4	0.35	0.02	508	254	9.40	2.30	1439	720	7.2	6.66
Transennella conradina	Colorful transennella	102	53	1.06	2.50	59	33	2.90	1.77	198	108	4.00	5.10	438	237	2.4	7.49
Veneridae	Venus clam													1	x		0.42
Bivalvia	UID Bivalves	39	x		0.60					81	x		3.50				
Balanus sp.	Acorn barnacles	211	55	1.10	5.40	3	1	0.09	0.26	658	188	6.96	15.80	1833	88	0.9	65.69
Mollusks	UID Mollusca															0.0	135.82
TOTAL INVERTEBRATES		**4211**	**1929**	**38.4186417**	**5528.5**	**2838**	**1129**	**99.38380282**	**6618.48**	**6334**	**2592**	**95.92894152**	**7712.3**	**18390**	**9927**	**100**	**5703.31**

Table 2.5. Summary of Operation P assemblages by major animal group

	P-10-99				P-10-101				P-1-103				P-10-105			
Taxa	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)	NISP	MNI	MNI%	wt (g)
Cartilaginous sharks and rays	11	1	0.02	0.32	3	1	0.09	0.38	20	4	0.16	3.84	11	3	0.03	2.41
Bony fishes	314	18	0.36	31.35	137	10	0.87	33.03	275	31	1.21	47.80	719	35	0.35	42.55
Turtles	0	0		0	2	1	0.09	3.53	9	1	0.04	10.08	14	3	0.03	28.49
Birds	6	1	0.02	0.33					7	1	0.04	0.27	1	1	0.01	0.08
Deer	0	0	0.00	0	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.01	26.73
Other mammals	0	0	0.00	0	2	1	0.09	0.71	5	1	0.04	3.38	8	2	0.02	37.35
Gastropods	5120	3929	78.80	2714	1150	621	54.05	4297.00	2320	1360	53.29	4863.70	5895	5565	56.24	2065.48
Bivalves	2084	1037	20.80	2847.8	1692	515	44.82	2321.30	3470	1154	45.22	2833.90	10675	4285	43.30	3436.49
Total	7535	4986	100	5593.8	2986	1149	100	6655.95	6106	2552	100	7762.97	17324	9895	100	5639.58

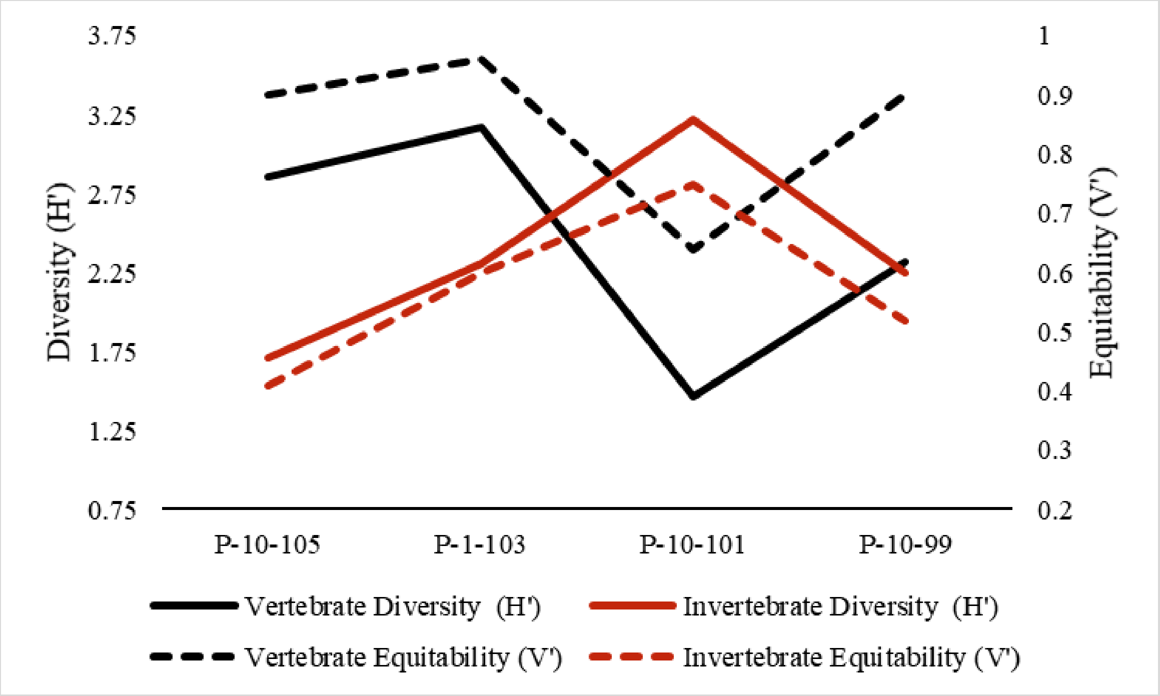


Figure 2.6. Change in estimations of diversity and equitability of vertebrate and invertebrate assemblage from Pineland RCM1, Operation P.

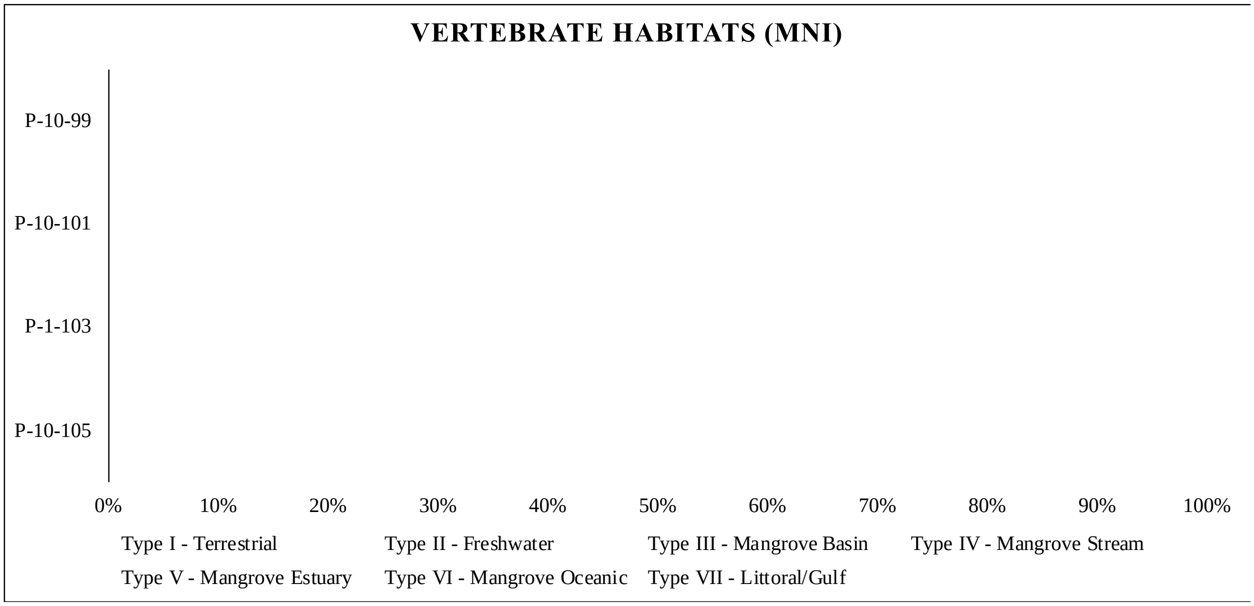


Figure 2.7. Distribution of represented habitat types, based on percentage of Pineland RCM1 Operation P vertebrate MNI, through time.

Between approximately 70-80% of the MNI vertebrate taxa in each level can be found in these types. Those taxa attributed to although P-10-101 measures low at 0.64. The low equitability measure of 0.64 from sample P-10-101 is likely affected by the high MNI of 13 sea catfishes.

Thirty different taxa were used to examine trends in the environmental habitat type trends through time (Appendix A). Over 90 percent of the MNI from each of the assemblages analyzed here are bony and cartilaginous fishes that can be attributed to Types IV (mangrove stream) through Type VII (littoral/gulf) (Figure 2.7). The proportion of those habitats is represented relatively evenly within each level as well as through time. This is likely more due to the fact that the taxa identified here can be found in more than one habitat type and thus the MNI are counted for more than one environment type. The vertebrates represented primarily can be found in shallow water, seagrass habitats of mangrove estuary (Type V), and mangrove oceanic (Type VI) like those found in close proximity to Pine Island today. Between 70 and 80 percent of the vertebrate MNI in each level can be found in these two types. Those taxa attributed to the terrestrial (Type I), freshwater (Type II), and mangrove basin (Type III) types account for approximately 10 percent of the total MNI. Level P-10-99 did not contain any vertebrate taxa other than cartilaginous and bony fishes while Level P-10-105 contained taxa representative of each habitat type. Of note, one boxfish (*Lactophrys* sp.), three grunts (*Haemulon*), and one grouper (*Epinephelus*) were identified in P-1-103 These fish are identified only in this level and they prefer relatively higher, marine salinities.

Zooarchaeology - Invertebrates

The four samples produced a total of 36,004 invertebrate shells and shell fragments (NISP identified to at least Class) with 18,798 invertebrate MNI (Table 2.4). Gastropods (53 to 56 percent) and bivalves (43 to 45 percent) are similarly represented in percent MNI in three of the four samples except for level P-10-99 which has a higher proportion of gastropods (79 percent) relative to bivalves (21 percent). The invertebrate diversity measures estimated here increase in diversity through the older three samples and decrease in the youngest one (Figure 2.6). The equitability estimates measured here demonstrate a similar pattern.

The presence and abundance of certain taxa changes stratigraphically through time (Figure 2.8). The MNI for crested oyster and eastern oyster changes inversely in relation to each other with a ratio of approximately three crested oysters for every two eastern oysters in level P-10-105 to a ratio of one crested oyster for every 18 eastern oysters. The MNI for large gastropod species such as crown conch (*Melongena corona*) increases from 50 to 126 and then decreases from 50 to 8 individuals and similarly, pear whelk (*Busycotypus spiratus*) increases from 36 to 117 and then decreases to 88 and 30 individuals. The MNI for marginella (*Prunum apicinum*) decrease from 101 to 36 and 2 then increase to 27 individuals. The MNI for the flyspeck ceriths decreases from 4067 to 190 and 92 then increases to 137 individuals. The MNI for slippersnails (*Crepidula* spp.) also decrease through time 131 to 69, 12, and 14. The MNI for pointed venus (*Anomalocardia auberiana*) also decreases through time from 1740 to 184, 47, and 63.

A total of 186 oyster shells, all left valves, were measured and results are presented in Figure 2.9 (Appendix C). Valve height among the four samples does not differ greatly. The range of valve lengths measurements in level P-10-105 (18.77 to 44.18

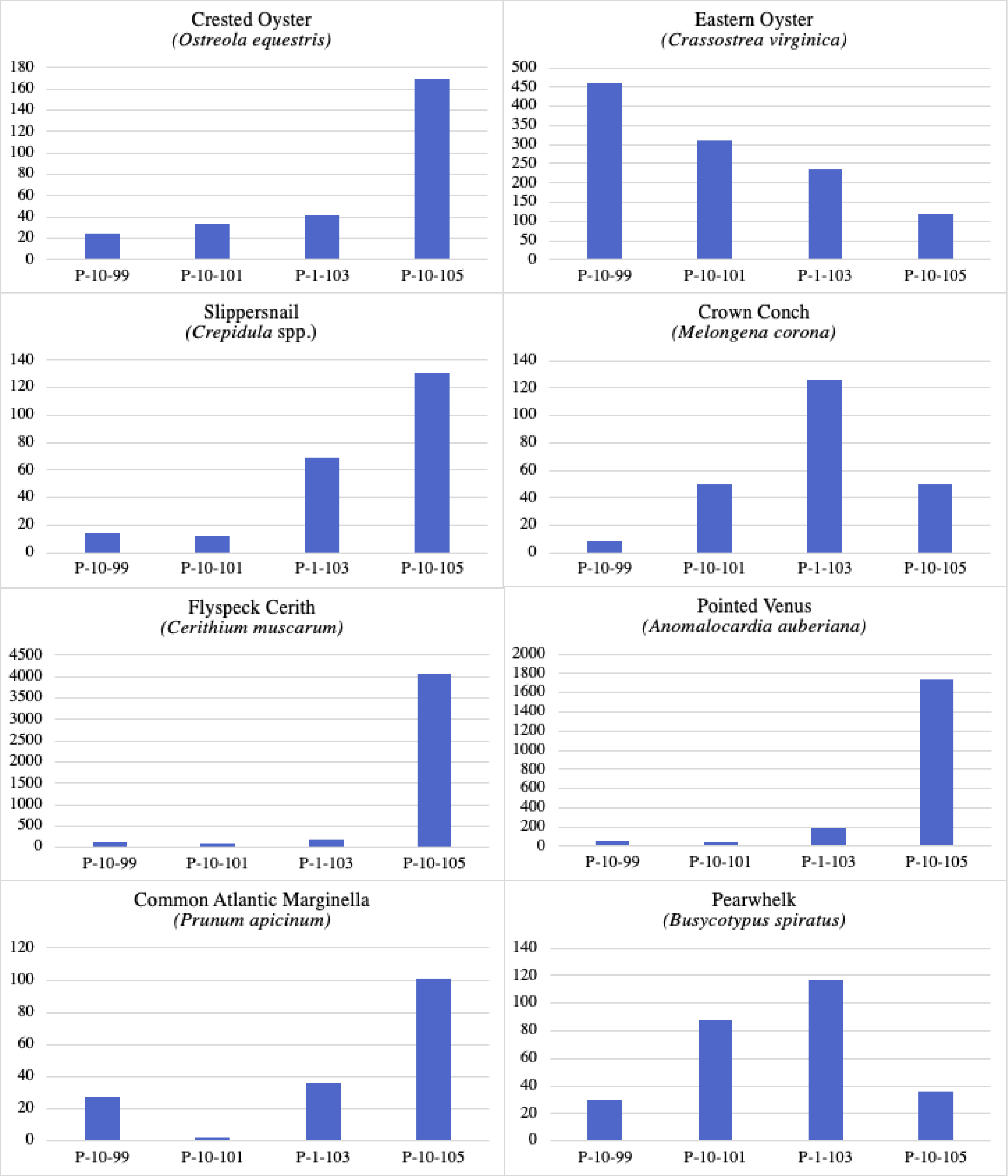


Figure 2.8. Pineland RCM1, Operation P, selected invertebrate taxa by MNI through time. (**Crepidula* spp. here includes all shells identified to at least the genus level.)

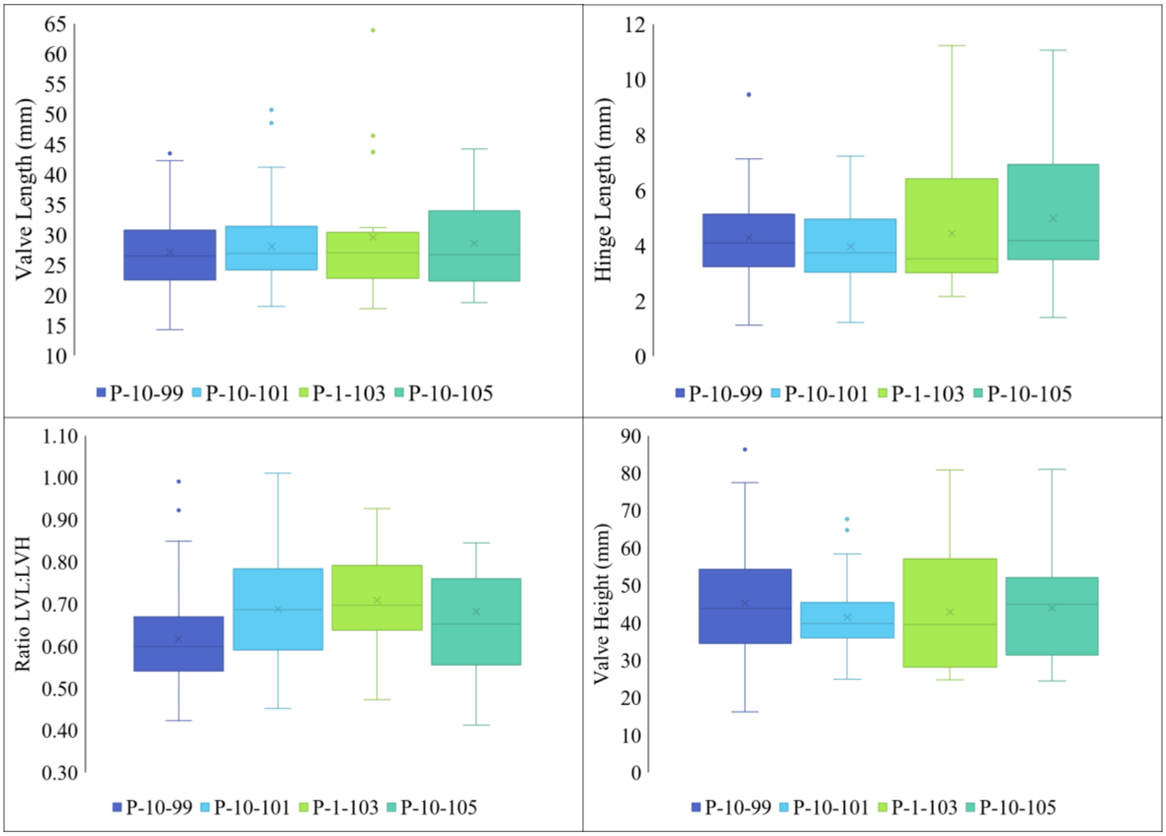


Figure 2.9. Boxplot comparisons of Pineland RCM1 Operation P's Eastern oyster (*Crassostrea virginica*) measurements of left valve length (LVL), left valve hinge length (LVHL), left valve height (LVH), and the ratio of LVL to LVH.

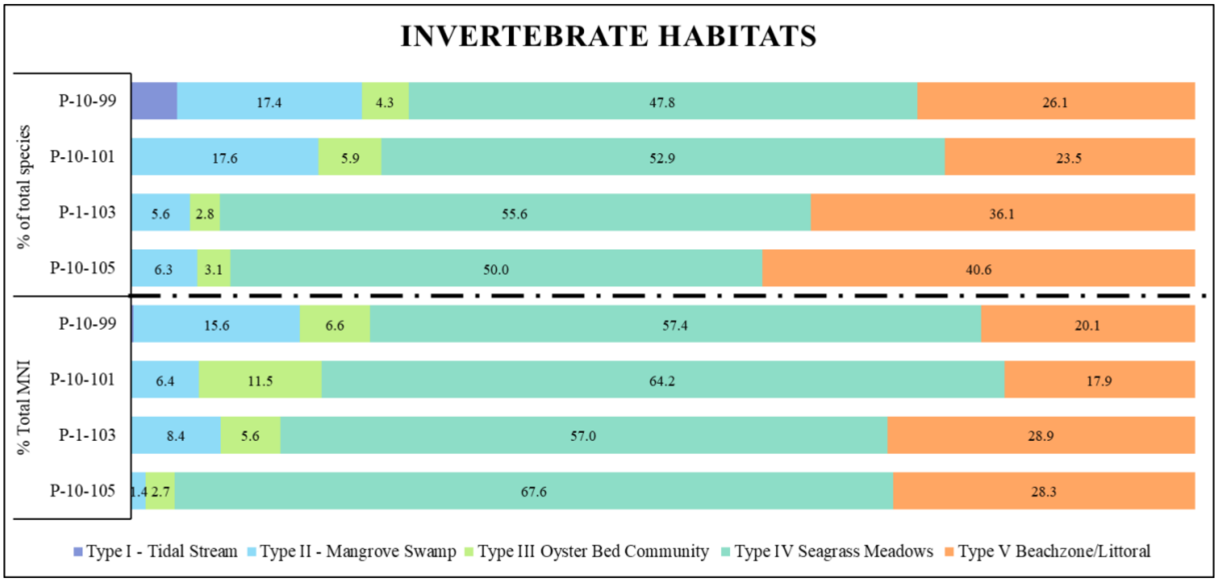


Figure 2.10. Distribution of represented habitat types, based on percentage of invertebrate taxa and MNI, through time.

mm) is only slightly larger than the range of valve lengths in P-10-99 (14.27 to 42.32 mm). However, the range of valve lengths is smaller in level P-1-103 (17.71 to 31.20 mm). A similar trend for valve height is recorded. The range of valve heights in P-10-105 (24.45 to 80.90 mm) is only slightly larger than the range of valve heights from P-10-99 (16.15 to 77.39 mm). However, the range of valve heights is smaller in P-10-101 (24.98 to 58.34 mm), as opposed to P-1-103 valve lengths. The ratio of valve lengths to valve heights slightly increases from P-10-105 (0.41 to 0.84 mm) to P-10-101 (0.45 to 1.01 mm) but decreases again in P-10-99 (0.42 to 0.85 mm).

The invertebrate taxa used to examine changes in local environmental conditions indicates a decrease in percent of total taxa and in percent of MNI of Type V taxa, those that prefer higher saline conditions (Figure 2.10). Also indicated is an increase in both percent total taxa and percent MNI of Types II and III taxa, those that prefer less saline, more brackish water conditions. Sample P-10-99 contains the only species indicative of Type I (tidal stream) environments. Looking only at only oyster bed communities, species such as slippersnails and crested oysters decrease in MNI through time (Figure 2.9).

Discussion

Zooarchaeological Indicators of Paleoenvironmental Change

There are several indications of changes in the local paleoenvironmental conditions in the Pineland locale. It is of no surprise that the majority of the vertebrate taxa come from the environment types associated with high-saline, seagrass meadows like those found in Pine Island Sound today. However, taxa from environments not in proximity provide indicators of possible environmental changes. The decreases in diversity in both the vertebrate (levels 101 and 99) and invertebrate (level 99) assemblages could indicate environmental stressors and community shifts in response to change likely in the form of a decrease in salinity. While there are multiple factors that can contribute to changes in the diversity of zooarchaeological assemblages, including, but not limited to sample size, recovery methods, and human agency in the creation of midden deposits, the trend in diversity of the invertebrate assemblages here is mostly likely resultant of changing environmental conditions. Most of the smaller invertebrates identified are non-food taxa and thus would not be influenced by the same taphonomic processes as food taxa. They are likely present in this midden due to its location along a shoreline. The accumulation of decaying biological material would have been attractive to many of these taxa who are scavengers.

The samples for the two earlier deposits do contain fish remains of taxa that prefer more saline waters. These are scale finned grunts (*Haemulon* spp.), trunk fish (*Lactophyrs* sp.), grouper (*Epinephelus* spp.), requiem sharks (Carcharhinidae), and hammer head sharks (Sphyrinidae). While these fishes prefer higher salinity waters they can move into lagoons and estuaries when higher salinities are present. These fishes are not present in the later samples of these deposits, supporting a possible shift in local salinity regimes with a reduction in local high-salinity environments after *cal. AD 1230 – 1255*. It is notable that the total MNI for fishes, bony and cartilaginous is higher (38 and 35) in the earlier two samples compared to the later two (11 and 19), suggesting a dampening of the fishery. A alternative possible explanation for the low abundance of vertebrate fish remains is the consumption and subsequent deposition of these types of remains elsewhere on the site.

Several trends in the abundance of invertebrate taxa MNI through time also suggest changing environmental conditions. The decrease of crested oysters and increase in eastern oysters suggests a lowered salinities. Modern day conditions of Pine Island Sound largely preclude the presence of wide-spread eastern oyster bars due to high salinities. Lowered salinity allowed for the development of eastern oyster bars in Pine Island Sound where there are essentially none located today. The decrease in slippersnails, another member of oyster bed communities, supports this interpretation because they also prefer habitats with mean salinities of approximately 29 ppt (Wingard and Hudley 2012). Species in the family Muricidae are euhaline, preferring fully saline waters of around 30 ppt or more decrease in MNI (Wingard and Hurley 2012). The small gastropods, the common Atlantic marginella (*Prunum* apicinum) and flyspeck cerith (*Cerithium muscarum*) also exhibit a marked decrease in MNI through time. These two species prefer brackish, shallow warm waters at salinities of 25 to 45 ppt and 18 to 41 ppt, respectively, but an increase in survivorship and reproduction occurs as salinities increase (Murray and Wingard 2006). Finally, the decrease in crown conch MNI and pear whelk MNI is similarly suggestive of lower salinities in Pine Island Sound through time. While crown conchs are able to tolerate a wide range of salinities, their presence in Florida waters is positively correlated with salinity and the mortality of crown conch larvae increases when water salinities reach at or below 15 ppt (Garland and Kimbro 2015). Mean observed salinities for pear whelks in southern Florida are approximately 35 ppt with a range from approximately 16 to 49 ppt (e.g. Wingard and Hudley 2012). These changes in the abundance of certain species suggest a change in the position of a saltwater wedge that affected the habitats of Pine Island Sound after *cal. AD 1230 – 1255*.

While the faunal data presented here call for a need for further investigation into the dynamics of local environmental change, support is provided for substantial changes to environmental conditions soon after AD 1250. Two likely possible factors that could influence these changes are a lowering of relative sea level or increased rainfall and freshwater input into Pine Island Sound. Both mechanisms affect local salinity regimes but at different temporal scales. Changes in sea level affect local salinity gradients and because of the relatively low-lying topography of the Gulf Coast, any slight change in sea level could quickly change the salinity characteristics of the nearby Pineland locales and thus critically affect the composition of ecological communities. Alternatively, increased rainfall causing increased freshwater input into Pine Island Sound could have affected the location of the saltwater wedge and thus altered the composition of local ecological communities. It is likely that we see these changes in the varying oyster size data presented here however more data is needed in order to address the rapidity and scale at which these changes could and did affect local oyster populations. The difference in species composition and abundance for the assemblages presented here suggest a response of local ecological communities at a magnitude and rapidity that would have certainly been experienced by the people of Pineland. The changes in environments of the organisms utilized by the Calusa were undoubtedly altered during this time period beyond the variability expected within an estuary.

Paleoenvironmental Change and Calusa Histories

The initial stages of this midden's accumulation likely began underwater or as intertidal midden until around *cal AD 1390 – 1405*. The deposits accumulating before ca. AD 1400 contain abundant materials in heightened states of preservation, such as preserved cordage and wood, resultant of anaerobic conditions of being water-logged. The presence of wrack-type vegetation, mostly occurring in the deposits dating from *cal 1250 – 1275* to *cal AD 1330 – 1350*, suggests that this midden accumulated at the water's edge until reaching past the high tide mark at around *cal AD 1390 – 1405*. Given the habitat preferences of the invertebrate taxa associated with tidal streams and mangrove swamps present in these deposits, it is likely these deposits reached an elevation at or above the high-tide mark by *AD 1385 – 1405* as a result of a combination of midden accumulation and lowering sea levels.

The zooarchaeological data, as situated within a Bayesian analysis of a series of radiocarbon dates, indicate changes to the local environments in Pine Island Sound. Previous research identifies a reoccupation of the Brown's Mound Complex during the tenth century AD corresponding to changes in environmental conditions as discussed above. The faunal assemblages presented here suggests a corresponding initial use of the edge of the Randell Complex around *cal AD 950 – 1020* with use of this area until *cal AD 1430 – 1500*. Previous research ties the Jerup sea level record, which indicates a severe drop in sea level at AD 850 and then reinundation (Tanner 2000), to an abandonment and reoccupation of Pineland as evidenced by deposits at Brown's and Randell complexes (Marquardt and Walker 2013b:837). Previous interpretations of zooarchaeological data from around AD 1200 at Pineland indicate that the people of Pineland continued to utilize resources most intensively from marine seagrasses meadows. The interpretations presented here support previous conclusions but do not contain assemblages dominated by lightning whelks nor do they contain the abundance, albeit low, of bird and mammal remains as seen in prior investigations (deFrance and Walker 2013).

While the exact timing for the emergence of heightened political complexity in southern Florida is unclear, such organizational complexity was likely realized by at least the first millennia AD and started as small, heterarchically organized communities (Thompson and Worth 2011; Thompson et al. 2018). Environmental conditions undoubtedly played a key role in both sociopolitical and socioeconomic structuring and restructuring of Calusa communities requiring them to partake in cooperative spheres of interaction given the known environmental fluctuations (Walker 2013). Marquardt and Walker (2013b:836) propose that an erratic sea-level regression associated with the Vandal Minimum global climatic episode ca. AD 550 – 850 created conditions that reduced the availability of stable fish resources. Thompson et al. (2014) propose a restructuring of household organization, kin relations, and labor roles at Pineland at the onset of the episode around AD 500-550. Prior to this episode, people lived in small (ca. <8 m in diameter), circular, single-family structures then shifted to large (27 m x 10 m), multi-family co-resident structures, likely reflecting the emerging importance of corporate kin groups and institutions of cooperative labor. Additionally, instead of arranging residential structures parallel to the shoreline they were now situated perpendicular to the shoreline and parallel to the Central Canal (Marquardt and Walker 2013:880; Thompson et al. 2014), indicating the emergence of a fully realized community plan. Faunal assemblages indicate a warm, relative sea-level peak ca AD 450-500 (Quitmyer et al. 2005; Wang et al. 2013) and shell midden remains that suggest cooler conditions with sea-level lowering ca. AD 500 – 550 (Marquardt and Walker 2013b:826-827), a transition coeval with the establishment of larger households and an integrated community.

Deteriorating environmental conditions AD 500 – 850 not only influenced the nature of residential patterns but would have required more cooperative labor as a response to changing resource availability (Marquardt 2014:11; Marquardt and Walker 2013b:878-879). Once conditions improved during the Medieval Warm Period (AD 850 – 1200), the cooperative labor was no longer a necessity for survival and provided a means by which to invest in alternative forms of public goods such as the construction and maintenance of canals including the Central Canal and Pine Island Canal (Thompson et al. 2018; Thompson 2016). The inception of these canals on the landscape provided a new mechanism for the diversion of freshwater runoff into Pine Island Sound. The Pine Island Canal, which extend east from the Central Canal, ran east-west approximately 4 km across Pine Island connecting to other water features along the way (Luer and Wheeler 1997). Archaeological evidence and eyewitness accounts suggest the canal was approximately 9 m wide, 1 m deep, and had levees on either side that rose 1 m (Luer and Wheeler 1997; Marquardt and Walker 2013:847-849). While the location of the Central Canal likely took advantage of a prior tidal creek and artesian flows, the magnitude of freshwater input into Pine Island Sound as a result of its construction could have increased significantly, creating habitats more suitable for the growth of oyster beds (deFrance and Walker 2013:324). Additionally, previous analyses on deposits identified an increased reliance on oysters at Pineland compared to nearby Josselyn Island that contains no tidal creeks or freshwater runoff significant enough to promote the propagation of oyster beds (deFrance and Walker 2013). Thus, the lowering of sea level associated with the Little Ice Age and the increased freshwater input created by canal construction likely created a combined effect on the local environments to Pineland, effects that are neither fully explained nor captured by the use of generalized models of global climatic change by themselves. By depositing these middens along the shoreline, the people of Pineland created an environment attractive to scavengers, as are many of these gastropod species. In doing so, these deposits provide a resolution and environment not normally captured in natural deposits.

Conclusions

This article follows and builds upon roughly 40 years of work investigating the historical ecology of the Calusa and their predecessors at Pineland and around around the region (e.g. Marquardt 1992, 1999; Mand Walker 2013). This research has provided a high-resolution, detailed, synthetic environmental and cultural history at a resolution of 50-year increments through a combination of stratigraphic, radiocarbon, artifact, zooarchaeological, archaeobotanical, and other analyses. The long-lived, 1700-year, occupational history at Pineland demonstrates that the people of Pineland were successful in this environment for a long time despite episodic periods of environmental stressors such as sea-level decline and changing availability and location of fisheries. This sustainability and resilience were driven by a complex balance between entangled socio-ecological and sociopolitical regimes. Environmental change bears the potential to greatly affect the structure and maintenance of social, political, and economic institutions that are fundamentally reliant on coastal resources. As we have demonstrated, however, generalized models of global climatic change are insufficient for elucidating the complexities of this balance. As such, it is critical that such long-term trends be articulated with local ecological, geomorphological, and climatic records within which these socioecological entanglements were actually forged. Utilizing changes in abundance of smaller gastropods not likely used as primary food resources, provides a line of environmental evidence mostly devoid of human agency. There is always a possibility changes observed in the archaeological record are products of human agency, environmental changes, or a combination of both, the use of smaller gastropods which were not likely used as a primary food source provides a way to more directly target local, environmental conditions.

By extending the high-resolution temporality for occupation at Pineland to *cal. AD 1430 – 1500*, this paper addresses the ecological the ramifications of climate change on a scale relative to the human experience. While much emphasis in archaeological studies from around the globe has been placed on analyzing how data sets supposedly representing regional, general, and global patterns of climate change correlated with social change in the past, less work has been devoted to addressing how these extant climatic periods were manifest and experienced at local levels in an explicit fashion. In this regard, this article demonstrates that by tying the archaeological record directly to paleoenvironmental data from archaeological sites within a fine-grained temporal framework, socio-ecological histories imbued with meaningful temporality and can be more readily connected to human lives and the transformation of cultural institutions.

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CHAPTER 3

ENGINEERING ESTUARINE ECOLOGIES AND SURPLUS PRODUCTION AT MOUND KEY, FLORIDA, DURING THE LITTLE ICE AGE[1]

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Abstract

The Mound Key site (8LL2) is a 51-hectare anthropogenic island in Estero Bay, Florida. It is comprised of a complex arrangement of midden-mounds of various sizes, canals, watercourts, causeways, and burial mounds. The Calusa occupied Mound Key from approximately AD 450 through European contact. Mound Key served as the capital of the Calusa kingdom, an extensive sociopolitical entity whose economy focused on fishing, gathering, and hunting. This paper employs high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate refuse for the time of occupation at Mound Key AD 1000 – 1450. Through these analyses, we identify local environmental changes warmer, wetter, and more amenable than expected of the characteristics of the global climate event known as the Little Ice Age (ca. AD 1200 – 1850). Additionally, we argue that the Calusa leveraged deeply rooted ecological knowledge, specifically through the exploitation of certain species of fish capable of inhabiting conditions created by anthropogenically engineered features used a pens to hold live fish, watercourts. In doing so they could further ensure the success of these watercourts as part of a web of social, political, ecological, and biological systems as supported by an environmentally amenable period evidenced by the isotopic measurements.

Introduction

Archaeological approaches to understanding relationships between people and their environments require a recognition of the challenges of living in climatically sensitive environments. Humans’ capacity to actively manipulate and produce favorable conditions related to the location and availability of resources demonstrates the need to explore the dynamics of past socio-ecologies. Strategies for managing resources develop over time through the accumulation of distinct and historically defined ways of knowing local landscapes (Balée and Erikson 2006). Complex, coastal fisher-gatherer-hunters, like those of the Pacific Northwest and the Calusa of southwestern Florida, developed sophisticated strategies of resource management that depended on generational knowledge of landscapes and resource ecologies (Arnold 1996; Marquardt 2014; Marquardt and Walker 2013; Newsom and Scarry 2013; Price 1995:140). These inscribed practices and histories across the coastal landscape of southwestern Florida allowed for flexible responses to shifting climatic conditions within a productive, yet climatically sensitive estuarine environment (Erlandson 1994, 2001; Thompson and Worth 2011).

General patterns in global climatic trends, and local manifestations of and responses to these trends, are situated at vastly different spatial and temporal scales. Thus, a substantive understanding of any socio-ecological trajectory, and the changing dynamics of such relationships, requires an explicitly local examination of climatic impacts, ecological conditions, and archaeological evidence. To this end, this paper employs high-resolution Bayesian chronological modeling, oxygen isotope geochemistry of incremental marine shell growth bands, and zooarchaeological analysis of vertebrate refuse from Mound Key (8LL2) in Estero Bay, Florida (Figure 3.1), once the capital of the Calusa Kingdom, an extensive sociopolitical entity built on an economy that focused on fishing, gathering, and hunting. Through these analyses, we examine localized environmental changes and the intentional ecological engineering of estuarine landscapes

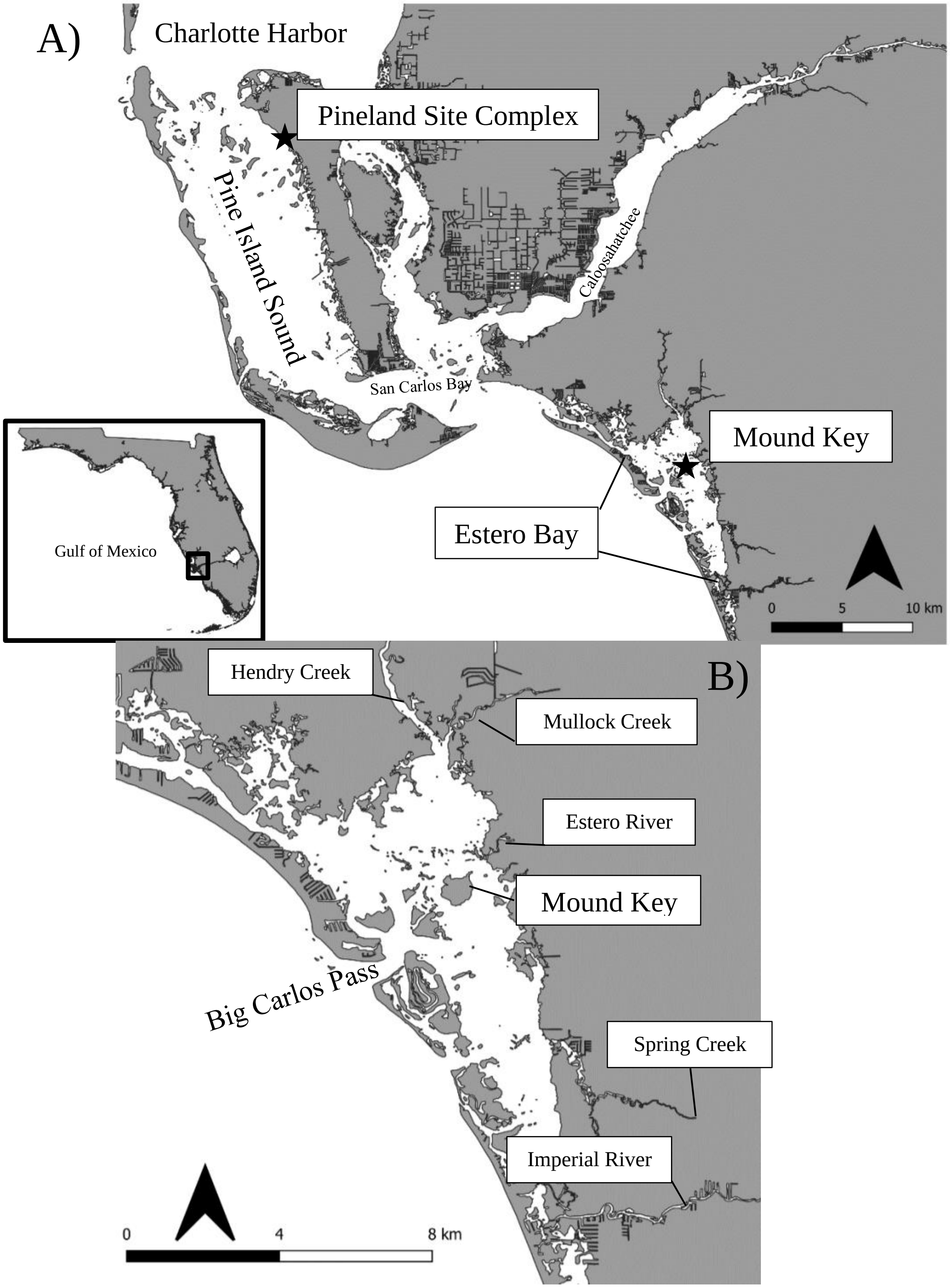


Figure 3.1. A) Map of Estero Bay and portion of Charlotte Harbor estuarine region in southwestern Florida, USA. B) Map of Estero Bay highlighting the natural features mentioned in text.

as they developed during the Little Ice Age (ca. AD 1200 – 1850). This work is contextualized within what is more broadly understood regarding the socio-political histories at Mound Key, and the Calusa in general.

Southwestern Florida serves as a prime locale to examine socio-ecological and socio-political trajectories of complex fisher-hunter-gatherer groups, to understand the localized impacts of a global climatic cooling event, and to explore the complexity of Indigenous landscape engineering. Both cultural practices and ecological variables are responsive to each other during times of change and stasis in these systems (see Marquardt and Walker 2013). Resources within the estuaries of southwestern Florida are patchy due to geographic configurations, differing salinity regimes, seasonal variations in freshwater flow, and fluctuations in relative sea level. These conditions are compounded by the unusual shallowness of these estuarine systems, leading to the amplification of minor changes in global climatic trends at the local scale (Beever III et al. 2009; Walker 2013). The most well-studied Calusa sites in the region include the Pineland Site Complex (8LL33, etc.) in Charlotte Harbor/Pine Island Sound and Mound Key (8LL2) in Estero Bay (Figure 3.1). Essential to Calusa success, just as with societies reliant on large-scale agriculture, was their ability to mediate changes to the location and availability of resources as a result of climate change via the collective organization and transformation of social, political, and economic institutions (Thompson et al. 2018a,b; Marquardt and Walker 2013). Recently, Thompson et al. (2020a) demonstrated the capacity of the Calusa to intensify and formalize fish resource management through landscape modification and to create a balance between both top-down and bottom-up strategies of sociopolitical action at Mound Key (Thompson et al. 2018a). Indigenous groups of southwestern Florida would have had intimate, generational knowledge of local environmental variations and how to manage the impacts of changing resources through different large-scale labor projects like the construction and maintenance of watercourts and canals (Thompson et al. 2020a). While the organization of labor would have been a key factor in completing such public works, an expert understanding of ecological and biological principles would have been critical to ensuring the success of such artificial constructions to store and maintain live fish resources. In this article, through paleoenvironmental and archaeological data, we outline the specific biological and ecological knowledge of the habitat requirements of certain species of fish as was leveraged by the Calusa to facilitate successful landscape engineering projects. In this regard, we interpret the isotopic data presented here to demonstrate that global signatures of the Little Ice Age fail to accurately capture the sometimes likely very amenable environmental conditions contained within this larger period in southwestern Florida. These engineering projects were likely used as a way to both buffer against environmental variations and support complex social, political, and economic institutions in a time of environmentally amenable conditions.

Complex Fisher-Hunter-Gatherers of Southwestern Florida

Complex fisher-gatherer-hunters are mostly sedentary, nonagricultural societies with structural, social differentiation that can manifest as inherited leadership and/or the organization and control of non-kin labor (Arnold 1996; Arnold et al. 2016; Fitzhugh 2003; Hayden et al. 1985). While there exists a wide range of variation among complex hunter-gatherer groups, what is most important in discussions here is sociopolitical integration and subsistence security (Arnold 1996; Arnold et al. 2016; Burch and Ellanna

1994). Specifically, these groups participate in delayed-return economies, display markers of social hierarchy, participate in extensive exchange networks, and partake in cooperative labor enterprises (Hiraguchi 1992; Jochim 2002; Kennett and Kennett 2000; Sassaman 2004). They often inhabit environments already characterized by high biodiversity and resource availability, relying on fishing, collecting and management of shellfish, hunting mammals on land and at sea, and the collection and management of reliable wild plant foods and exploitation of small home gardens (Arnold et al. 2016; Lepofsky et al. 2015; Norton 2007).

Complex hunter-gatherers are often characterized by resource specialization, a feature often accompanied by surplus (economic) production (Ames 1994; Arnold et al. 2016). Notably here, the production of surplus provides a means by which to divert labor to other large-scale projects and public-works like mound construction, which can further contribute to and reinforce complex organizational forms (Carballo et al. 2016; Morehart and De Lucia eds 2015). Creating and controlling surplus production, as aided by environments with high biodiversity, can subsequently contribute to the creation and maintenance of social inequality and can facilitate group cohesion through participation in communal activities (Testart et al. 1982; Pluckhahn et al. 2016; Thompson and Moore 2015). Surplus production of food resources, when focused on multiple species, also provides a mechanism with which cope with stressors, such as climatic variability (Hayden 2009; Kennett and Kennett 2000; Thompson and Moore 2015). The degree to which complex fisher-gatherer-hunter communities successfully buffered against risk or stress depends on the degree of connectedness between socioeconomic and socio-ecological systems (Solich and Bradtmöller 2017).

Highly developed systems of ecological knowledge can aid in the production and maintenance of surplus resources, especially among complex hunter-gatherers whose institutions are intimately tied to the exploitation of local resources (Morgan 2015; Smith 2012). Especially critical for aquatic resources, the production of surplus requires adequate strategies for storage or food preservation, both of which have been explained as mechanisms to combat environmental variability but also as a key component to the development of more sedentary lifeways and social complexity (Erlandson 2001; Keeley 1988; Testart 1982; Solich and Bradtmöller 2017). The production of surplus can occur opportunistically, like the exploitation of beached whales, or as anticipated events such as seasonal salmon runs in the Pacific Northwest, but both require intimate generational knowledge of the environment (Thompson and Moore 2015). The amount of time between collection of surplus resources and consumption may require the use of storage or food preservation techniques, which could take many forms, including stockpiling nuts, drying, smoking, or salting meat or fish (Morgan 2012). Storing such resources acts as an averaging mechanism on seasonal variability, especially in those environments where the reliability of natural resources is highly variable. Thus, surplus production fosters resilience against both internal and external variations, such as long and short-term environmental variability (Hayden 1996). In considering the tropical and subtropical environments of southwestern Florida, temperature and humidity present problems when it comes to storing plant and animal foodstuffs (Scarborough and Lucero 2010:188). While these environments contain great diversity with frequently abundant resources, these resources are often heterogeneously distributed and sensitive to minor variations in environmental changes. However, these issues could have been mediated, likely on a short-term basis, through surplus storage by way of salting or smoking fish and shellfish or through “holding” groups of fish or fishes in impoundments, also known as watercourts (Thompson et al. 2020a).

The Calusa

The Calusa of southwestern Florida were organized as a complex chiefdom or weak tributary state who did not engage in agricultural production like other Indigenous groups across the broader southeastern United States (Hutchison et al. 2016; Thompson et al. 2018a; Thompson et al. 2013). Estuarine and marine resources found along the Gulf Coast of Florida, wild plant foods, and small home gardens were the foundations of social, political, and economic organization (deFrance and Walker 2013; Newsom and Scarry 2013; Walker 1992). At the time of Spanish arrival, the Calusa exhibited a centralized social and political organization, governing and collecting tribute from neighboring polities across the lower third of peninsular Florida. They participated in long-distance exchange networks, had religious and military specialists, generated significant surplus production, maintained social stratification between an elite class and the wider populace, and had a king bestowed with sacred status (Marquardt 2014:14). Even during early encounters with the Spanish, the Calusa were able to maintain these complex organizational structures until the early 18th century (Marquardt 1988; Thompson et al. 2018b; Worth 2014). Environmental conditions and local ecological histories undoubtedly played a crucial role in the sociopolitical and socioeconomic character of Calusa communities witnessed by the Spanish in the 16th century and thus their ability to buffer against both social and environmental variations.

The Calusa consumed a wide variety of vertebrates, mostly estuarine and marine fish, and marine shellfish that were available and utilized both seasonally and year-round (deFrance and Walker 2013; Walker 1992; Quitmyer 2013). Thompson et al. (2014) argue that the shift to multi-family households ca. AD 500, during a time of climatic uncertainty, fostered collective labor enterprises aimed at resource procurement. Erratic sea level during the Vandal Minimum (ca. AD 550 – 850) likely reduced the availability of stable fish resources used by the Calusa (Marquardt and Walker 2013). When climate stabilized during the Warm Medieval Period (ca. AD 850 – 1200) these collective labor groups were able to refocus efforts on projects such as mound construction, canal construction, and other large-scale water features that contributed to the development of increasing political complexity (Marquardt 2014:12; deFrance and Walker 2013; Marquardt and Walker 2013; Thompson et al. 2018a). Thompson et al. (2018a:39-40) highlight the construction of canals as the "…ultimate collective action project among the Calusa…" that both required and fostered a high degree of inter-community cooperation. The creation of large surpluses of resources via the construction of watercourts at Mound Key was likely a strategy that supported increasing political complexity, further differentiated already powerful house lineages, and buffered against shifting environmental conditions (Thompson et al. 2020a). These watercourts were used to produce surplus food that served as the economic backbone of the Calusa capital at Mound Key (Thompson et al. 2020a). We have demonstrated previously the importance of mullet (*Mugil* spp.) at Mound Key (Thompson et al. 2020a).

What is less certain are the more specific subsistence practices that accompanied the production of surplus food stores and the importance of species other than mullet which we address in this paper. The creation of these watercourts would have been akin to the creation of lagoon-type features. These features would have acted as a shallow body of water separated from open bay conditions. Decreased exchange with more open waters could have limited water circulation and dissolved oxygen content. It could also have altered the nutrient content of these waters compared to the surrounding bay and estuarine systems (Spaulding 1994). In this way, conditions within the watercourts likely created conditions stressful to the organisms residing in them. As such, to be used as engineered features to hold live-fish surpluses, an intimate knowledge of local fish ecologies and biologies would have been critical to surplus production at Mound Key.

Mound Key and Estero Bay

Mound Key

Mound Key is a 51-hectare anthropogenic island composed primarily of repurposed and in situ shell midden (Thompson et al. 2016) located in Estero Bay, Florida. Previous Bayesian analyses of radiocarbon chronologies estimate the start of occupation activity at Mound Key to begin at *cal AD 460 – 530 (68% probability)* and lasting beyond initial Spanish contact (Thompson et al. 2016). The island is a complex arrangement of midden-mounds of various sizes, canals, watercourts, causeways, and burial mounds (Figure 3.2). By AD 1000, the two largest mounds, Mounds 1 and 2, reached almost their current heights of ca. 10m and 6m, respectively (Thompson et al. 2016). Mound 1, the tallest mound, held a mound-top structure with at least 3 phases of construction and repair beginning around AD 1000 (Thompson et al. 2016). Sixteenth-century historic documents describe this structure as the king's house, which could have held over 2,000 people and is estimated to have been 24 m long and 20 m wide, limited in size by the area of the mound top (Solís de Merás 1964:145; Thompson et al. 2018b). Bayesian analyses of radiocarbon dates from post mold features estimate three phases of construction and use lasting between cal AD 950 and 1570 (Thompson et al. 2018b). Mound 2 is more extensive and was the location of the Spanish Fort San Antón de Carlos in the 16th century (Thompson et al. 2020b). A large canal, termed the Grand Canal, bisects the area between Mounds 1 and 2 and extends across the entire island at 365m long and averages 28m wide. Previous work demonstrates the construction on the Grand Canal began ca. *cal AD 885 – 1010 (68% probability)*, roughly at the same time as the king's house upon Mound 1 was first constructed (Thompson et al. 2016; Thompson et al. 2020a). At the southern end of the canal, lying at the base of Mounds 1 and 2, exist two large watercourts that mirror each other, although there is some size variation, on either side of the canal (Thompson et al. 2020a). Recent work has placed the final construction phases at *cal AD 1385—1450 (68% probability),* coeval with the final phases of the use of the king's house and Mound 1 (Thompson et al. 2020a).

Immediately prior to the onset of the Little Ice Age, the first construction phases of the king's house commence sometime after AD 950 (Thompson et al. 2018a). At the nearby Calusa site of Pineland, zooarchaeological evidence suggests the concomitant increase in use of fish and shellfish that inhabit seagrass communities during the Medieval Warm Period which were previously decimated by the severely low sea levels of the Vandal Minimum (AD 550 – 850) (deFrance and Walker 2013; Walker 1992). Previous research suggests the Calusa built their organizationally complex social and political institutions through a history of collective action projects at multiple scales that operated on corporate-based political strategies (Thompson et al. 2018). The long-lived houses, like the king's house at Mound Key, similar to those seen among groups along the US Northwest Coast, served as seats of authority from which people were able to exercise control and exact collective effort efficiently (Ames 1996; Thompson et al. 2018a). Calusa lifeways were intimately tied to their environment, so it is not unlikely that the collective projects used to foster increasing political complexity initially were born from solutions to uncertainties faced during times of environmental strain on local ecological communities. By creating resilient relationships with resources in terms of how these resources were intertwined in social and political ties, the Calusa were able to foster a community built on collective buy-in strategies later used in the process of state formation (Thompson et al. 2018a).

Southwestern Florida and Estero Bay

Southwestern Florida is characterized by a subtropical, humid climate with average cold month temperatures at 17.4±1.7°C and average warm month temperatures averaging 28.1±0.6°C (www.ncdc.noaa.gov). This region is characterized by a small tidal range, a series of shallow estuarine systems, and an extended continental shelf. Many species found within these shallow-water ecosystems are susceptible to freeze damage and changing salinity regimes. Dominant ecological communities within this region include pine flatwoods, scrubby flatwoods, coastal strand, freshwater marshes, mangroves, and seagrasses. Walker (2013) presents a predictive warming and cooling model for Florida based on data from Dohrenwed and Harris (1975) and Harris and Cropper (1992). This model demonstrates the drastic climate-driven ecotonal shifts that can occur with a ± 2°C change in temperature and ±200 mm change in annual precipitation. These characteristics make these coastlines vulnerable to even minor variations in sea-level as well as other impacts such as rainfall and freshwater input.

Estero Bay

Estero Bay is a shallow, micro-tidal bay generally considered a sub-estuary of the larger Charlotte Harbor estuarine system (Figure 3.1). The daily tidal range is approximately 1 m. It receives freshwater directly from the Hendry, Mullock, and Spring Creeks, and the Estero and Imperial Rivers. The northern Caloosahatchee River provides an indirect influx of freshwater. Estero Bay is approximately 14 km north-south, 3 km wide, and covers about 78 km^2. Like the Charlotte Harbor estuarine system, shoal grass (*H. wrightii*) dominates seagrass beds across Estero Bay. Depths across the bay average 1 m but can reach up to almost 3 m during high tides in some areas. A series of barrier islands separated by several passes protects the bay from open ocean conditions of the Gulf of Mexico, but all allow for the circulation of ocean seawater into the bay. Of these passes, conditions surrounding Mound Key are most affected by Big Carlos Pass, which acts as a dominant influencer to the conditions of the bay as a whole. As such, modern salinity generally ranges monthly on average from about 25 – 32 ppt (Byrne and Gabaldon 2007). This range is affected by seasonal variation in rainfall and is thus lowest during the wet season from June to November and highest during the dry season from December to May.

As previously mentioned, research at the Calusa site of Pineland on Pine Island (Figure 3.1) just north of Estero Bay demonstrates that the Vandal Minimum climatic episode from ca. AD 550 – AD 850 incited changes in economic practices due to localized shifts in resource availability and location (Marquardt and Walker 2013:836).

However, little is known about the impacts of environmental change on the landscape of southwestern Florida during the Little Ice Age ca. AD 1200 – 1850. The changes seen across the sociopolitical landscape in southwest Florida during the Little Ice Age were undoubtedly entrenched in ties to local ecological conditions. By AD 1000, the island underwent significant modification with Mounds 1 and 2, reaching approximately their peak elevations (Thompson et al. 2016). Construction was also started on the large structure on Mound 1 at this time (Thompson et al. 2016). As previously summarized by Walker (2013), the coasts of southwest Florida could have been impacted by variations identified within the time period of the Little Ice Age. See Walker (2013) for more in-depth analysis. The Haeberli and Holzahauser (2003:14) alpine glacial record demonstrate that the Little Ice Age was a time of high climatic variability and documents three likely global episodes of cooling from AD 1250 – 1350, AD 1500 – 1650, and AD 1750 – 1850. Eddy (1994:29-31) demonstrates that periods of lower solar activity, associated with cooler global temperatures, characterized the Little Ice Age with the Wolf Minimum (ca. AD 1280 – 1340), the Spoerer Minimum (ca. AD 1410 – 1510), and the Maunder Minimum (ca. AD 1640 – 1710). Several other records supporting this variability include, but are not limited to, a Sargasso Sea record (Keigwin 1996),and a Puerto Rico record (Nyberg et al. 2002). These records suggest that conditions were cooling and drying between ca. AD 1150 and 1550 (Huag et al. 2003; Keigwin 1996). These variations, as compounded by the characteristics of the southwestern Florida shallow-water ecosystems, would have played a critical role in contextualizing the sociopolitical histories of southwestern Florida and the Calusa, but what remains less understood are the practices that supported socio-ecological and sociopolitical resilience.

As such, this research aims to elucidate the nature of these local ecological changes across Estero Bay from the transition to the Little Ice Age through the 15th century and to evaluate how these changes were tied resource management strategies at Mound Key.

Methods

Excavations

Excavations for this study were conducted during one field season in 2017. These excavations targeted locations associated with the construction and use of the West Court (watercourt) on the southern portion of Mound Key at the bases of Mounds 1 and 2 (Figure 3.2). Materials from these excavations were chosen for analysis based on location and 22 associated AMS radiocarbon dates (see Thompson et al. 2020a). Previous Bayesian chronological modeling of these dates estimates the start of activity associated with the construction and use of the Grand Canal and watercourt features at *cal. AD 885 – 1010 (68% probability)* and lasted until *cal. AD 1385 – 1405 (68% probability)* respectively. Excavations were conducted on the northeast edge of the West Court (Operations N-1 and N-1). This berm separates the interior of the watercourt and the canal (Operation O units), and on the ridge above the northeast edge of the court (Operation N-3) (Figure 3.2). Operation N units were all excavated as 1-m-x-1-m excavations while Operation O units were excavated as three contiguous 1-m-x-2-m units. A sump pump was required and used to remove water and suspended sediment to excavate subaqueous deposits in Units N-1 and O-2.

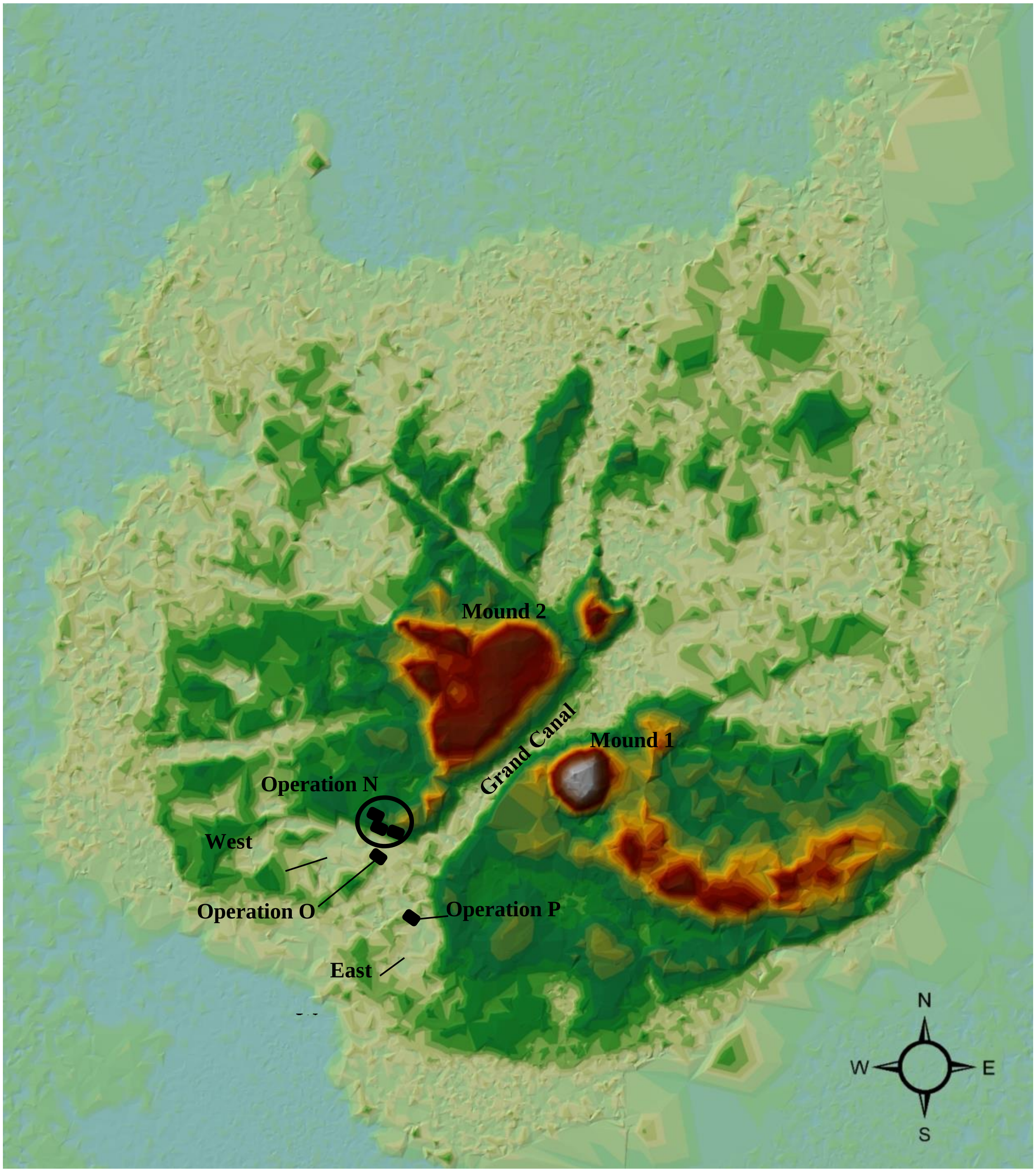


Figure 3.2. LiDAR digital elevation model of Mound Key (8LL2).

Operation N, Units N-1, and N-2: Operation N, units N-1 and N-2, were excavated to target the northeastern edge of the West Court (Figure 3.2). Both units contained dark shell midden strata with abundant vertebrate remains, and carbonized botanical remains suggestive of burning and many small post molds (Thompson et al. 2020a). These small post mold features are likely to be too small to be posts for large structures, so thus are likely to be from drying or smoking racks similar to those found in Peru (Sandweiss 1993; Thompson et al. 2018b). Previous Bayesian modeling estimates the start of this midden accumulation at *cal. AD 1025 – 1120 (68% probability)* and the end for midden accumulation in this area at *cal. AD 1115 – 1155 (68% probability)* (Thompson et al. 2020a).

Operation N, Unit N-3: Operation N unit N-3 was excavated on the ridgeline northeast of the West Court (Figure 3.2). These strata were more sediment-rich and contained no post mold features but did contain whole and fragmented shells with abundant vertebrate remains and artifacts. Previous Bayesian modeling estimates the deposits used here to date to between *cal. AD 1155 – 1205 (68% probability)* and *cal. AD 1295 – 1395 (68% probability)* overlapping with the date ranges for the construction and use of the West Court (Thompson et al. 2020a).

Operation O: Operation O units were excavated to target the West Court’s eastern berm (Figure 3.2). The upper levels of this unit were comprised mainly of non-shell sediments of fine sands and few vertebrate remains. These deposits graded into higher concentrations of fragmentary shell with little sediment to nearly whole shell below the water table. Based on the orientation of the shell in these deposits that extends to below the water table, it is likely these deposits were dumped and piled for the construction of the berm (Thompson et al., 2020a). Based on analyses of several different Bayesian chronological models for these deposits using dates from this deposit and dates from an associated geological core, it seems that the deposits used to construct the berm were from both contemporary and slightly older midden, a pattern seen in other deposits at the site (Thompson et al. 2016; Thompson et al. 2020a). Below these deposits, which are below the water table, exists an intact shell midden deposit with preserved wood debitage, cordage, and *Cucurbita* sp. gourd/squash seeds (Thompson et al. 2020a). Previous Bayesian modeling for these dates estimates the start of this pre-watercourt midden at *cal. AD 1285 – 1305 (68% probability)* and estimates the end of berm construction at *cal. AD 1385 – 1405 (68% probability)* (Thompson et al. 2020a).

Radiocarbon Dating and Oxygen Isotope Analysis

To evaluate changing local environmental conditions at critical junctures during the occupational history of Mound Key, a series of new radiocarbon dates and stable oxygen isotopic measurements were obtained from the temporally sensitive growth profiles of three hard clam (*Mercenaria campechiensis*) shells. While many radiocarbon dates have been obtained at Mound Key to evaluate the timing and temporality of occupation at the site (see Thompson et al. 2016, Thompson et al. 2018b, Thompson et al. 2020a), the use of older midden for construction material combined with high taphonomic preservation of hard clams required additional radiocarbon dates to situate the isotopic measurements in time securely. Thus, an additional nine AMS radiocarbon dates, three dates from each clam shell, were collected from clams also suitable for stable isotopic analyses (Table 3.1). These dates were calibrated and modeled via Bayesian statistical analysis, which uses radiocarbon dates and archaeological data to provide

Table 3.1. Radiocarbon dates from *Mercenaria campechiensis* shells sampled for stable oxygen isotope analyses used in these analyses. Dates calibrated and modelled using the Marine20 curve in OxCal version 4.4.1. Delta R reservoir correction (-44, ±49) calculated via methods detailed in Hadden and Schwadron (2019) and recalculated using the Marine20 curve (Hadden, personal communication).

Site	**Unit**	**Level**	**Species**	**RC Sample ID**	**UGAMS**	**δ^{13}C,‰**	**^{14}C age years, BP**	**±**	**pMC**	**±**	***Modelled Date Range***	
											68% probability	*98% probability*
8LL2	L-1	7	*Mercenaria campechiensis*	8LL2L170332SHE2A	45666	-0.25	1240	20	85.71	0.22	*1185 - 1300*	*1100 - 1340*
8LL2	L-1	7	*Mercenaria campechiensis*	8LL2L170332SHE2B	45667	-0.54	1240	20	85.71	0.22	*1175 - 1290*	*1090 - 1330*
8LL2	L-1	7	*Mercenaria campechiensis*	8LL2L170332SHE2C	45668	-0.58	1300	20	85.07	0.21	*1165 - 1280*	*1080 - 1320*
8LL2	O-1	85	*Mercenaria campechiensis*	8LL2O1851006SHEA	45669	-0.10	1120	20	86.96	0.22	*1265 - 1370*	*1205 - 1420*
8LL2	O-1	85	*Mercenaria campechiensis*	8LL2O1851006SHEB	45670	-1.53	1160	20	86.54	0.22	*1255 - 1360*	*1195 - 1410*
8LL2	O-1	85	*Mercenaria campechiensis*	8LL2O1851006SHEC	45671	0.02	1220	20	85.90	0.22	*1245 - 1350*	*1185 - 1400*
8LL2	N-3	75	*Mercenaria campechiensis*	8LL2N3751661SHE3A	45672	-0.16	1110	20	87.03	0.22	*1345 - 1445*	*1280 - 1475*
8LL2	N-3	75	*Mercenaria campechiensis*	8LL2N3751661SHE3A	45673	-0.26	1160	20	86.59	0.22	*1335 - 1435*	*1270 - 1465*
8LL2	N-3	75	*Mercenaria campechiensis*	8LL2N3751661SHE3A	45674	-0.02	1140	20	86.79	0.22	*1325 - 1425*	*1260 - 1425*

better evaluations of chronologies by enabling high-resolution date estimates (Bayliss et al. 2007; Bayliss 2009). This method avoids overestimation of time and establishes temporal trends for the activity or locale in question. The posterior density estimates from the OxCal output are presented in calendar years and *italics* as probability ranges at the 68% confidence interval with endpoints rounded outward to the nearest five years. Because the posterior estimates are produced through modeling, they are not absolute. However, they are interpretive estimates that hold the flexibility to change as more data become available. OxCal code is included as Supplemental Material A.

Only whole and complete left valves, which had no damage to any portion of the shell along the axis of maximum growth and were void of any epibiont activity, were selected to ensure complete growth profiles for analysis. Once selected, each shell was bisected along the axis of maximum growth using a table saw to create two thick sections, each from the opposite side of the cut. The thick sections were then mounted to glass slides using Crystalbond^{TM} thermal adhesive. No adhesive was included on the sections of the shell that were sampled. Using a Dremel, three radiocarbon samples were drilled from the prismatic (outer) microstructural layer of each shell: one sample was obtained from the most recent shell growth, one sample was obtained from approximately half-way through the organism's lifespan, and the last sample was selected from the earliest stages of shell growth. This methodology follows Kennett and Culleton (2012).

The dates were then incorporated into a Bayesian model using OxCal 4.4.1 with the Marine20 curve (Heaton et al. 2020) and a local marine reservoir correction of -44 ±49 (see Table 3.1). The *D_Sequence* command in OxCal v. 4.4.1 (Bronk Ramsey 2001) with Marine curve data from Heaton et al. (2020) was used for each separate shell to evaluate dates with known age separations (based on counted growth bands) between the dated samples from each shell. However, due to the error range in radiocarbon dates, usually plus/minus 20 years, and an average lifespan of 15 to 20 years for hard clam a standard age of separation of 10 years was used in the *D_Sequences* of the Bayesian model. The provides for the maximum accountability for the lifespan of the organism while maintaining model sensitivity. The three individual *D_Sequence* models were then ordered within a larger *Sequence* based on the previously dated proveniences from which they were pulled. This model provides the temporal framework for the stable oxygen isotope analyses.

Using stable oxygen isotopes from hard clam to elucidate past environmental conditions is limited by the chronological control over the deposits from which they were recovered. The absence of secure chronological control, the taphonomic durability of hard clams, and the extended use life of these organisms as tools make it difficult to confidently associate the isotopic samples acquired from hard clam to the time period in question without also acquiring radiocarbon dates directly from the organisms themselves. However, the uncertainty around the source of carbon used by mollusks to create their shell material, known as both the marine and hard water reservoir effects, often hinders our ability to obtain reliable dates on shell carbonate. The ^{14}C composition of the global ocean reservoir (*R*) lags behind the atmosphere by roughly 400 years. Local reservoirs, as influenced by other factors created local offsets resulting in a unique signature influenced by the combined effects of ocean circulation patterns, upwelling, dissolved inorganic carbon in freshwater, and biological processes (Stuiver et al. 1986; Stuiver and Reimer 1993; Stuiver et al. 1998). By acquiring three dates and modelling these dates with Bayesian statistics, we more reliably situate the isotopic measures in time. While the date ranges produced by the model suggest coarser-resolution when compared to the probability distribution of a single radiocarbon date, the method of using three dates here addresses the temporality of the lifespan of the organism rather than addressing a single probability for the death of the organism (Kennett and Culleton 2012).

Hard clams, like oysters, precipitate their shells near the oxygen isotopic equilibrium with the ambient conditions of growth, with the composition and temperature of the water acting as the controlling factor on oxygen isotope fractionation between shell growth and environment (Elliot et al. 2003; Jones and Quitmeyer 1996; Surge and Walker 2006; Surge et al. 2008). Since water temperature and the isotopic composition of the shell material displays an inverse relationship, the analysis of the oxygen isotopic composition of shell can provide data that correlates with past changes environmental conditions. The oxygen isotopic composition of water, which is a function of evaporation rates, precipitation patters, and rates of terrestrial run-off, positively correlates with the oxygen isotopic composition of shells (Bemis and Geary 1996; Dansgaard 1964; Eagle et al. 2013; Grossman and Ku 1986; Shackleton 1969). Evaporation and increased input of marine waters not only increase salinity but also increase the oxygen isotopic composition of the water. This project recognizes that multiple variables, such as temperature, rainfall patterns, freshwater input, etc., contribute to the oxygen isotopic signatures recovered from marine shell. However, the data provided from such analyses still supply meaningful tools to interpret past environmental conditions.

Hard clams (*Mercenaria campechiensis*) are sessile bivalves that inhabit the estuarine and marine waters of southwest Florida. Water temperature and salinity limit shell growth at or below 9 C or above 31 C, or below 17 ppt (Ansell 1968; Grizzle et al. 2001; Kraeuter and Castagna 2001). In the warm, subtropical waters of southwestern Florida, this means the time during which hard clam shells may slow growth is during the dry summer months (Arnold et al. 1998; Elliot et al. 2003; Jones and Quitmeyer 1996; Surge and Walker 2006; Surge et al. 2008). Previous studies across the Pine Island Sound to the north of Mound Key demonstrate the modern $\delta^{18}O_{water}$ values vary inter-annually between wet and dry seasons between -1‰ and +1‰ (VSMOW), respectively but do not necessarily vary by the same magnitude from year to year which makes it challenging to estimate temperature. However, we can assume a $\delta^{18}O_{water}$ of +1per mil (VSMOW) providing a mechanism with which to evaluate winter temperatures while only overestimating summer temperatures slightly. The amount of error in estimating summer temperature is dependent upon the input of freshwater as influenced by varying precipitation patterns. However, we can use the most negative $\delta^{18}O_{shell}$ values to infer variability in summer $\delta^{18}O_{water}$ values (see Surge and Walker 2005). This is possible because winter temperature varies year to year within 1.7°C, and summer varies less at 0.6°C (Surge and Walker 2005). We use published modern $\delta^{18}O_{water}$ values and summer $\delta^{18}O_{shell}$ values to compare the archaeological shells analyzed here (Surge and Walker 2005; Wang et al. 2011).

Thus, to evaluate local paleoenvironmental conditions, the three dated hard clam shells were also sampled for stable oxygen isotope analysis. As such, all of the isotopic data are firmly bracketed temporally by high-resolution chronological modeling. Of the two thick sections made for each shell, the second one was used to collect the needed carbonate samples. We sampled across the thick section by drilling with a table-top, mechanical micromill fitted with a Brasseler round carbide dental drill bit following ontogenetic growth. We focused on sampling the inner cross-lamellar (middle) microstructural layers sequentially from the most recent growth band until sampling could no longer be isolated to the inner growth bands. Sampling targeted to produce more than 100µg of carbonate powder for each sample. All samples were weighed and loaded into 4.5-ml borosilicate vials. Fifty carbonate shell samples were collected from two of the shells, and 51 were collected from the third to total 151 samples for stable oxygen isotope analysis. All samples were submitted to the Center for Applied Isotope Studies at the University of Georgia, where all samples were analyzed for both $\delta^{13}C$ and $\delta^{18}O$. All samples are reported in per mil units (‰) relative to the Vienna Pee Dee Belemnite (VPDB) standard (Supplemental Material B).

Zooarchaeology

All zooarchaeological samples used in this study were collected and screened on-site using ¼-inch mesh. The assemblage presented here is identified to the lowest possible taxon using the comparative collections in the Zooarchaeology Laboratory at the University of Georgia Museum of Natural History and the Florida Museum of Natural History. For this study, we used the following quantitative measurements to assess the vertebrate remains: number of identifiable specimens (NISP), Minimum Number of Individuals (MNI), and bone weight (Reitz and Wing 2008). We rely on estimations of MNI for comparison and discussion, so a brief discussion of the benefits and limitations of MNI follows. The species identified here are also summarized into faunal categories based on vertebrate class, which include Sharks and Rays, Bony Fishes, Turtles, Alligator, Wild Birds, Deer, and Other Wild Mammals which includes cottontail rabbit and cotton rat. Using the established Bayesian chronology and depositional histories of these deposits, 23 sampled contexts were chosen to target the timeframe from AD 1000 – 1450. These samples include Levels 72 through 74 from Unit N-3, Levels 91 through 98 from Operation O, and Levels 83 through 88 from Operation N.

MNI or the minimum number of individuals was estimated by pairing elements and separating individuals by age structure and size classes when possible at the lowest possible taxonomic level, usually for species using the maximum distinction method (Grayson 1978; Reitz and Wing 2008). However, when specimens could not be identified beyond family or genus, MNI may be estimated at a higher taxonomic level. Although MNI is a standard estimation for zooarchaeological quantification, the measure has several well-known biases, which include emphasizing large over small species and some elements which are more easily identifiable. In addition to these primary biases, screen size and other collection and excavation methods introduce other secondary biases. The use of ¼-inch mesh does not capture the very smallest faunal remains like those small-sized fish from the Clupeidae family but still provides meaningful data with which to examine patterns in vertebrate resource use.

Once the species lists for the samples were created, diversity was estimated via the Shannon-Weaver function, which provides a way to measure species presence and abundance to classify the heterogeneity of a given analytical unit (Reitz and Wing 2008). The diversity indices are first compared between Operations to assess the potential contributions of space as a factor related to diversity. Further, diversity was estimated for successive levels that are securely associated with radiocarbon dates which facilitates a more nuanced understanding of the subsistence practices as they relate to the stable isotopic measurements (described below) and radiocarbon dates reported here. In addition to diversity, equitability for each operation, as well as the dated levels, was measured. Values closer to 1.0 indicate an even distribution of taxa, and lower values suggest the dominance of one or a few taxa (Reitz and Wing 2008).

Results

Radiocarbon Dating

The model for the radiocarbon chronology of the hard clam shells shows good overall agreement between the ^{14}C dates and the model assumptions (A_{model} =166.6; $A_{overall}$=121.6) (Figure 3.3). The model estimates the time range for the earliest shell (sample ID 8LL2L170332SHE2S1) to be *cal AD 1185 – 1300*, the time range for the second shell (sample ID 8LL2O1851006SHES1) to be *cal AD 1265 – 1370*, and the time range for the third shell (sample ID 8LL2N3751661SHE3S1) to be *cal AD 1345 – 1445*. One of the dates, UGAMS-45669, was marked as an outlier in the model and thus was not included in the statistical calculations of the model. This was likely due to the sensitivity of the model out weighting the probability range of the radiocarbon date itself because the date itself fits chronologically but is very similar to the previous date within the shell. In regard to extant global climate events and the timing of activity areas on Mound Key, these shells capture the conditions within the Little Ice Age. This timeframe captures the period during which we have evidence for activity along the shoreline of the West court and coeval use of the watercourts as pens to generate and hold surplus

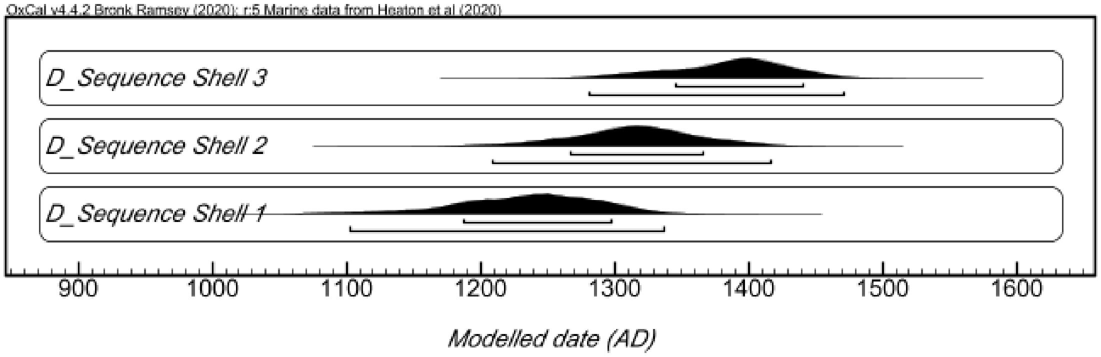


Figure 3.3. Bayesian model of clam shell dates from which samples for stable oxygen isotope analysis were extracted. Code provided as Appendix E.

resources. It also captures the period during which the second and third phases of construction of the king's house occur.

Stable Oxygen Isotope Analysis

The profiles of the three shells demonstrate each having temporal variation in $\delta^{18}O_{shell}$ values that follow a quasi-sinusoidal trend. Due to the age of the shells selected and the wide diameter of the drill bit used to acquire the needed sample volume, the sinusoidal nature of the samples closest to the growing edge reduce in amplitude likely due to decreased growing with increasing age which has been recorded elsewhere (Stecher III et al. 1996; Walker and Surge 2006). Values range from 1.9‰ to -1.6‰, 1.3‰ to -1.7‰, and 1.2‰ to -2.2‰. All three archaeological shells record more positive values than the modern shells which have an average summer $\delta^{18}O$ value of -2.4‰ +- 0.2‰ (Figure 3.4). However, when the shells are arranged in chronological order, they demonstrate a trend in more negative $\delta^{18}O$ values, with the last shell recording the most negative values.

The isotopic signatures of the shells analyzed here display more negative summer values over time, a trend which somewhat contradicts the global signature of the Little Ice Age. In the subtropics of southwestern Florida, the $\delta^{18}O_{shell}$ values correspond most closely to $\delta^{18}O_{water}$ values as temperature has little influence on summer $\delta^{18}O_{shell}$ values with the low interannual variability in summer temperatures (Wang et al. 2013). The $\delta^{18}O_{water}$ values are influenced by the amount of freshwater in the systems as influenced by mechanisms such as changing sea levels, changing precipitation rates, and the amount of other freshwater input into the estuarine system. Seasonal trends in patterns of salinity in the nearby Charlotte Harbor suggest the onset of the summer rainy season results in a decrease of estuarine salinity and thus more negative $\delta^{18}O_{water}$ values (Walker and Surge

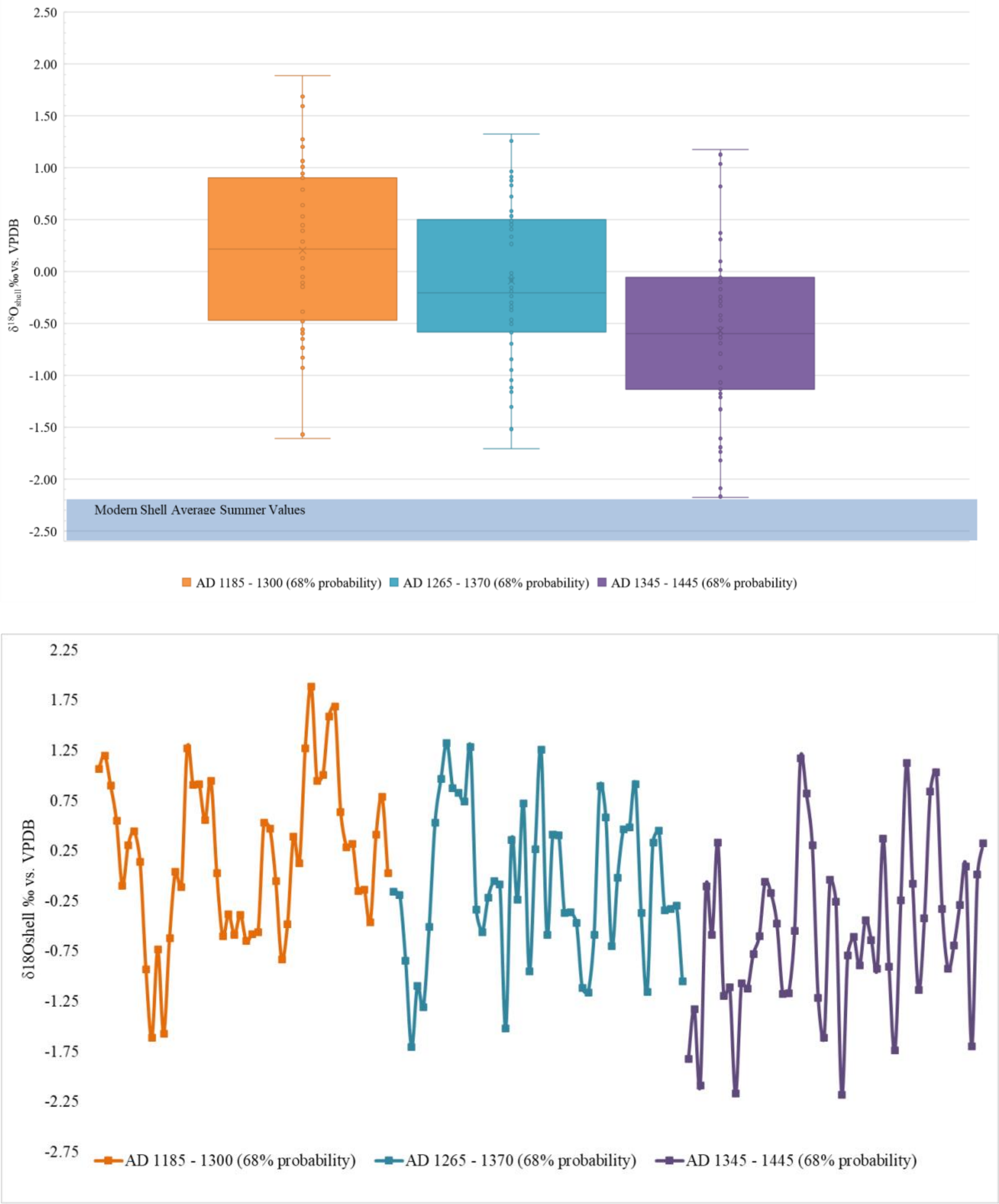


Figure 3.4. *Mercenaria campechiensis* stable oxygen isotope measurements reported as $\delta^{18}O_{shell}$ vs. VPDB (‰). A) Box plot of all measurements for each shell including the modern shell averages for summer values used from Walker and Surge (2006). B) Isotopic measurements displayed as sampled through ontogeny. Isotopic measurements provided as Appendix F.

2006). In contrast to Lund and Curry (2004) but in conjunction with Walker and Surge (2006), the data presented here likely suggest lowering salinities as a product in increased freshwater input within Estero Bay during the 14th and 15th centuries AD.

Zooarchaeological Analysis

The four areas of the site used for analysis here produced a total of 4,164 vertebrate bones and bone fragments (NISP identified to at least Class) with a vertebrate MNI of 459 (Tables 3.2 and 3.3). Specimens were identified to a total of 122 taxa. Most of the vertebrate remains are from bony fishes, which represent approximately 80% of the total assemblage with an MNI of 380. (Table 3.4). The distribution of the taxa represented among the different areas of the site is relatively homogenous with bony fish dominating each sample. The greatest species richness comes from Units N-2 and O-2. More specifically, catfish (both *Ariopsis felis* and *Bagre marinus*), toadfish (*Opsanus* spp.), mullet (*Mugil* spp.), sheepshead (*Archosargus probatocephalus*), and burrfish (*Chilomycterus schoepfi* and *Diodon* spp.) are the most abundant fishes in terms of MNI. Sharks and rays are the second most abundant taxa, while deer (*Odocoileus virginianus*) and other wild mammal specimens remain low throughout the assemblage consisting of only 6 and 8 MNI, respectively.

The distribution of vertebrate remains is not stratigraphically consistent. Units O-2 and N-1 display similar patterns in the presence and abundance of vertebrate remains. The radiocarbon dates from Unit O-2 and previous interpretations of this locale suggest the redeposition of older midden to separate the watercourt from the canal by building up a berm (Thompson et al. 2020a). The zooarchaeological samples from this unit demonstrate low amounts of vertebrate remains and low species richness within the levels

Table 3.2. Vertebrate Species list for Zooarchaeological Assemblage from Operation N. Screened to ¼”.

		N-1				**N-2**				**N-3**			
Taxon	**Common Name**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**
Chondrichthyes	Cartilaginous fishes	31	10	11.2	11.26	83			20.26	26	5	8.2	6.04
Ginglymostoma cirratum	Nurse Shark					7	4	1.9	0.34				
Negaprion brevirostris	Lemon Shark					1	1	0.5	0.08				
Carcharhinus isodon	Finetooth Shark					1	1	0.5	0.08				
Rajiformes	Rays, skates					6	2	0.9	1.45				
Myliobatidae	Eagle rays					4	3	1.4	0.94				
UID Actinopterygii	Indeterminate bony fishes	466		0.0	43.45	939			67.81	415			34.15
Acipenser oxyrinchus	Atlantic Sturgeon					1	1	0.5	0.03				
Albula vulpes	Bonefish					4	1	0.5	0.11				
Lepisosteus spp.	Gar	1	1	1.1	0.27					2	2	3.3	0.63
Siluriformes	Catfish	2		0.0	0.09	16			0.98	35			2.74
Ariidae	Sea catfish	32	14	15.7	11.66	43			11.9	54			11.06
Ariopsis felis	Hardhead catfish	43		0.0	4.82	69	12	5.6	6.2	95	10	16.4	5
Bagre marinus	Gafftopsail catfish	11		0.0	1.56	11	3	1.4	1.48	19	4	6.6	1.63
Opsanus spp.	Toadfish	13	5	5.6	1.74	56	11	5.1	7.41	4	2	3.3	0.32
Mugil spp.	Mullet	33	7	7.9	4.32	37	7	3.3	2.29	47	8	13.1	9.15
Tylosurus crocodilus	Houndfish									1	1	1.6	0.06
Belonidae	Needlefishes					4	1	0.5	0.2				
Serranidae	Sea basses and grouper	1	1	1.1	0.07	1	1	0.5	0.15				
Carangidae	Jacks					9			0.44	5	2	3.3	0.28
Caranx spp.	Jacks, trevallies, and kingfishes					2	1	0.5	1.03				
Lutjanidae	Snapper					3	1	0.5	0.16	2	2	3.3	0.34
Sparidae	Sea breams and porgies	4		0.0	0.37	4			0.27	4			0.3
Archosargus probatocephalus	Sheepshead	26	11	12.4	9.52	42	11	5.1	13.86	22	8	13.1	6.05
Sciaenidae	Drum fishes					4			0.61	3			0.68
Cynoscion spp.	Seatrout					2	2	0.9	0.43				
Cynoscion nebulosus	Spotted seatrout					2	2	0.9	0.62				

Cynoscion nothus	Silver Seatrout									1	1	1.6	0.05
Pogonias cromis	Black drum	3	3	3.4	12.55	3	2	0.9	1.75	2	1	1.6	1.14
Sciaenops ocellatus	Red drum	1	1	1.1	0.13	5	4	1.9	1.65	2	2	3.3	2
Chilomycterus schoepfi	Striped burrfish	33	20	22.5	7.12	91	60	28.0	17.72	1	1	1.6	0.21
Diodon spp.	Porcupinefish	8	7	7.9	1.68	92	73	34.1	16.65	3	3	4.9	0.7
Diodontidae	Burrfishes and porcupine fishes	7		0.0	0.25	48			1.32				
Tetraodontidae	Pufferfish	1	1	1.1	0.21	5	3	1.4	0.2	1	1	1.6	0.16
Reptilia	Reptiles									1	1	1.6	0.13
UID Testudines	Indeterminate turtles	9	5	5.6	3.44	6			3.87	4	2	3.3	2.14
Malaclemys terrapin	Diamondback terrapin					2	2	0.9	0.65				
Cheloniidae	Sea turtles					1	1	0.5	1.15				
Serpentes	Snakes	1	1	1.1	0.01								
Lacertilia	Lizards					1	1	0.5	0.2				
Aves	Bird	1		0.0	0.26	7	2	0.9	0.78	13			0.83
Gavia immer	Common loon	2	1	1.1	0.65								
Anatidae	Ducks and Geese									1	1	1.6	0.52
Laridae	Gulls and terns									4	2	3.3	0.64
Mammalia	Mammals	3		0.0	7.77	20			17.43	10			13.52
Silvilagus sp.	Cottontail Rabbit	1	1	1.1	0.48								
Sigmodon hispidus	Cotton rat									2	1	1.6	0.09
Odocoileus virginianus	Whitetail deer					1	1	0.5	6.34	1	1	1.6	8.51
Vertebrata	Vertebrate				12.7				14.79				9.78
Total		733	89	100	136.38	1633	214	100	223.63	780	61	100	118.85

Table 3.3. Vertebrate Species list for Zooarchaeological Assemblage from Operations O and P. Screened to ¼".

		O-1				O-2				O-3				P-1			
Taxon	**Common Name**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**	**NISP**	**MNI**	**% MNI**	**WEIGHT (g)**
Chondrichthyes	Cartilaginous fishes	4	2	11.8	4.12	10			4.36					2	1	14.3	1.97
Rajiformes	Rays, skates					2	2	2.9	0.47								
Myliobatidae	Eagle rays					1	1	1.4	0.99								
UID Actinopterygii	Indeterminate bony fishes	12			5.68	479			44.53					12			10.4
Amia calva	Bowfin					1	1	1.4	0.1								
Lepisosteus spp.	Gar					1	1	1.4	0.12								
Siluriformes	Catfish					15			0.7								
Ariidae	Sea catfish					26			6.33								
Ariopsis felis	Hardhead catfish	4	2	11.8	0.29	43	9	12.9	6.65								
Bagre marinus	Gafftopsail catfish					2	1	1.4	0.27								
Opsanus spp.	Toadfish					1	1	1.4	0.12								
Mugil spp.	Mullet	14	2	11.8	1.74	52	9	12.9	9.42					1	1	14.3	0.18
Centropomus undecimalis	Common snook					2	1	1.4	1.86								
Mycteroperca sp.	Grouper					1	1	1.4	0.31								
Carangidae	Jacks					3	1	1.4	1.03								
Lutjanidae	Snapper					1	1	1.4	0.16								
Sparidae	Sea breams and porgies					3			0.2								
Archosargus probatocephalus	Sheepshead	4	3	17.6	1.71	25	6	8.6	8.86								
Sciaenidae	Drum fishes	3	2	11.8	1.07	10			3.27								
Cynoscion spp.	Seatrout					1	1	1.4	0.17								
Cynoscion nebulosus	Spotted seatrout					7	3	4.3	2.46								
Micropogonias undulatus	Atlantic croaker					1	1	1.4	0.59								
Pogonias cromis	Black drum					8	3	4.3	18.14					4	1	14.3	9.31
Sciaenops ocellatus	Red drum					19	8	11.4	7.93								
Scarus sp.	Parrotfish					1	1	1.4	0.03								
Chilomycterus schoepfi	Striped burrfish	1	1	5.9	0.39	4	3	4.3	0.58								
Diodontidae	Burr and porcupine fish					1			0.8								

Lagocephalus laevigatus	Smooth Pufferfish					1	1	1.4	0.6								
Reptilia	Reptiles					2			0.71								
Alligator mississippiensis	Alligator					1	1	1.4	0.22								
UID Testudines	Indeterminate turtles	2	2	11.8	1.77	8			3.18								
Trachemys sp./*Pseudemys* sp.	Sliders, cooters					1	1	1.4	4.7								
Malaclemys terrapin	Diamondback terrapin					12	1	1.4	4.97								
Cheloniidae	Sea turtles													1	1	14.3	2.62
Colubridae	Non-venomous snakes									1	1	100.0	0.03				
Aves	Bird	6			2.22	152			12.87								
Cathartes aura	Turkey vulture	3	2	11.8	1.38	11	3	4.3	5.9								
Laridae	Gulls and terns					2	2	2.9	0.79								
Corvidae	Crows					1	1	1.4	0.59								
Mammalia	Mammals	1			0.83	13	5	7.1	14.33					13			4.21
Odocoileus virginianus	Whitetail deer	1	1	5.9	22.19									5	3	42.9	43.25
Vertebrata	Vertebrate				7.47				16.51								3.54
Total		55	17	100	50.86	924	70	100	185.82	1	1	100	0.03	38	7	100	75.48

Table 3.4. Mound Key (8LL2) Operations N, O, and P Summary Table

	Operation N											
Taxa	N-3				N-1				N-2			
	NISP	**MNI**	**% MNI**	**Weight**	**NISP**	**MNI**	**% MNI**	**Weight**	**NISP**	**MNI**	**% MNI**	**Weight**
Sharks and Rays	26	5	8.20	6.04	31	10	11.24	11.26	102	11	5.14	23.15
Bony Fishes	718	48	78.69	76.65	685	71	79.78	99.81	1493	196	91.59	155.27
Turtles	4	2	3.28	2.14	9	5	5.62	3.44	9	3	1.40	5.67
Other Reptiles	1	1	1.64	0.13	1	1	1.12	0.01	1	1	0.47	0.20
Wild Birds	18	3	4.92	1.99	3	1	1.12	0.91	7	2	0.93	0.78
Deer	1	1	1.64	8.51	0	0	0.00	0.00	1	1	0.47	6.34
Other Wild Mammal	12	1	1.64	13.61	4	1	1.12	8.25	20	0	0.00	17.43
Total	780	61	100	109.07	733	89	100	123.68	1633	214	100	208.84

	Operation O								Operation P			
Taxa	O-1				O-2				P-1			
	NISP	**MNI**	**% MNI**	**Weight**	**NISP**	**MNI**	**% MNI**	**Weight**	**NISP**	**MNI**	**% MNI**	**Weight**
Sharks and Rays	4	2	11.11	4.12	13	3	4.35	5.82	2	1	14.29	1.97
Bony Fishes	38	10	55.56	10.88	708	53	76.81	115.23	17	2	28.57	19.89
Turtles	2	2	11.11	1.77	21	2	2.90	12.85	1	1	14.29	2.62
Other Reptiles			0.00		3	1		0.93				
Wild Birds	9	2	11.11	3.60	166	6	8.70	20.15	0	0	0.00	0.00
Deer	1	1	5.56	22.19	0	0	0.00	0.00	5	3	42.86	43.25
Other Wild Mammal	1	1	5.56	0.30	13	5	7.25	14.33	13	0	0.00	0.00
Total	55	18	100	42.86	924	70	100	169.31	38	7	100	67.73

Taxa	Total			
	NISP	**MNI**	**% MNI**	**Weight**
Sharks and Rays	178	32	7.0	52.36
Bony Fishes	3659	380	82.8	477.73
Turtles	46	15	3.3	28.49
Other Reptiles	6	4	0.9	1.27
Wild Birds	203	14	3.1	27.43
Deer	8	6	1.3	80.29
Other Wild Mammal	63	8	1.7	53.92
Total	4163	459	100	721.49

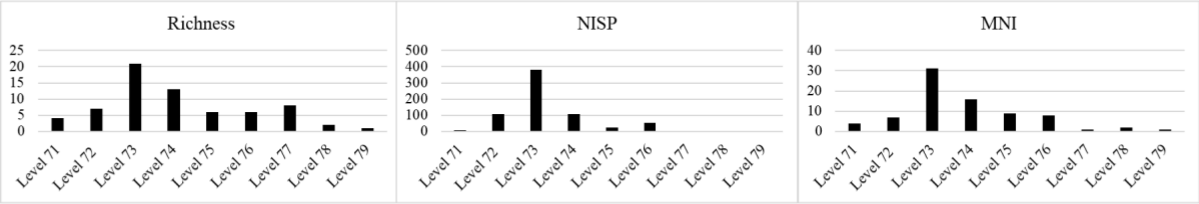
thought to be construction material. Moving lower from Level 97 to Level 98, the NISP of vertebrate remains, and species richness drastically increase from 8 to 147 and 2 to 16 respectively. The midden present in Level 98 through Level 100 represents a pre-watercourt midden. The NISP of vertebrate remains increases above Level 91 to a combined total of 396 for the next 4 levels. Unit N-1 displays a drop-off in the species richness and NISP starting in Level 88 (Figure 3.5).

The samples that represent the targeted timeframe for the area directly northwest of the watercourt as represented by Operation N Levels 84 through 88 demonstrate an increase in diversity through time (Figure 3.6). For the Operation O samples as represented by Levels 91 through 98, only diversity from Level 98 was assessed due to the lack of faunal material recovered from Levels 97 through 91 (Figure 3.6). If these deposits are a product of construction efforts to build up the berm, enclosing the watercourts, this pattern of minimal faunal fits with this interpretation. Unit N-3 also displays an increase in diversity through time.

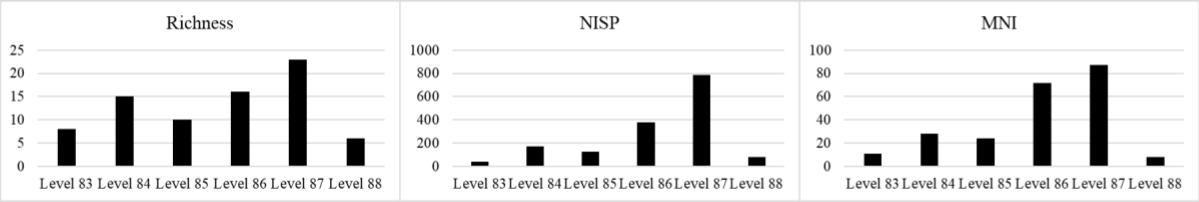
Discussion

Bayesian modeling of radiocarbon dates places the earliest clam shell, *cal. AD 1185 - 1300*, during the onset of the Little Ice Age and the Sanibel Low sea level record beginning at AD 1200 (Figure 3.7). This period is characterized by environmental conditions of relatively cooler temperatures and decreased precipitation rates with periods of high climatic variability. The $\delta^{18}O$ values of this shell display summer $\delta^{18}O$ values indicating drier conditions than those of today. The high species richness and species composition of the zooarchaeological samples here suggests procurement from a wide range of estuarine and marine habitats. The pre-watercourt deposits represented by the

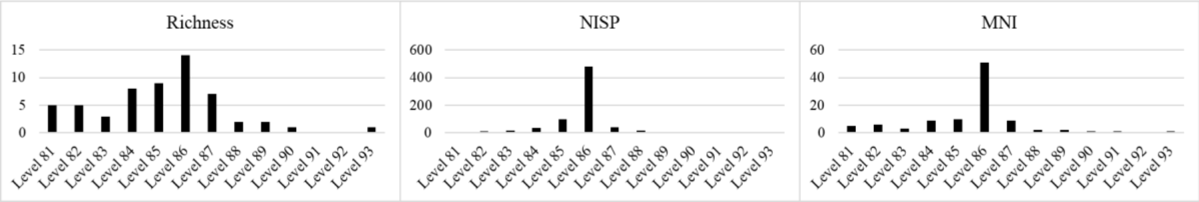
N-3



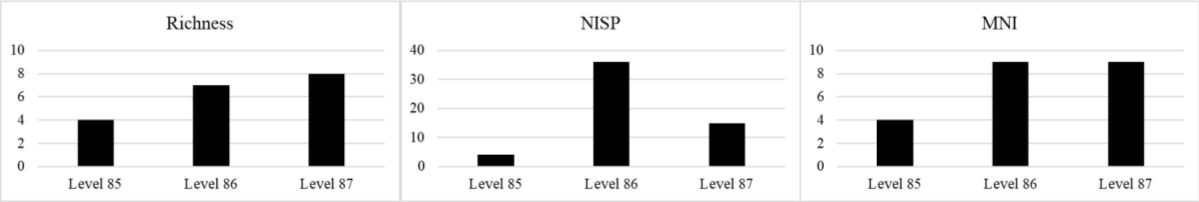
N-2



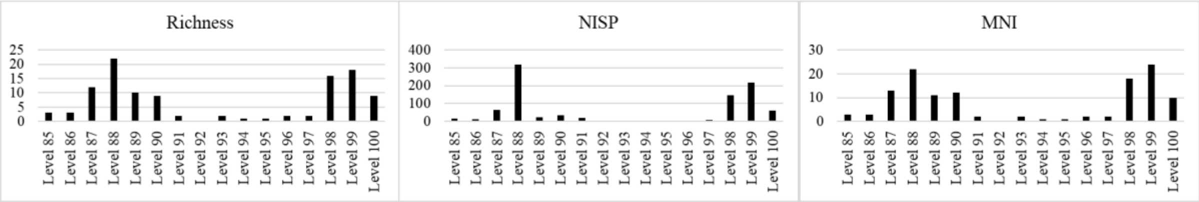
N-1



O-1



O-2



P-1

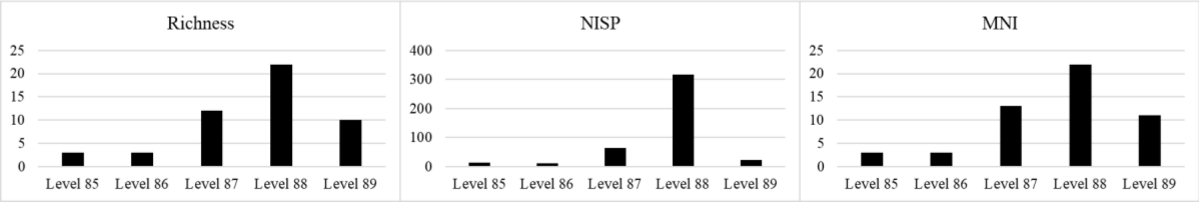


Figure 3.5. Changes in species richness, NISP, and estimations of MNI of the vertebrate and invertebrate assemblage from Mound Key (8LL2), Operations N, O, and P. Unit O-3 had only a single snake vertebrae and so is not displayed here.

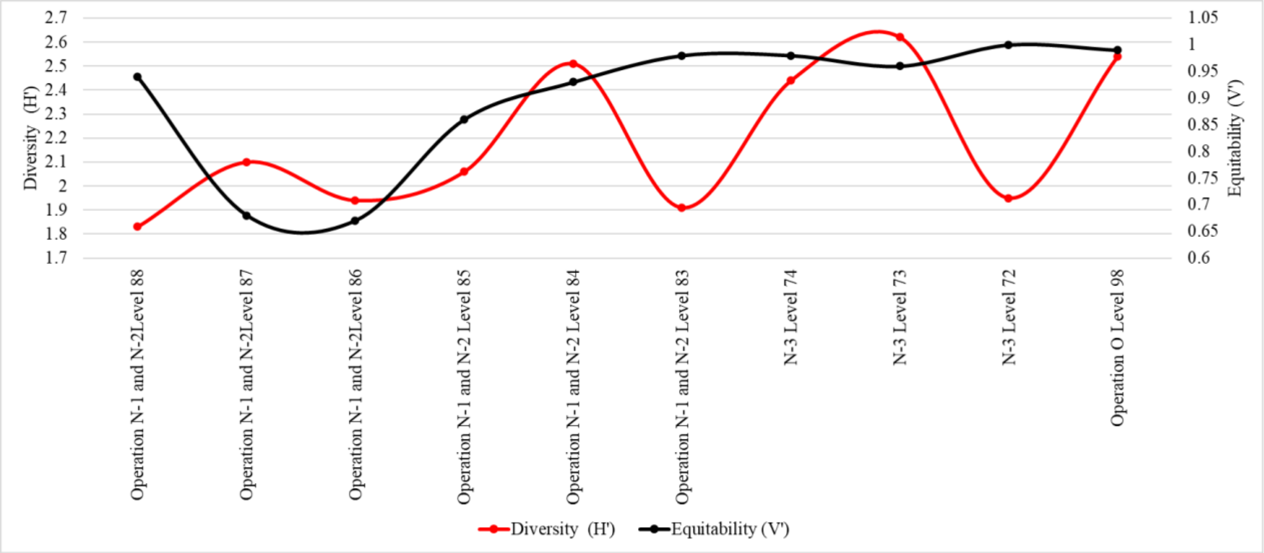


Figure 3.6. Change in estimations of diversity and equitability of vertebrate assemblages from Mound Key, Operations N and O

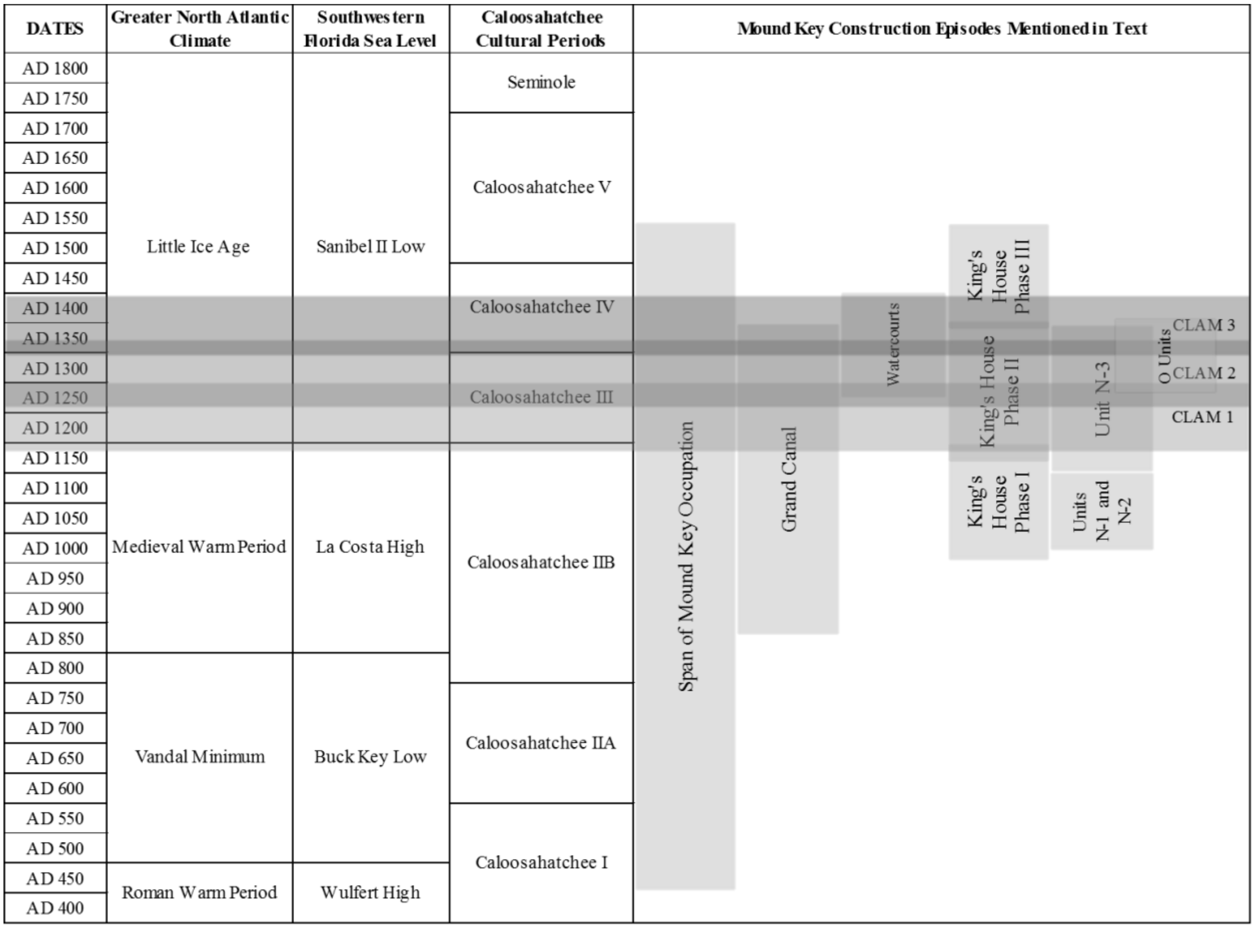


Figure 3.7. Generalized Mound Key chronology for extant global climatic periods and site components mentioned in text.

lower levels of Unit O-2 suggest a heavy reliance on bony fishes form a wide range of estuarine and marine habitats. This clam shell record correlates with the occupation as recorded in the stratigraphy in Units N-3 and pre-watercourt midden of O-2. This is also the time during which the second phase of construction of the "king's house" on Mound 1 occurs (Thompson et al. 2016; Thompson et al. 2018a). The shell isotope records that date from *cal AD 1265 – 1370* and *cal. AD 1345 – 1445* continue to record conditions during the middle of the Little Ice Age and capture the time frame during which the king's house goes into its final phase of construction, and the construction of the watercourts commences and ceases (Thompson et al. 2016; Thompson et al. 2018b; Thompson et al. 2020a) (Figure 3.7). The trends in summer isotopic values recorded in these shells demonstrate values trending more negative overall indicating increased precipitation during the rainy seasons and warmer winters compared to the isotopic values from the previous shell. The isotopic trends suggest a period only mildly impacted, at least as indicated by these estuatine shells, by the Little Ice Age global climatic episode in southwestern Florida. Overall, the archaeological shells record colder summer temperatures than modern shell values, representing drier summers than today. However, overall, the isotopic values trend more negative overtime representing a shift in environmental conditions to wetter summers, contradicting overall global signatures. It could be that this record is in the estuaries differs from that of species that spend part of their life in more offshore habitats (see Surge et al. 2005). It could be that these shells are capturing some of the intra-Little Ice Age warming trends.

During the time that the shells presented here record environmental conditions, the deposits from Levels 73 and 74 of Unit N-3 suggests a heavy reliance on bony fishes from a wide range of estuarine and marine habitats, suggestive of a productive local estuarine system which aligns with the isotopic signatures. However, while the majority of faunal remains recovered from the excavations do come from a wide range of estuarine and marine conditions, the consistent reliance on a few fishes warrants further discussion. Sea catfishes, sheepshead, mullet, gulf toadfish, and burrfishes make up the largest portion of the MNI percentages of not just bony fishes but of all taxa identified in this assemblage. These fishes have high tolerances for a range of salinities, and most can tolerate waters in low dissolved oxygen and live among the seagrasses and along muddy or sandy bottoms in estuarine waters. Mullet tolerate water salinities ranging from 0 to 75 ppt. Both hardhead and gafftopsail sea catfish, as well as sheepshead, can tolerate a wide range of salinities from the open ocean to almost fresh waters. Overall, the ability of all these fishes to endure varying environmental conditions likely played a large part in their preferential use as live surplus held in the watercourts at Mound Key. Problems of storage and distribution of surplus could have been mediated through the use of such hardy fishes, demonstrating an intimate knowledge of the ecological and biological requirements necessary for the survival of these types of fish in the engineered watercourts.

Of particular interest is the toadfish. They are often found year-round in shallow, Gulf waters along sandy bottoms and in and among seagrass beds (Snyder and Burgess 2016). While they prefer higher salinities, toadfish can tolerate low levels of dissolved oxygen and can even survive out of the water for an extended period. Recent work at the earlier, more northern site of Garden Patch discusses large quantities of toadfish in the mound as linked to seasonal feasting events and their potential cultural significance related to their ability to live out of water for extended periods and the somewhat potential hazards in handling these fish (Hyde and Wallis 2020). As of 2010, only one modern fishery along the Atlantic Coast, Long Island in New York, targets toadfish as their appearance and secretion of an irritating mucus on their skin makes them an unappealing catch (Kritzer and Hughes 2010). In addition to their hardy biologies and tolerance for hostile conditions, toadfish serve as important actors in structuring shellfish populations by decreasing crab-induced mortality of hard clams and lowering mortality of juvenile oysters by feeding on the predators, mainly crabs, of these invertebrates (Grabowski 2004; Kritzer 2005; Raposa and Oviatt 2000). Surrounded by the shallow-waters of Estero Bay, the inhabitants of Mound Key exploited and likely controlled the surrounding oyster reefs of Estero Bay, making the health of these reefs of great importance as evidenced through oyster demographic data (Savarese et al. 2016). It is unclear the exact reason for intensive use of toadfish but it is likely the people of Mound Key understood their role in these local ecosystems.

As we have previously discussed, the impact of the subtropical climate of southwestern Florida on the preservation of surplus resources required alternative methods of storing surplus food stores such as keeping live fish in watercourts, or rather pens used to store and hold live fish (Thompson et al. 2020a). We do not know the specific water quality characteristics of such water features but do understand the hydrological capability of these features to efficiently hold water, even throughout the tidal cycles (Thompson et al. 2020a). Based on the zooarchaeological analyses of fish found in contexts associated with use of the watercourts, we are able to gain insight into the ecological consequences of constructing such features. They are likely most closely related to those of coastal lagoons, essentially acting as a shallow, coastal body of water physically separated from open ocean conditions with a restricted inlet. Decreased exchange with more open waters by both berm restriction and location within the island of Mound Key itself could have limited water circulation and dissolved oxygen content. It could also have increased the nutrient content of these waters (Spaulding 1994). Lagoons provide refuge and can act as a nursery and feeding habitat for a variety of organisms, but because they promote primary production, low flushing rates influenced by limited interaction with ocean waters can lead to excessive primary production and possibly eutrophication (Heck and Thoman 1984; Harris et al. 2004; Phleger 1981; Valiela et al. 1992). While conditions within the watercourts likely never reached levels that lead to eutrophication, they created conditions stressful to the organisms residing in them. By choosing hardy fishes able to survive in less than optimal conditions, we argue the Calusa possessed intimate knowledge of the ecological, hydrological, and biological consequences of using watercourts to create surplus stores of food and thus chose species suited for the habitats they created. Previous work demonstrated extensive knowledge related to architectural engineering within these landscapes through the use of shell and earth, but what is also needed for these types of features to be successful is knowledge of the biological and ecological character of these engineered microenvironments as well as the biological and ecological thresholds for particular species present throughout the Calusa’s watery, estuarine domain. Our previous research demonstrates an intensive use of mullet, but the analysis here broadens the list of species used by the Calusa for intensive surplus production and highlights the varied strategies and sophisticated nature of Calusa surplus production and environmental mediation (Thompson et al. 2020a).

Without the local signatures of environmental conditions provided by the stable isotopes presented here, in contrast to a reliance on generalized global trends, interpretations of the socio-ecological relationships, and the climatic contexts within which they were situated, have the potential to be substantively misinterpreted. Referencing the global characteristics of the Little Ice Age as a time of general cooling and drying would suggest that the sociopolitical and socioeconomic institutions that developed at Mound Key did so during a time of less favorable climatic and environmental conditions, lending a flawed perspective on the environmental factors that would have structured the distribution, abundance, and quality of available marine resources. The localized dataset presented here suggests the opposite, demonstrating instead that local conditions were warmer and wetter than would be expected if drawing on generalized global characteristics of the Little Ice Age. These conditions were not only amenable to the strategies deployed at Mound Key but likely bolstered the development of increasingly complex socioeconomic and sociopolitical institutions. These institutions benefitting from favorable environmental conditions were thus afforded the social, political, and economic capacity to buffer against episodes of climatic uncertainty that were likely occurring during portions of the Little Ice Age not captured in the isotopic record presented here.

Conclusions

The subsistence practices of the Calusa provided a means of supporting a range of complex social and political institutions in the absence of any form of large-scale agricultural production. The Calusa undoubtedly posessed intimate, generational knowledge of the ebbs and flows of ecological change within the estuaries of southwestern Florida. However, creating systems of resource management that could reduce the risks accompanying environmental change resulted in opportunities to invest in complex organizational strategies (Hayden 2009; Thompson et al. 2018a; Thompson et al. 2020a). The construction of the watercourts, sometime between AD 1300 and 1400, occurred during a period of trending warmer and wetter conditions. These changes would have impacted the location of the saltwater wedge and would have changed the location and availability of resources common in these types of estuarine environments. The creation of watercourts, essentially anthropogenically engineered lagoons, to store surplus fish, supported the increasingly centralized power at Mound Key (Thompson et al. 2020a). We have shown that the Calusa leveraged deeply rooted ecological knowledge, specifically through the exploitation of certain species of fish capable of inhabiting conditions within such anthropogenically engineered features to further ensure the success of these watercourts as part of a web of social, political, ecological, and biological systems as supported by an environmentally amenable period.

Generalized models of environmental change insufficiently address changes at a scale necessary for understanding the complexities of coastal hunter-gatherer groups. Additionally, here, we have combined several approaches to understanding the complexities of Calusa subsistence practices in the context of changing environmental conditions during the Little Ice Age at Mound Key. In doing so we are better able to understand the coupled natural and social systems that served as the scaffolding for the development of the complex sociopolitical organization witnessed by Spanish colonizers in the 16th century. By chronologically situating stable oxygen isotope measurements from hard clam via direct, high-resolution dating, we are able to more accurately address the timing of local climatic fluctuations, including more accurate understandings of trends in temperature and precipitation that would have served as key factors in managing socio-ecological systems. This type of analysis is critical to not only articulating the socio-ecological and sociopolitical histories of these groups but providing a way to evaluate archaeological data from climatically sensitive environments more meaningfully.

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CHAPTER 4

TOXIC ECONOMIES: THE USE OF BURRFISHES BY THE CALUSA AT MOUND KEY, FLORIDA, USA[1]

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Abstract

Examinations of the role animals played beyond their contributions to subsistence practices or as indicators of past ecological conditions provide more holistic perspectives on past Indigenous lifeways. Mound Key (8LL2) is a large, anthropogenic, midden-mound island located in Estero Bay. It was the capital of the Calusa at the time of Spanish contact in the 16th century. Recent zooarchaeological investigations identified unique assemblages that contained high numbers of toxic burrfishes (*Diodon* spp. and *Chilomycterus schoepfii*) remains, represented only by their beaks. Many species of burrfishes, including those assessed in this paper, carry tetrodotoxin in various parts of their body, a potentially lethal toxin. In this paper, I identify an unprecedented number of burrfishes recovered from Mound Key and determine they likely represented specialized production and use of a toxic resource not previously identified in the US Southeast. The analysis of these fish remains provides further insight into the behaviors and institutions that comprised Indigenous Calusa economies.

Introduction

Understanding the role of animals beyond their use as food or as indicators of past climatic and environmental conditions provides an avenue towards a more holistic perspective on Indigenous lifeways. Zooarchaeologists focus much of their research on subsistence economies. The role of animals in human society extends far beyond meeting nutritional needs and understanding the nature of human-animal relationships within wider socio-political realms is crucial to interpretations of human behavior (Gidney 2000; Jackson and Scott 1995; Jackson et al. 2014; Reitz and Wing 2008; Russel 2012). The use of animals certainly extended beyond the production, consumption, and redistribution of food resources. Both food and non-food animal resources are intimately linked to the economics of surplus production, exchange networks, craft specialization, wealth accumulation (Emery 2003; Jochim 2006; Spielmann 2002; Twiss 2012). However, the archaeological examination of the role that animals played extends beyond meeting basic biological needs varies widely and is most often examined in the context of complex societies that rely on domesticated animals (see deFrance 2009 for discussion). In this paper, I highlight an unusual abundance of porcupine fish (*Diodon* spp.) and burrfish (*Chilomycterus schoepfii*), hereafter referred to as burrfishes, two often overlooked species in the southeastern United States. I seek to examine their role in both the political and ideological realm of the Calusa, a complex coastal society living in southwestern Florida.

Reference to an "economy" or something as being "economic" encompasses the socially instituted ways of managing the production, consumption, and exchange of good and the wider role of these phenomena within human cultures (Kowalewski and Thompson, In press). Subsistence economies are not the only kinds of economies tied to animal resources. This narrow focus on subsistence economies by zooarchaeologists is especially prevalent in the study of non-state societies, and even more so across non-agricultural societies (deFrance 2009). A subsistence economy references the labor, resources, time, and institutions devoted primarily to meeting subsistence (e.g., food, nutrition) needs. An understanding of subsistence aspects of economies can be critical to exploring broader social, political, and economic processes beyond merely determining "what people ate." For instance, along the Pacific Northwest Coast, the control of resource patches were often tied to territorial ownership and the development and maintenance of hierarchical social systems in which groups maintained kinship-based rights to seal camps, salmon streams, sea otter camps, and other fishing grounds (Emmons 1991:46-47; Matson and Coupland 1995; Moss 2010). Thus, the amount of data generated by leveraging zooarchaeological data to unravel patterns of subsistence and human behavior provides information critical to understanding the role of animals beyond meeting basic needs.

As Kowalewski and Thompson (2020) highlight, there are few archaeological studies of the economies of the Indigenous southeastern United States beyond certain themes. This paucity seems to exist despite ethnohistoric records and cross-cultural comparisons that suggest complex, overlapping economic institutions should and did play a central role within these societies. When we narrow this down to publications that do address economy, or more specifically that leverage zooarchaeological data to address Indigenous economics, the scope of Indigenous economics is often a narrow and overwhelming focus on subsistence economies alone. While economies encompass the behaviors and institutions that allocate resources to different ends (Kowalewski and Thompson, 2020), zooarchaeological data is often used to address either subsistence or environmental conditions. Of the 53 articles published in *Southeastern Archaeology* that are returned with the search term zooarchaeology and that were not review articles, 23 dealt explicitly with subsistence, 5 with climate and environment, 3 with technology, and 1 with dog domestication. Only 4 of these 53 articles linked zooarchaeological data to socio-political and economic institutions beyond subsistence (Jackson and Scott 1995; Pauketat 1997; Rees 1997; VanDerwarker 1999). More broadly, there have also been recent discussions on the possible ritual use of toads and widespread trade in lightning whelks across the US Southeast (Kozuch et al. 2017; Whyte and Compton 2020). When interpretations center on faunal remains, this fixation on subsistence masks the important variation that would have existed among such behaviors and institutions that comprised the Indigenous economies of the southeastern United States.

Indeed, beyond meeting subsistence needs, animals are often used as nonfood resources that can be critical to wider social, political, and economic institutions. Mammals provide skins and furs and birds provide feathers and down which can be traded and whose display and use can be used to reinforce social hierarchy, for example (Baxter and Hamilton 2003; Lapham 2005). Bones, teeth, and shell are often used in personal adornment (as in tattooing, accoutrements, or the manufacture of clothing) (Weiner 1988). Bone and shell are used in a wide variety of tools (Marquardt and Kozuch 2016). Nonfood animal products play integral parts not only in everyday life but also as part of ceremonial and ritual institutions (Jackson and Scott 1995; Kelly 2001; Sugiyama et al. 2019). While many of these uses are easily identified in the archaeological record as modified bone and shell remains, there remains a real difficulty in identifying nonfood faunal remains that left no particular modifications to the preserved bones. When animals, and/or their products become critical components of social, cosmological, or gendered relationships extending beyond their consumption as food items, archaeologists must rely on context at varying socio-spatial scales. In cases where animals may be used to express social or political status, avoided due to esoteric social norms, deployed as signals of group affiliation, or their production required a high degree of specialized knowledge, context becomes the most important line of evidence in unraveling such behaviors and linking these behaviors to broader economic contexts. The recognition of zooarchaeological remains as non-subsistence requires in-depth inquiry dependent on an understanding of local environmental conditions, sociocultural histories, and ethnographic and comparative evidence when available (see Kansa and Campbell 2004; Reitz and Wing 2008:275-286; deFrance 2009).

Burrfishes are commonly found in archaeological assemblages from varying contexts, however, low numbers of burrfishes from the southeastern United States are low, with only a handful of individuals identified at sites where they have been recorded (see below for further discussion). Culinary taboos due to negligible amounts of meat, the solitary nature of the species, and the potential hazards of consuming these toxic fish can all be used to interpret the low number of observed individuals in the archaeological record.

One exception to this comes from the site of Mound Key in southeastern Florida, the capital of the Calusa at the time of Spanish contact in the 16th century. Here, an unprecedented number of individuals have been identified in highly localized deposits associated with the surplus production of fish resources (Chapter 4; Thompson et al. 2020a). Distributional evidence, along with the complete absence of particular elements, suggests a form of specialized production, consumption, and exchange of this toxic resource. To understand the possible role of burrfishes within Calusa economies, I first discuss a range of nonfood animal economies and provide examples of the incorporation of these resources into the social, political, economic, and ritual fabrics of societies. I then provide an overview of burrfishes, including their biology and ecology, with particular attention to the potential use and effects of their tetrodotoxins. Finally, I explore the unique assemblage of burrfishes remains from Mound Key provides information about Calusa economics, sociopolitics, and ritual gleaned from both the archaeological and ethnohistoric records.

Zooarchaeology Beyond Subsistence

Discerning the uses and meanings of zooarchaeological remains proves difficult without a thorough consideration of context. The following sections provide a brief, non-inclusive summary of some of the different examples of nonfood resources interpreted in the global archaeological record and some of the roles that animals play in human economies beyond satisfying nutritional needs. With this is mind, there are certainly distinctions to be made among these kinds of resources. We might distinguish between by-product economies and those economies based on the use of animals for uniquely nonfood purposes. For example, while deer may be key components of a subsistence economy, we know that deer were used as more than simply food (e.g., bone tools, hides, etc.). In contrast, certain animals likely were acquired for nonfood uses and integrated into institutions beyond subsistence economies. Examples of both of these kinds of nonfood animal resources are included below. I argue that the economic processes, behaviors, and institutions linked to the exploitation of toxic burrfishes likely a case where the labor, resources, and institutions intertwined with the exploitation of burrfishes were those supporting, and intertwined with, non-subsistence economies of the Calusa.

Economies of Identity and Representation

Animals bones crafted into items of adornment can become valorized through inputs of labor and resources and can be incorporated into a range of institutions including those related to political structure, social inequality, kinship, religious rights, etc. While in some cases these materials may have been byproducts of animals that were consumed, they also may have been acquired particularly for incorporation into these institutions. This is particularly the case for dangerous or deadly animals which are often imbued with symbolic meaning (Cooke 2004; Reitz et al. 2020). In these cases, where the transformation of animal bones into the items is costly, it is this costliness and the economics surrounding these processes that contributes to these items' effectiveness as signals and symbols within a cultural system (Bliege Bird and Smith 2005). Fine craftsmanship requires learned skills and experience that comes from education, practice, and even apprenticeship which can be intimately tied to kinship structures and wider networks of social interaction. Among the Trobriand Islands of Papua New Guinea, men exchange shell bead necklaces to reinforce trade relations, establish prestige, and to maintain social networks critical to the maintenance of sociopolitical interactions (Weiner 1988).

Adornments express group identity represent social status, or gender identity, for example, and often are interpreted through ethnohistoric documentation, contextual recovery, or some combination of the two. At the mortuary precinct of Sitio Conte, Panama, impressive amounts of animal-derived objects were recovered including peccary incisor necklaces, a carved whale tooth capped with gold, and numerous other cut, worked, and carved bones reinforcing hierarchical social structure and signaling group membership through display (Cooke and Jiménez 2010; Bliege Bird and Smith 2005). More broadly, elements from animals perceived as dangerous are often nonfood and likely associated with symbolic meanings discerned through ethnography, comparisons of animal imagery, and comparisons of midden refuse (Cooke 2004; Emery 2004; Jackson and Scott 1995; 2003; Kelly 2010; Kirch and O'Day; 2003). Similarly, crocodilian teeth, porpoise teeth, bear teeth, deer teeth, shark and ray vertebrae, and even bone shaped into a crocodilian recovered from archaeological sites in Florida were likely used to reinforce various social dynamics of group membership and hierarchal group relations (Patton 2013; Richarson and Pohl 1985:132).

People also commonly use marine shell to imply relationships or sociopolitical status across the southeastern United States (Marquardt and Kozuch 2016; Trubitt 2003). One of the most widespread emblems in the Mississippian world of the southeastern and midwestern United States are the marine shell gorgets or pendants (Hally 2007; Trubitt 2003). The distributions of these emblems testifies to complex social, political, and economic relationships among elite actors (Lulewicz and Coker 2018). Shell plummets, like those recovered from the Woodland site of Crystal River on the Florida Gulf coast, were likely used as part of public ritual, worn as a collection, and were made of local and non-local material such as marine shell, stone, copper, and bone (Pluckhahn and Thompson 2018; Thompson et al. 2017). Marine shell production and ownership of marine shell ornaments are often situated within complex socio-political and socio-economic relationships, especially in those areas far from the shell’s coastal origins (Kelly 1995; Lulewicz and Coker 2018; Moholy-Nagy 1995; Pauketat 1993; Trubitt 2003).

A secondary form of adornment reliant on animal resources gleaned from the global archaeological and ethnographic records are tattoos, often applied using tools made from various types of animal bones, teeth, and spines (Deter-Wolf and Diaz-Granados 2013; Deter-Wolf and Peres 2013). Many ethnographic records depict the widespread use of tattooing in North America (Laudonnière 2001 [1586]:9-11; Le

Challeux 1875 [1579]:461; Raudot 1904:64-65; Sinclair 1909). Experimental archaeology using different types of tattooing implements identified in ethnographic records suggests bone tools were the most efficient material type (Deter-Wolf and Peres 2013; Arcos 2017). Identifying the bone tools, points, and needles used for tattooing requires specific contextual evidence and complex analyses such as microwear analyses and analyses of possible ink and pigment residues (e.g., Gates St-Pierre 2018; Kononenko et al., 2016). Across the ethnographic record, tattooing practices can be understood as a practice to integrate the self into varied social, political, religious, and economic systems whether based on achievement, age, gender, or other milestones (Ambrose 2012; Argent 2013; Balvay 2008; Barton 1918; Krutak 2013a, b).

Economies of Ritual

In this section, I want to highlight the fact that in many cases provisioning such behaviors rooted in magic, ritual, and the supernatural cannot be separated from wider non-ritual economies. This is somewhat different from classic ideas of ritual economies consisting of the acquisition, production, and distribution of social-value laden objects and how to recognize the presence of such behaviors in the archaeological record (Spielmann 2002; Rapport 1968). If particular rituals and magics are essential cogs in wider economic systems (e.g., political economies, critical exchange networks, etc.), then it follows that the animals provisioned for such rituals represent resources leveraged within institutions that cannot be adequately described through a narrow definition of the ritual economy. For example, dugong bone mounds found in the Torres Strait represent hunting magic used to aid in the capture of dugong and thus represent the intertwining of subsistence and spirituality (McNiven and Feldman 2003). Bird bones fashioned into snuff kits are found in context of priestly dwelling in Peru and Chile (Burger 2011; Sayre 2018; Torres et al. 1991). The widespread distribution of such snuff kits and paraphernalia suggest that up to 20% of men living during the Middle Horizon in Chile used snuff kits and hallucinogenic substances (Torres et al. 1991). This widespread use by both priests and commoner visitors to these temples, and the practice of such rituals at temples across the region, suggests that these hallucinogenic substances played a key role in public rituals, shared participation in which would have tied together communities with radically different histories (Burger 2011:137) and likely provided a set of shared affiliative identities that would have greased the cogs of economic transactions. For the Khanty of Siberia, the maintenance of relations with spiritual beings requires the routine deposition of bear and elk remains (Jordan 2002). Such relations are critical to the health and welfare of communities (Jordan 2002). The material gifts (e.g., bear and elk) are deposited at sacred sites and intimately linked to general patterns of Khanty movement that include seasonal and cycles of dispersals and aggregations (Jordan 2002).

Swanton (1946:249) states that ankle rattles used in dances were made from deer hooves and sometimes turtle shells. Indeed, across North America, archaeological evidence, supported by the ethnographic and historical records, demonstrates the use of turtle shell as rattles, often in reference to creation stories in ceremonial settings (Gilreath-Brown 2019; Gilreath-Brown and Peres 2017, 2018). Among the Calusa, Juan Lopez de Velasco described a shaman’s dress during a memorial as having horns which most likely were made of bone or deer antlers (Hann 1991:316).

The intentional burial or inhumation of animals provides insights into the complex relationship between commensal animals and humans and the economies encapsulated in such interactions that exist beyond predator-prey or food-based economies. Animal inhumations could represent gifts ritually sacrificed, spiritual guides, or a particular relationship between that individual animal and its human companions. Partial or whole bodies of animals have been buried alongside elites, likely as ritual offerings. While in life, dogs among the Maya during the Preclassic period and elsewhere were used for companionship, forms of tribute payment, and hunting, in death their bones and teeth were used for personal adornment and ritual tribute (see Cooke and Jiménez 2010). Globally, the kinds of animals interred with humans have varied wildly and include the likes of crocodiles (Harrison 1999:83-86; Rice 2020), big cats (Sugiyama et al. 2015, 2018), horses (Bliujienė et al 2017; You et al. 2020), and others (Linseele et al. 2007, 2008, Van Neer et al. 2014). In Illinois, a Woodland period mound contained the burial of a juvenile bobcat wearing a necklace/collar of large canine teeth and marine shell likely signifying an emotional connection to the deceased kitten (Perri et al. 2015). In the Venda region of South Africa, animals are buried in replacement for someone who died far from home (Hutten 2008). Additionally, the two sites in southern Florida contain evidence for the intentional internment of animals. The Palmer site (8OS2) has an alligator burial and four bog burials while the Margate-Blount site (8BD41) in Florida has a "ceremonial precinct" with several animal burials including alligator, coiled and decapitated rattlesnake, turtles, dogs, and raccoons (Bullen and Bullen 1976: 46; Felmley 1991:101-102; Wheeler 1992:89-90). These signify vastly different mechanisms with which these animals were interred, highlight the importance of contextual information in their interpretation, and encourage us to widen our perspectives on the scope of economies and economic institutions beyond subsistence-based that would have been tied to such practices.

Economies tied to achieving altered and hallucinogenic states also represent substantive systems of resource expenditure unrelated to subsistence yet integral to wider social, political, and economic functions. The use of plant psychoactive plants, toxins, and poisons has been well documented among many Native groups (e.g., Schultes et al. 2001 for list of hallucinogens). To date, only a few animal derived toxic, poisonous, or psychoactive substances have been identified. Several species of the Bufonidae family (bufonid toads) contain toxic chemical compounds of bufotoxin, bufogenin, and bufotenin that when ingested may cause increased heart rate, paresthesia, cyanosis, when smoked may cause hallucinations, and is thought to have an effect on serotonin levels (Chen and Kovaříková 1967; Davis and Weil 1992; Schultes and Hofmann 1980; Weil and Davis 1994). The use of such toxins has been documented in the US southeast (e.g. see Whyte and Compton 2020 for review). Coincidentally (or not) the toad was a prominent symbol in Olmec, Mayan, and Aztec iconography where toads and their parotoid glands, the glands that hold the toxins, are depicted on several different types of artifacts (Dobkin de Rios 1974; Furst 1972, 1976; Kennedy 1982; Tozzer and Allen 1910). One ethnohistoric document describes the Pokoman Maya practices of stewing poisonous toads in alcoholic beverages in an attempt to increase beverage’s potency (Thompson 1970).

Hunter-gatherers in South Africa are known to have used animal-based poisons from snake venom, trapdoor spider venom, scorpion venom, ground beetles, and leaf beetles to create venom-tipped arrows (Bradfield et al. 2015). In South America, poisons extracted from the skin of several species of frogs, mostly from Poison Dart frogs, are used to tip arrows (Myers et al. 1978). Aztec priests anointed their skins with a dark, hallucinogenic paste called *Teotlaqualli* which was made through combining *Nicotiana rustica*, ololiuhqui, soot, and live poisonous animals including spiders, scorpions, centipedes, lizards, and vipers (Elferink 1999). However, there seems to be no extensive literature regarding the use of toxins and poisons derived from fish, despite zooarchaeological evidence for their presence in archaeological deposits.

When zooarchaeological data are used to elucidate subsistence economies, it is clear how changes to the distributions and availability of animal resources, whether due to natural or anthropogenic factors, could have critical effects on the economic institutions entangled with the organization of subsistence. What becomes lost, however, is the way that changes to the distribution of animals could affect, threaten, and transform critical behaviors and institutions that structure and support nonfood economies as well. A narrow focus on subsistence masks the reality that changes to social, political, and religious practices have the potential to transform the institutions that structure and shape the acquisition, production, and consumption of particular animal resources and thus alter the representation of such animal resources in the archaeological record.

Burrfishes

"I have heard from Dr. Allan of Forres, that he has frequently found a Diodon, floating alive and distended, in the stomach of the shark, and that on several occasions he has known it to eat its way, not only through the coats of the stomach, but through the sides of the monster, which has thus been killed. Who would ever have imagined that a little soft fish could have destroyed the great and savage shark?"
(Darwin, Voyage of the Beagle, 1845, pg. 17)

Biology and Physiology

The Tetrodontiformes order includes boxfishes, pufferfishes, burrfishes, porcupine fishes, triggerfishes, and ocean sunfishes. Here, I will focus on the Diondontidae family, *Diodon* spp. (porcupine fish) and *Chilomycterus schoepfii*, referred to collectively as burrfishes unless specified. Burrfishes are demersal fish who prefer temperate marine waters with soft sandy or muddy bottoms. They inhabit a wide range of habitats, generally occupying inshore areas that offer shelter such as caves, reefs, and ledges or among the seagrass beds in bays or coastal lagoons down to 100 m depth (Felder and Camp 2011). Burrfishes are common in both the marine and brackish waters of the Gulf of Mexico and tolerate a wide range of salinities and water temperatures.

Diodontidae possess modified dental configurations where the teeth are fused together to form a parrotlike beak (Fraser et al. 2012). With these beaks, burrfishes primarily feed on hard-shell crustaceans, mollusks, and echinoderms, but sometimes graze on seagrasses or algae. Burrfishes are small to medium sized fish that can reach lengths of 1 m but are most commonly between 20 – 50 cm in length (Figure 4.1). Burrfishes possess modified scales that protrude from the body as spines. *Chilomycterus schoepfii* spines have a three pronged base that sits underneath the skin with one spine permanently erect protruding from the body. *Diondon* spp. have longer spines with a 2-pronged base beneath the skin. These spines lay flush with the body until erected (Wainwright and Turigan 1997).

Burrfishes are capable of inflating their bodies as defense mechanisms against predators by swallowing mouthfuls of water (Wainwright and Turingan, 1997; Stump et al., 2018). Modification to the pelvic girdle and head provide the functioning mechanism to pump water while the lack of ribs allows the body to expand freely (Wainwright et al. 1995; Brainard 1994). Similarly, these fish also exhibit “coughing” and “water blowing” behaviors that are functionally and mechanically similar to inflation and are often used to manipulate, expose, or clean prey or to expel the indigestible portion of prey (Wainwright and Turnigan 1997).

Generally, burrfishes are not deemed valuable or as desirable food sources. Firstly, these fish consist of very little meat other than innards. Secondly, fish of this order contain a toxin, tetrodotoxin, and are most colloquially recognized as the culinary delicacy known as fugu. In Japan today, fugu chefs must be licensed and undergo ca. 11 years of training that includes a three-year apprenticeship, many courses, and both written and skill-based exams. If prepared incorrectly, tetrodotoxin acts on both the central and peripheral nervous systems as an inhibitor to nerves-to-muscles signal transmission and can cause numbness, increasing stages of paralysis, gastrointestinal distress, and respiratory failure (Isbister et al., 2002). Tetrodotoxin is both heat-stable and water-soluble so boiling or frying the fish does not deactivate the toxin and when prepared carelessly or incorrectly the toxin has the potential to kill a human within an hour of consumption (Ahasan et al. 2004; Islam et al. 2011). The toxin is usually found in the gonads, skin, liver, intestines, and the ovaries zebra fish demonstrate the gonads and skin of *Diodon hysterix* are extremely toxic (Ravi et al. 2016).

Burrfish in Ethnography

The dried skins of burrfishes are found in any number of curio shops today. Despite the relative ubiquity of burrfishes throughout temperate and subtropical environments worldwide, little information exists regarding the use of burrfishes in

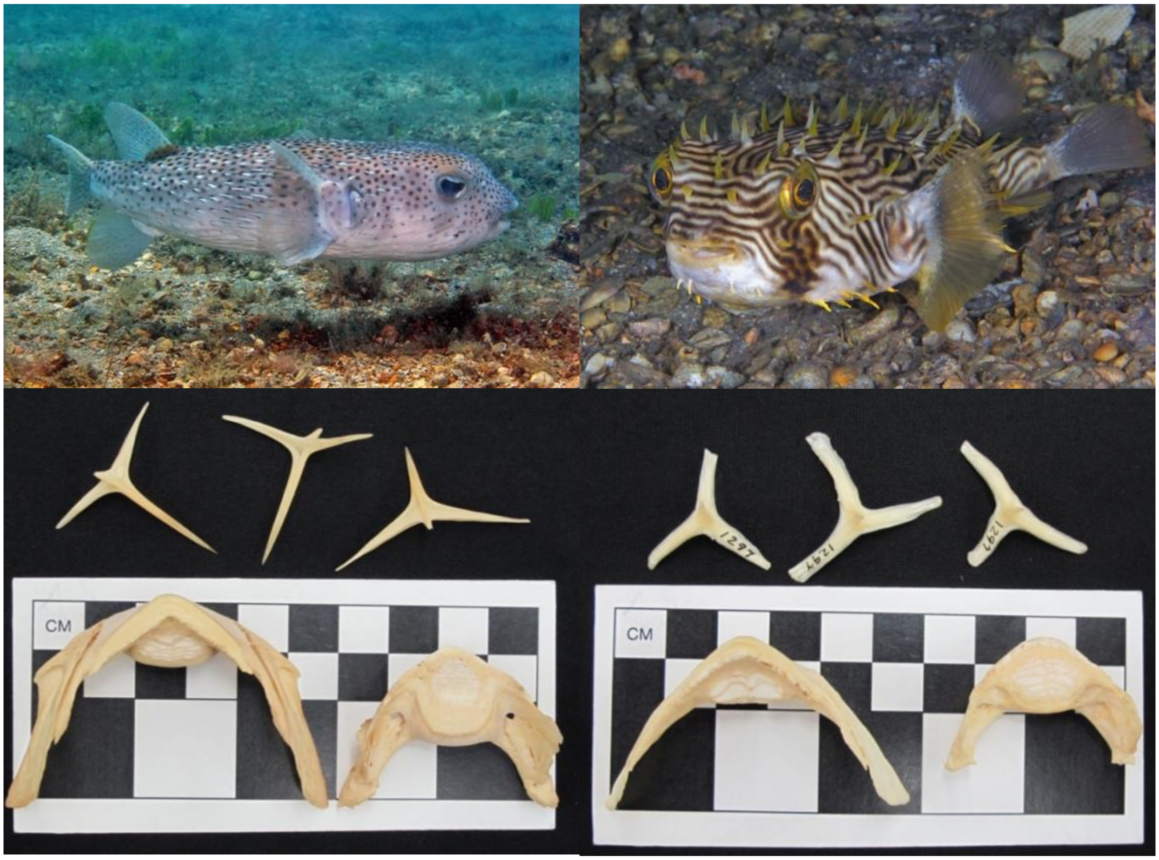

Figure 4.1. Burfishes *Diodon hystrix* (porcupine fish) on left and *Chilomycterus schoepfii* (burrfish) on right. Note the flat-lying spines of the porcupine fish and the erect spines of the burrfish. Images of live animals are licensed under creative commons CC BY-NC-SA 2.0: "IMG_3148a porcupine Porcupinefish (Diodon hystrix)" byKevin Bryant, DMD and "IMG_1375wa Striped Burrfish (Chilomycterus schoepfi)" byKevin Bryant, DMD. Photo credit for skeletal elements from comparative collection at University of Georgia: Elizabeth J. Reitz, Georgia Museum of Natural History.

during reproductive seasons (Mohid Nor et al. 2014; Ravi et al. 2016). Toxicity tests on history beyond items of curio. The use of burrfishes appears in ethnographic and ethnohistoric records from several different regions which provide some insight into the potential uses of burrfishes in the past. In Brazil, *Chilomycterus antillarum* and *Chilomycterus spinosus spinosus* are cited to be used in treating wounds or lumps (Alves et al. 2017). The Gilbert Islanders of Melanesia used the skins of porcupine fishes to make war helmets by killing the fish while inflated and drying the skin (Gudger 1930). These helmets reportedly acted as a defense against weapons adorned with sharks teeth (Gudger 1930). Additionally, ethnographic accounts suggest that burrfishes are used in the Caribbean in voodoo practices of "zombification." Ethnobiologist E. Wade Davis (2000) witnessed and recorded the preparation and use of the porcupine fish, locally known as fou-fou, in Haitian vodoun (voodoo) practices. In this practice, the victim appears to die after being administered "coupe poudre" (magic powder) (Keegan and Carlson 2008). A fish effigy bowl likely depicting a porcupine fish was also recovered from Haiti within a context that contained other ritual paraphernalia (Keegan and Carlson 2008).

Burrfish in the Archaeological Record

It is not unusual to find burrfishes and porcupine fish in the archaeological record. Often times they are present in high numbers of identified specimens (NISP) with low minimum numbers of individual (MNI) fish recovered from archaeological sites. This discrepancy is often a product of the recovery of high numbers of dermal spines which, along with the beaks, are quite taphonomically durable. The species *Diodon hystrix* has between 29 – 38 spines that run the length of its body. Both skeletal elements have high taphonomic stability making it likely that if utilized in the past they will be present in archaeological deposits.

Sites in Latin America, in the Caribbean, and along the Gulf Coast of Florida commonly contain burrfishes remains. Porcupine fish spines have been recovered in ritual deposits at the Maya site of Tikal (Maxwell 2000). Maxwell (2000) identified hundreds of dermal spines most often found in deposits associate with private ritual settings. Temporally, the highest frequency of spines occurs during a time of social unrest at Tikal. Maxwell (2000:94) interprets the use of these dermal spines as implements for bloodletting or toxin consumption. In conjunction with porcupinefish, Tikal also contains caches with other toxic marine life including stingrays, cone shell, sponges, and corals (Maxwell 2000). Similarly, burrfishes were among the most abundant in a ritual offering deposits at the Templo Mayor at Monte Albán (Martínez-Lira 2014). Three ritual caches at Dzibilchaltun contain *Chilomycterus schoepfii.* spines and one at San Jose contained spines of *Diodon* spp. (Teeter 2001). Burrfishes are also commonly found in deposits from archaeological sites across the Caribbean and Florida. In the Caribbean, five sites on Anguilla and En Bas Saline, a Taino village on Haiti, both contain the remains of burrfishes and porcupine fishes (Crock and Carder 2011; Carder and Crock 2012; Lefebvre 2015). Several deposits from the Bird Island and Ehbar sites in Florida contain a few identified *Chilomycterus schoepfii* (McFadden and Palmiotto 2012; Palmiotto 2016). Sites further south, near Charlotte Harbor, Florida, contain slightly higher numbers of burrfishes (Walker 1992; deFrance and Walker 2013). However, while the sites listed here may have high numbers of identified specimens (NISP), all have low numbers of minimum number of individuals (i.e., MNIs of 1-10).

Mound Key, the Calusa, and Toxic Economies

Mound Key and the Calusa (8LL2)

Mound Key is a 51-hectare anthropogenic, shell island constructed of repurposed midden and primary midden located in modern day Estero Bay, Florida (Thompson et al. 2016) (Figure 4.2). The island is a complex layout of midden-mounds, watercourts, canals, causeways, and burial mounds. Mound Key occupation spans from ca. AD 450 through Spanish contact to the seventeenth century (Thompson et al. 2016) (Figure 4.3). The two largest mounds are separated by the largest canal that extends the length of the island. The largest mound contains evidence of a very large mound-top structure (Thompson et al. 2016, 2018a). Historic documents from the sixteenth-century describe this structure as being capable of holding over 2,000 people and refer to it as the king's house. Recent investigations estimate the dimensions of this structure to be approximately 24 m long and 20 m wide (Solís de Merás 1964:145; Thompson et al. 2018). At the southern end of the central canal, two large watercourts, interpreted as impoundments for holding live fish, mirror each other on each side of the canal (Thompson et al. 2020a).

The Calusa were organized as a complex chiefdom or weak tributary state and their subsistence practices supported a wide range of complex social and political institutions without reliance on farming (Hutchison et al. 2016; Marquardt 2014; Thompson et al. 2018; Thompson et al. 2013). They possessed highly developed systems of ecological knowledge that aided in the development of complex socioeconomic and sociopolitical institutions (see Chapter 4, Thompson et al. 2020a). They also kept a standing military force, exacted control and collected tribute from other groups, and

Figure 4.2. Map of the Gulf of Mexico showing the location of Mound Key.

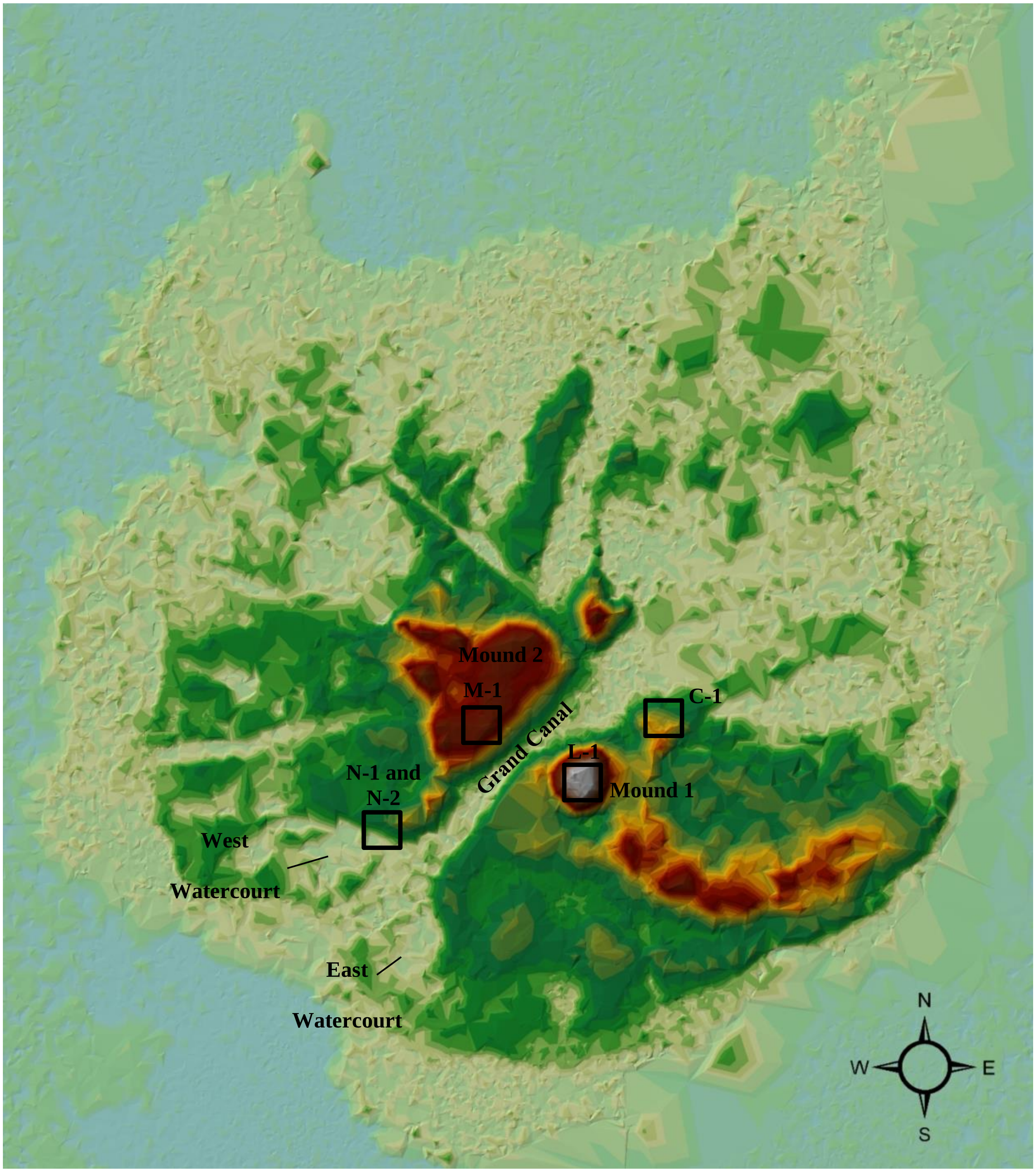

Figure 4.3. Map of Mound Key (8LL2) showing location of Excavation Units discussed, C-1, L-1, M-1, N-1, and N-2.

maintained hereditary-based class systems (Hann 1991; Marquardt 2014; Thompson et al. 2018). Their subsistence economy was based on fishing, gathering, and hunting and was intimately tied to the ebbs and flows of the estuarine and marine communities of southwestern Florida (Chapter 3; Chapter 4; Walker 1992; deFrance and Walker 2013; Newsom and Scarry 2013).

Remains of Burrfishes at Mound Key

Previous zooarchaeological research at Mound Key identified deposits both rich in burrfishes and those with only a few individuals (see Chapter 4; Jarrett 2014; Anderson 2006; Ellison 2006; Kavountzis 2006). Samples from Units C-1, Operation L-1, Operation M-1, and Units N-1 and N-2 are included here for comparison of burrfishes remains across Mound Key (Figure 4.3). These deposits are located along the northern edge of the western watercourt at the base of Mound 2 (Units N-1 and N-2), on top of Mound 2 (Unit M-1), on top of Mound 1, and off of the northern flank of Mound 1 (Unit C-1) (Figure 4.3). For comparison purposes burrfish (*Chilomycterus schoepfi*) and porcupine fish (*Diodon* spp.) identifications and elements are only attributed to Diodontidae and were collated under the category burrfishes in Table 4.1 but are listed by species in Table 4.2.

The deposits located along the western edge of the watercourt are dated to ca. AD 1000 – 1150 (Thompson et al. 2020). The zooarchaeological samples from Units N-1 and N-2 (both 1-m-x-1-m excavation units) were recovered in 2017 using 6 mm mesh. They contained NISP totals of 48 and 225 burrfishes specimens respectively and MNI totals of 27 and 141 individuals, respectively, is estimated. Thus, a total MNI of 168 burrfishes is estimated for these two units.

The zooarchaeological samples from Unit C-1 (2 m x 1 m excavation unit) were recovered in 1994 using 6 mm mesh. The unit contained an NISP of 18 burrfishes specimens and an MNI total of 11 burrfishes is estimated (Table 4.1). Torrence et al. (1994) dates these deposits to ca. 500 BC – AD 800 based on artifact types. However, recent reexamination of these deposits suggests this area contains redeposited midden used in mound construction based on radiocarbon date reversals and examinations of sediment cores (Thompson et al. 2016). Two dates occur in sequence above the date reversals and both dates situate the deposits between ca. AD 1300 – 1400 (Thompson et al. 2016). The zooarchaeological samples included here are from deposits above the mound construction deposits so I assign this sample of 11 burrfishes individuals (NISP 228) found on the northern side of Mound 1 to ca. AD 1300 – 1400.

The Mound 2 deposits were excavated in 2013 and a report of faunal remains from this field season reports an NISP of 200 burrfishes specimens with an MNI total of 100 burrfishes (2 m x 2 m excavation unit) (Jarrett 2014). Of these 100 individuals, 43 were recovered from a single post/pit feature that also contained botanical remains, Calusa ceramics, a lightning whelk (*Busycon sinistrum*) hammer, and a ponderous ark (*Noetia ponderosa*) shell net weight with a radiocarbon date that places the feature between ca. AD 1400 – 1600 (Ritchison et al. 2019; Thompson et al. 2020). The other 57 individuals were recovered from general matrix fill from the unit at the same level as the feature. I apply a general date range of AD 1400 – 1600 for these deposits as well. A zooarchaeological sample from the top of Mound 1 was also recovered during the 2013 field season, but these included only two individual burrfishes. Of all the burrfishes remains recovered at Mound Key no deposits contain any spines. All burrfishes

Table 4.1. Total burrfishes remains from Mound Key

Unit	NISP	MNI	Time Period
N-2	204	132	AD 1000 - 1150
M-1	200	100	AD 1400 - 1600
N-1	48	27	AD 1000 - 1150
C-1	18	11	AD 1300 - 1400
L-1	2	1	AD 1400 - 1600
Total	**472**	**271**	

Table 4.2. Burrfishes remains as identified during analysis from Mound Key (8LL2) Units N-1, N-2, M-1, L-1, C-1.

Data Source	Species identified during analysis	Unit-Level-Feature	NISP	MNI	Time Period
Jarrett 2014	*Chilomycterus schoepfii*	M-1-33-Feature	2	1	AD 1400 - 1600
Jarrett 2014	*Chilomycterus schoepfii*	M-1-35-Feature	84	42	AD 1400 - 1600
Jarrett 2014	*Chilomycterus schoepfii*	M-1-34	67	33	AD 1400 - 1600
Jarrett 2014	*Chilomycterus schoepfii*	M-1-35	47	24	AD 1400 - 1600
Jarrett 2014	*Chilomycterus schoepfii*	L-1-9	2	1	AD 1400 - 1600
Anderson 2006	*Chilomycterus schoepfii*	C-1-67-1	1	1	AD 1300 - 1400
Anderson 2006	*Chilomycterus schoepfii*	C-1-68	2	1	AD 1300 - 1400
Ellison 2006	*Chilomycterus schoepfii*	C-1-69	2	1	AD 1300 - 1400
Kavountzis 2006	*Chilomycterus schoepfii*	C-1-83	8	5	AD 1300 - 1400
Kavountzis 2006	*Chilomycterus schoepfii*	C-1-84	5	3	AD 1300 - 1400
Chapter 4	*Chilomycterus* spp.	N-1-81	1	1	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-1-84	1	1	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-1-84	1	1	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-1-85	1	1	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-1-85	1	1	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-1-86	27	15	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-1-86	6	5	AD 1000 - 1150
Chapter 4	Diodontidae	N-1-86	7	_	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-1-87	3	2	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-83	1	1	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-2-84	4	4	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-84	2	2	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-2-85	10	9	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-85	7	4	AD 1000 - 1150

Chapter 4	Diodontidae	N-2-85	2	_	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-2-86	37	22	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-86	35	32	AD 1000 - 1150
Chapter 4	*Chilomycterus* spp.	N-2-87	37	23	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-87	45	32	AD 1000 - 1150
Chapter 4	Diodontidae	N-2-87	19	_	AD 1000 - 1150
Chapter 4	*Diodon hystrix*	N-2-88	5	3	AD 1000 - 1150
		Total	**472**	**271**	

recovered from the watercourt and mound contexts are represented by beaks only and no other elements from these fish were recovered.

Toxic Economies

While it is not uncommon to identify burrfishes in archaeological assemblages from the US Southeast, these deposits usually contain high numbers of identified specimens and proportionally low numbers of individual fish represented. This is usually a product of high numbers of spines. However, spines are absent in all other Mound Key deposits studied to date. While the beaks of these fish are robust enough to have potentially higher preservation rates compared to other skeletal elements, the presence of both beaks and spines at other archaeological sites across the US Southeast suggests different processes were at play on Mound Key. Additionally, the presence of more fragile fish elements of various different fish species in the same deposits at Mound Key suggests that taphonomic processes do not explain the high burrfishes MNI and the absence of spines in the majority of deposits from Mound Key. I suggest that the use of these fish at Mound Key transcends explanations of by-catch or simply for subsistence. Instead, Mound Key represents the central locale of a specialized economy within which burrfishes played a critical role. Differential recovery of elements at Mound Key further distinguishes it from other Calusa sites. This heterogenous distribution at the regional scale suggests that burrfishes use (or at least this particular form of production and consumption) was unique to social, political, or religious institutions that either were centered at Mound Key or that exclusively were restricted exclusively to practices taking place at Mound Key.

The anomalous representation of burrfishes beaks suggests specialized processing areas near the western watercourt and the top of Mound 2. I argue that this disparity in concentration of elements suggests restricted areas of processing, distinguishing special use and esoteric practices had their place away from the king's house on Mound 1. Just as in modern culinary practice, it is likely there were specialists who had specific knowledge about processing these dangerous fish. There exists rather convincing evidence for craft specialization among the Calusa. Dietler (2008) suggests that Calusa boat construction and the technology used for it may have been controlled by the elite. The numerous wooden and bone carvings suggest specialist craft production as evidence from artifacts recovered from other south Florida sites of Key Marco, Fort Center, and Pineland (Clark 2013; Purdy 1991). Thus, if we accept that burrfishes are not being processed for food, it is likely that the resources expended on their production relate to specialized economies comprised of exclusive or specialist institutions, as we see in modern day Japan.

The question still remains as to why burrfishes were used and by whom. The lack of spines from across the site suggests a by-product involving the spines or innards where the toxin is most abundant. While the global ethnographic record contains references to conspicuous uses of burrfishes, like the Melanesian war helmets, such highly visible uses would have likely been included in Spanish descriptions of the Calusa but there are none. Others have suggested use of spines for bloodletting practices (Maxwell 2000) although they could have also been used in tattoo kits, as arrow or spear points, or for any number of other uses. The Calusa could have utilized the properties of the tetrodotoxin in medicinal, ritual, or even military contexts. The use of plant and animal based toxins and poisons on the tips of arrows is a practice documented historically across the US

Southeast (Jones 2007). In fact, during the 1513 expedition of Antioio Herrera, the Calusa "…with their arrows and spears tipped with pointed bones and fish spines, wounded two Castilians…" (Worth 2014:50, translated). A mere few months later, Juan Ponce de Leon was fatally injured by a Calusa arrow (Worth 2014:52, 61, 63. 65. 86) that has been purported to be tipped with poison. Burrfishes may represent the source of any such toxins although I find it more likely burrfish toxin was used for altered state practices. The Calusa certainly had the knowledge and skill to extract tetrodotoxins.

The discrepancy in identified elements from Mound 1 and Mound 2 suggests that only finished products (e.g., spines, innards, toxin-coated materials) were being utilized or exchanged. While the acquisition of burrfishes does not require skill beyond net fishing (and even hand-catching), the handling and preparation of these fish requires specialized knowledge to avoid the potentially fatal risks. Given the absence of similar deposits of burrfishes at other sites, it seems likely that this knowledge of how to prepare burrfishes was not readily available to the general populace. This does not mean, of course, that finished products were not distributed among the general populace or exclusive to elites. In terms of the archaeological record, these signatures could be absent of these products that do not preserve (meat) or are invisible (toxin-coated materials). If they do represent a commodity only consumed by elites, religious leaders included, they would have certainly been a component of economic institutions that served to reinforce and maintain the hierarchical structure and class-based system of Calusa socio-politics.

Conclusion

The unprecedented number of burrfishes recovered from Mound Key likely represent specialized production and use of a toxic resource not previously identified in the US Southeast. The analysis of these fish remains provides further insight into the behaviors and institutions that comprised Indigenous Calusa economies. Given the physiological characteristics of burrfishes, including the presence of tetrodotoxin and the distributional evidence, at both the site and within the larger south Florida region, the data presented here suggests an economy centered on the production of some good likely made from the spines, hides, and/or innards of burrfishes. The location of burrfishes remains within deposits associated with the watercourts and production of surplus fish resources suggests the same labor, resources, and institutions related to the Calusa subsistence economy were intertwined with those related to the production of a toxic, non-food resource. Even if burrfish products were used by more than elite members of society, centralized production at Mound Key would have further served to reinforce and maintain Calusa socio-political structure through exclusive, specialist-based, institutional production.

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CHAPTER 5

CONCLUSIONS

The vulnerability of the shallow-water, low-lying ecosystems of the Gulf Coast of Florida necessitate investigations into the impacts of global-scale climatic changes on local ecosystems and into how the various economic institutions of the Calusa operated in the context of such changes. This research does not view the interactions between humans and their environments as deterministic but instead as synergetic, emphasizing humans as co-producers of their environments. This dissertation contributes to our understanding of how complex fisher-gatherer-hunter coastal populations adapted to changing socioecological systems. The research presented herein has been guided by principles rooted in the premise that the Indigenous peoples of southwestern Florida were intimately familiar with the effects of perturbations to their coastal environments and were experienced in responding to both small and large scale ecological changes and challenges.

Throughout this dissertation, my colleagues and I have contributed new insights on (1) the dynamic relationship between coastal economies and environmental change and on (2) the important use of local paleoenvironmental reconstructions in examining resiliency in coastal communities. Environmental change clearly articulates in complicated ways with the structure and maintenance of social, political, and economic institutions. The construction of localized environmental contexts is imperative to any investigation into past lifeways, economies, or politics, not just among hunter-gathers or coastal populations but among any society regardless of sociopolitical strategies or geographic context.

In Chapter 2 we combined Bayesian statistical analyses of radiocarbon dates with zooarchaeological analyses of a water-logged midden to generate a high-resolution, localized view of socioecological interactions before and throughout the onset of the Little Ice Age. This article demonstrates that by tying the archaeological record directly to paleoenvironmental data from archaeological sites within a fine-grained temporal framework, socio-ecological histories imbued with meaningful temporality can be more readily connected to human lives and the transformation of cultural institutions. Importantly, we empirically explore the nature of the local ecological changes linked to this broader climatic event rather than deploying generalized assumptions.

In Chapter 3, we concluded that local environmental changes, during a period that has often been characterized by cooler and dryer conditions, were actually characterized by warmer, wetter, and more amenable conditions. These results, rooted in empirical climatic reconstructions via stable isotope geochemistry, stand in direct contrast to generalized expectations derived from the use of global climatic events as broad climatic contexts. Specifically, these results challenge the utility of global climatic categories (particularly the Little Ice Age) for characterizing local environments at particular points in time and at particular places on the landscape.

We also demonstrate in Chapter 3 that the Calusa possessed and leveraged intricate ecological knowledge upon which they built complex social, political, and economic institutions. This is evidenced through the exploitation of certain species of fish capable of inhabiting conditions created by the anthropogenically engineered features called watercourts for use in storing surplus marine resources. Beyond serving as benign containers for surplus fish, these watercourts required biologically and ecologically minded solutions to make their use successful. That is, the Calusa deployed their deep ecological knowledge actively select species that could thrive in these anthropogenically constructed micro-ecologies. In doing so, the success of these watercourts played a critical role in the complex web of social, political, ecological, and biological systems that came together to give form to Calusa histories.

In Chapter 4, I explored a uniquely high number of burrfishes remains excavated from localized deposits on Mound Key. The analysis of these fish remains provided further insight into the practices that comprised Indigenous Calusa economies beyond meeting basic biological needs. The location of the burrfishes remains across the site provides a window into the labor, resources, and institutions related to the production of surplus fish resources, including those important as non-food and non-subsistence resources. Given the presence of tetrodotoxin and other physiological characteristics of burrfishes, the data presented in Chapter 4 suggests that these animals were not consumed as foodstuffs, but likely were produced, distributed, and consumed as non-food commodities. Whether this consumption was restricted to elite members of society or the wider populace, evidence for the centralized and restricted production of burrfishes resources, along with evidence for the distribution of particular burrfishes elements (e.g., spines), certainly suggests the important economic roles of particular animal resources beyond subsistence. This case study makes clear that the role of zooarchaeological analyses extend far beyond subsistence and that these data can contribute substantively to exploring economies wider than those related to foodstuffs.

Resilience, Environmental Change, and Complex Fisher-Hunter-Gatherers

Environmental change bears the potential to greatly affect the structure and maintenance of social, political, and economic institutions that are fundamentally reliant on coastal resources. Coastlines like those in southwestern Florida are especially susceptible to fluctuations in environmental characteristics that effect the location and availability of resources. Thus, groups living in these dynamic environments need to be able to develop institutions that can mediate the repercussions of such changes. The sustainability and resilience of coastal populations was possible in southwestern Florida only through a complex balance between entangled socio-ecological and sociopolitical regimes. The research presented here demonstrates that Indigenous populations of southwestern Florida lived in climatically sensitive environments, possessed extensive knowledge of the estuarine systems of southwestern Florida, and were able to actively manipulate the environment to maintain and promote plasticity within socioecological and sociopolitical institutions.

This research recognizes that this plasticity in resource likely mirrored the plasticity and resiliency of cultural institutions. Certainly, humans utilize a variety of resources, to the point of being considered generalist in nature, which inherently builds resiliency into socioeconomic institutions. This is undoubtedly the case in southwestern Florida, as demonstrated by the zooarchaeological data presented here (Chapters 2 and 3) that identifies a wide variety of taxa. However, the identification of specific taxa for use in the watercourt contexts at Mound Key (Chapter 3) further demonstrates attempts to create resilient institutions to produce and manage surplus resources that would have played an integral role in contextualizing social, political, and economic relationships. By the time the watercourts themselves were constructed, intensive and costly investments in the landscape has already been expended at both Mound Key and Pineland (canals, mounds, etc.) over previous generations. These long histories of investment in complex and large-scale labor projects certainly mirror investments in the kinds of complex sociopolitical arrangements that bolstered the resilience of these Calusa socio-natural systems in the face of climate fluctuations.

This research also demonstrates the utility of developing more robust chronological control over archaeological deposits that are used to explore the linkages between environmental and social changes and they ways that communities built resilience into their institutions through time. The ability to draw robust and representative correlations between paleoenvironmental proxies and the archaeological records necessitates comparable chronological resolution and precision among the two datasets. Relatedly, as means to bypass the need to correlate disparate datasets, this research demonstrates the utility of paleoenvironmental proxies drawn directly from archaeological/anthropogenic deposits. In such cases the boundaries between human histories and environmental histories become indistinguishable.

Local Manifestations of Global Climatic Trends

Global climatic trends can generally be considered as averages of change and do not accurately reflect the kinds of changes happening in different locales at different spatial and temporal scales across the globe. Indeed, the magnitude of such changes are not uniform across the landscape. Compounding the difficulties of relying on global categories of climatic trends for understanding local environmental histories, is the obvious recognition that profiles of faunal resources also vary globally. Thus, understanding the ecological conditions in the direct vicinity of archaeological interest is critical to understanding how local animal populations, given the characteristics of specific species, were altered (or not) by these climatic episodes. The imperativeness of local reconstructions grows even more critical, then, when interpreting changes to subsistence economies or economies rooted in the exploitation of faunal resources.

Records of past environmental and climatic variability often operate at different scales relative to archaeological inquiry. The use of high-resolution, radiocarbon chronological modelling in this research demonstrates one way to create comparable records for understanding the relationships between past environmental variability and Indigenous economies (Chapter 2). It also allows for the examination of changes to local abundances of taxa at a relatively high temporal resolution (e.g., generational scales or less) (Chapter 2). Like directly leveraging the archaeological deposits at Pineland as a high-resolution environmental record, by directly dating hard clams used for stable isotope analysis at Mound Key, we were able to directly situate the environmental signatures gleaned from the isotopic measurements in time (Chapter 3).

This research demonstrates that generalized models of global climatic change are insufficient for elucidating the complexities socioecological systems and that local environmental conditions remain critical to understanding the contexts in which coastal communities were able to be more or less resilient. In the absence of these local signatures, in concert with high-resolution chronological anchors, it remains difficult to explore environmental histories at a scale that represents the environmental reality faced by people at these places in the past. As we have been able to illuminate here, the pace of environmental impacts related to global climate trends likely did not occur at a rapidity that caused a wholesale collapse of the social and economic institutions of southwestern Florida at the onset of the Little Ice Age. Certainly, some institutions were more resilient than others, but the plasticity of the socioecological system as a whole, by way of a complex entanglement of both natural elements and anthropogenic histories and decisions, contributed to the long-term survivance of Calusa traditions.

Future Research Directions

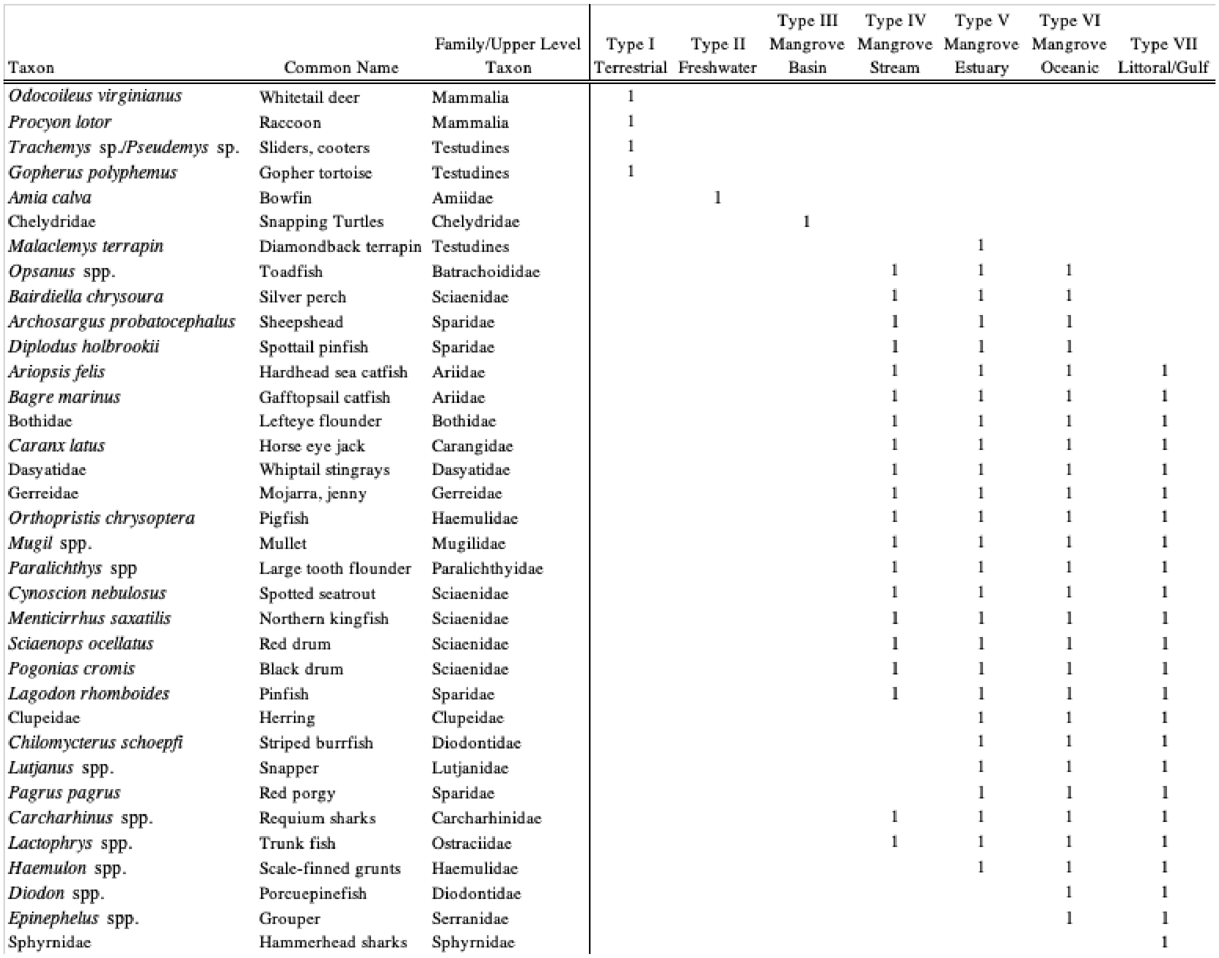
Southwestern Florida harbors a deep archaeological-environmental history that continues to be elucidated through the thoughtful use of various scientific methods including radiocarbon dating, zooarchaeological analyses, and stable isotope analyses. Research into these histories has demonstrated that the combination of diverse datasets and proxies can contribute to exceedingly holistic narratives of the Indigenous past. The rich archaeological record of southern Florida provides many opportunities to further investigate the questions put forth in this research and beyond. The data presented in this dissertation represents initial investigations into these complex human-ecological relationships. Moving forward, we must continue to model local ecological conditions during the Little Ice Age as well as further investigate the economic use of animals beyond subsistence. As I have demonstrated throughout, the use of categorical, global climatic trends is an ineffective way of investigating the complex relationships between human and ecological histories.

The results from Chapter 2 demonstrate the utility of invertebrate assemblages as indicators of localized environmental change in this region. The next step would be to continue to collect small-fraction zooarchaeological samples from coastal sites dating to this time period from both Pineland and across the wider region. It would be most useful to target deposits likely to have been located along the shoreline in the past in direct association with archaeological deposits/sites. The continued use of high-resolution radiocarbon dating will remain key to situating these deposits in time and to exploring the temporality of environmental change and human decision-making. Relatedly, results put forth in Chapter 3 demonstrate the utmost need to continue building a database of stable oxygen isotope data to evaluate local estuarine conditions during the Little Ice Age. The discrepancy between the global characteristics of the Little Ice Age and the results of the stable isotope analysis presented here demonstrate the need for more data to understand these local conditions. Moving forward, the sampling strategy should utilize a multispecies approach, gathering samples from both oysters and hard clams.

Finally, few investigations have been conducted that explicitly consider (and empirically explore) the relationships between large socio-economic centers (like those at Pineland and Mound Key) and the rest of the populace across southern Florida and the wider sociopolitical domain of the Calusa. It remains unclear how life at Mound Key, for instance, differed from life outside of this large political capital. While ethnohistoric accounts give us insight into the role of these important political centers, limited bottom-up approached have been undertaken that actually explore what these regional political and economic institutions looked like materially. A regional survey of contemporary communities outside of these large centers would provide a perspective not often adopted. While modern-day construction has destroyed many of these site, there still exists intact as well as extant data that could contribute to analyses of regional socio-economic networks.

Expanding the studies presented here, these suggestions for future research directions would surely continue to expand our understanding of the ways that the Little Ice Age impacted the estuarine systems of southwestern Florida as well as the ways that Indigenous societies remained resilient in the face of environmental change. I hope that I have successfully demonstrated the importance of using archaeologically derived data to effectively evaluate local environmental conditions. In this way, our archaeological resources represent some of the most robust datasets on deep histories of climatic and environmental change. As Florida (and coastal environments around the world) continues to face many of the ecological and environmental challenges today as it did in the past, these deep histories represent invaluable resources for making sense of our continually changing world.

APPENDIX A - HABITAT DESIGNATIONS FOR VERTEBRATE SPECIES



Taxon	Common Name	Family/Upper Level Taxon	Type I Terrestrial	Type II Freshwater	Type III Mangrove Basin	Type IV Mangrove Stream	Type V Mangrove Estuary	Type VI Mangrove Oceanic	Type VII Littoral/Gulf
Odocoileus virginianus	Whitetail deer	Mammalia	1						
Procyon lotor	Raccoon	Mammalia	1						
Trachemys sp./*Pseudemys* sp.	Sliders, cooters	Testudines	1						
Gopherus polyphemus	Gopher tortoise	Testudines	1						
Amia calva	Bowfin	Amiidae		1					
Chelydridae	Snapping Turtles	Chelydridae			1				
Malaclemys terrapin	Diamondback terrapin	Testudines					1		
Opsanus spp.	Toadfish	Batrachoididae				1	1	1	
Bairdiella chrysoura	Silver perch	Sciaenidae				1	1	1	
Archosargus probatocephalus	Sheepshead	Sparidae				1	1	1	
Diplodus holbrookii	Spottail pinfish	Sparidae				1	1	1	
Ariopsis felis	Hardhead sea catfish	Ariidae				1	1	1	1
Bagre marinus	Gafftopsail catfish	Ariidae				1	1	1	1
Bothidae	Lefteye flounder	Bothidae				1	1	1	1
Caranx latus	Horse eye jack	Carangidae				1	1	1	1
Dasyatidae	Whiptail stingrays	Dasyatidae				1	1	1	1
Gerreidae	Mojarra, jenny	Gerreidae				1	1	1	1
Orthopristis chrysoptera	Pigfish	Haemulidae				1	1	1	1
Mugil spp.	Mullet	Mugilidae				1	1	1	1
Paralichthys spp	Large tooth flounder	Paralichthyidae				1	1	1	1
Cynoscion nebulosus	Spotted seatrout	Sciaenidae				1	1	1	1
Menticirrhus saxatilis	Northern kingfish	Sciaenidae				1	1	1	1
Sciaenops ocellatus	Red drum	Sciaenidae				1	1	1	1
Pogonias cromis	Black drum	Sciaenidae				1	1	1	1
Lagodon rhomboides	Pinfish	Sparidae				1	1	1	1
Clupeidae	Herring	Clupeidae					1	1	1
Chilomycterus schoepfi	Striped burrfish	Diodontidae					1	1	1
Lutjanus spp.	Snapper	Lutjanidae					1	1	1
Pagrus pagrus	Red porgy	Sparidae					1	1	1
Carcharhinus spp.	Requium sharks	Carcharhinidae				1	1	1	1
Lactophrys spp.	Trunk fish	Ostraciidae				1	1	1	1
Haemulon spp.	Scale-finned grunts	Haemulidae					1	1	1
Diodon spp.	Porcuepinefish	Diodontidae						1	1
Epinephelus spp.	Grouper	Serranidae						1	1
Sphyrnidae	Hammerhead sharks	Sphyrnidae							1

APPENDIX B - HABITAT DESIGNATIONS FOR INVERTEBRATE SPECIES,

Taxon	Common Name	Type I Tidal Stream	Type II Mangrove Swamp	Type III Oyster Bed Community	Type IV Seagrass Meadows	Type V Littoral/Gulf
**Blauneria heteroclita*	Left-hand melampus	1				
Cerithidea costata	Costate hornsnail	1	1			
Geukensia granosissima	Southern ribbed-mussel	1	1			
Melampus coffeus	Coffee melampus	1	1			
**Cerithidea scalariformis*	Ladder hornsnail		1			
**Littoraria angulifera*	Mangrove periwinkle		1			
**Melampus bidentatus*	Eastern melampus		1			
**Melampus bullaoides*	Bubble melampus		1			
**Microtralia occidentalis*	Tiny melampus		1			
Brachidontes exustus	Scorched mussel		1	1		
Busycon sinistrum	Lightning whelk		1	1		
Crassostrea virginica	Eastern oyster		1	1		
Diodora cayenensis	Cayene keyhole limpet		1	1		
Nassarius vibex	Bruised nassa		1	1		
Urosalpinx perrugata	Gulf oyster drill		1	1		
Urosalpinx tampaensis	Tampa drill		1	1		
Assiminea succinea	Atlantic assiminea		1		1	
Costoanachis semiplicata	Gulf dovesnail		1	1	1	
Crepidula plana	Eastern white slippersnail		1	1	1	
**Ostreola equestris*	Crested oyster			1		
Anomia simplex	Common jingle			1	1	
Boonea impressa	Impressed odostome			1	1	
Fasciolaria tulipa	True tulip			1	1	
Melongena corona	Crown conch			1	1	
Urosalpinx cinerea	Atlantic oyster drill			1	1	
**Anadara transversa*	Transverse ark				1	
**Argopecten gibbus*	Atlantic calico scallop				1	
**Argopecten irradians*	Bay Scallop				1	
**Atrina spp.*	Pen shell				1	
**Bittiolum varium*	Grass cerith				1	
**Bulla striata*	Striate bubble				1	
**Busycotypus spiratus*	Pearwhelk				1	
**Cerithium eburneum*	Ivory cerith				1	
**Cerithium muscarum*	Flyspeck cerith				1	
**Conus (cf) anabathrum*	Florida cone				1	
**Costoanachis sparsa*	Sparse dovesnail				1	
**Crepidula maculosa*	Spotted slippersnail				1	
**Dinocardium robustum*	Atlantic giant cockle				1	
**Eupleura sulcidentata*	Sharp-rib drill				1	
**Mercenaria campechien*	Southern quahog				1	
**Nitidella nitida*	Glossy dovesnail				1	
**Noetia ponderosa*	Ponderous ark				1	
**Olivella pusilla*	Tiny dwarf olive				1	
**Pilsbryspira leucocyma*	White-knob drilla				1	
**Prunum apicinum*	Common Atlantic marginella				1	
**Pyrgospira tampaensis*	Tampa turrid				1	
**Schwartziella catesbyan*	Catesby's Risso				1	
**Semele proficua*	Atlantic semele				1	
**Strombus alatus*	Florida fighting conch				1	
**Trachycardium egmonti*	Florida pricklycockle				1	
Bulla striata	Striate bubble				1	
Conus spp.	Cone				1	
Acteocina canaliculata	Channeled barrel-bubble				1	1
Cerithium lutosum	Variable cerith				1	1
Chione cancellata	Cross-barred venus				1	1
Hesperisternia multangul	Ribbed cantharus				1	1
Lucinisca nassula	Woven lucine				1	1
Modulus modulus	Buttonsnail				1	1
Neverita duplicata	Shark eye				1	1
Plicatula gibbosa	Atlantic kittenpaw				1	1
Tagelus spp.	Tagelus				1	1
Triplogusus giganteus	Horse conch				1	1
Crepidula fornicata	Common Atlantic slippersnail			1	1	1
Fasciolaria lilium	Banded tulip			1	1	1
Eulimastoma canaliculat	Channeled odostome			1		1
Odostomia laevigata	Ovoid odostome			1		1
Balanus spp.	Acorn barnacles	1	1	1	1	1
Turritella exoleta	Eastern turretsnail		1		1	1
**(cf) Macrocallista nimbo*	Sunray venus					1
**Agathotoma candidissim*	Sugar mangelia					1
**Anomalocardia auberia*	Pointed venus					1
**Arcinella cornuta*	Florida spiny jewelbox					1
**Calliostoma sp.*	Topsnail					1
**Carditamera floridana*	Broad-ribbed carditid					1
**Cerodrillia thea*	Tea drilla					1
**Crassinella (cf) lunulata*	Lunate crassinella					1
**Diplodonta spp.*	Diplodonta					1
**Donax variabilis*	Variable coquina					1
**Geomphus tinctus*	Tinted cantharus					1
**Seila adamsii*	Adams miniature cerith					1
**Solenosteria cancellaria*	Cancellate cantharus					1
**Spisula spp.*	Surf clam					1
**Suturoglypta iontha*	Lineate dovesnail					1
**Tellina spp.*	Tellin					1

*Indicates A Species Unique To A Single Habitat

APPENDIX C - OYSTER MEASUREMENTS, ALL MEASUREMENTS IN MM.

Site	ANTH #	Provenience (Unit-Level-Feature)	Valve Length (LVL)	Hinge Length (LHL)	Valve Height (LVH)	Ratio LVL: LVH
8LL33 Pineland RC	2017-3-46	P-10-99	36.45	9.45	86.26	0.42
8LL33 Pineland RC	2017-3-46	P-10-99	22.19	4.16	33.79	0.66
8LL33 Pineland RC	2017-3-46	P-10-99	39.15	5.09	49.32	0.79
8LL33 Pineland RC	2017-3-46	P-10-99	30.39	5.57	68.95	0.44
8LL33 Pineland RC	2017-3-46	P-10-99	29.98	5.1	54.31	0.55
8LL33 Pineland RC	2017-3-46	P-10-99	34.26	5.26	72.97	0.47
8LL33 Pineland RC	2017-3-46	P-10-99	29.7	5.16	54.52	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	30.77	5.8	51.08	0.60
8LL33 Pineland RC	2017-3-46	P-10-99	26.22	3.31	37.4	0.70
8LL33 Pineland RC	2017-3-46	P-10-99	38.63	9.47	45.51	0.85
8LL33 Pineland RC	2017-3-46	P-10-99	28.92	4.31	53.81	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	32.28	4.05	48.02	0.67
8LL33 Pineland RC	2017-3-46	P-10-99	34.62	5.97	61.63	0.56
8LL33 Pineland RC	2017-3-46	P-10-99	42.32	4.89	77.39	0.55
8LL33 Pineland RC	2017-3-46	P-10-99	35.88	5.82	56.95	0.63
8LL33 Pineland RC	2017-3-46	P-10-99	40.09	6.62	69.58	0.58
8LL33 Pineland RC	2017-3-46	P-10-99	26.74	3.69	53.27	0.50
8LL33 Pineland RC	2017-3-46	P-10-99	30.26	6.17	55.75	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	37.8	6.27	63.97	0.59
8LL33 Pineland RC	2017-3-46	P-10-99	26.19	6.32	59.52	0.44
8LL33 Pineland RC	2017-3-46	P-10-99	28.38	4.32	65.73	0.43
8LL33 Pineland RC	2017-3-46	P-10-99	43.5	5.14	61.53	0.71
8LL33 Pineland RC	2017-3-46	P-10-99	23.88	4.16	38.83	0.61
8LL33 Pineland RC	2017-3-46	P-10-99	28.48	3.82	55.71	0.51
8LL33 Pineland RC	2017-3-46	P-10-99	30.69	4.39	45.69	0.67
8LL33 Pineland RC	2017-3-46	P-10-99	32.74	7.13	60.58	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	36.23	5.2	58.55	0.62
8LL33 Pineland RC	2017-3-46	P-10-99	34.99	4.01	52.46	0.67
8LL33 Pineland RC	2017-3-46	P-10-99	30.68	3.66	52.1	0.59
8LL33 Pineland RC	2017-3-46	P-10-99	27.83	4.96	54.15	0.51
8LL33 Pineland RC	2017-3-46	P-10-99	23.99	4.41	41.45	0.58

8LL33 Pineland RC	2017-3-46	P-10-99	26.85	3.03	43.15	0.62
8LL33 Pineland RC	2017-3-46	P-10-99	27.83	3.68	36.18	0.77
8LL33 Pineland RC	2017-3-46	P-10-99	22.63	4.4	40.44	0.56
8LL33 Pineland RC	2017-3-46	P-10-99	23.4	3.51	46.03	0.51
8LL33 Pineland RC	2017-3-46	P-10-99	31.94	4.08	43.17	0.74
8LL33 Pineland RC	2017-3-46	P-10-99	25.57	3.29	43.75	0.58
8LL33 Pineland RC	2017-3-46	P-10-99	25.82	2.98	43.85	0.59
8LL33 Pineland RC	2017-3-46	P-10-99	22.93	3.2	46.36	0.49
8LL33 Pineland RC	2017-3-46	P-10-99	30.68	3.19	46.17	0.66
8LL33 Pineland RC	2017-3-46	P-10-99	26.95	3.25	45.67	0.59
8LL33 Pineland RC	2017-3-46	P-10-99	26.44	3.82	43.1	0.61
8LL33 Pineland RC	2017-3-46	P-10-99	22.89	3.29	34.68	0.66
8LL33 Pineland RC	2017-3-46	P-10-99	25.06	3.12	41.06	0.61
8LL33 Pineland RC	2017-3-46	P-10-99	22.37	2.64	34.35	0.65
8LL33 Pineland RC	2017-3-46	P-10-99	20.59	2.27	28.6	0.72
8LL33 Pineland RC	2017-3-46	P-10-99	25.36	5.22	32.27	0.79
8LL33 Pineland RC	2017-3-46	P-10-99	22.45	2.94	37.47	0.60
8LL33 Pineland RC	2017-3-46	P-10-99	25.68	2.95	42.82	0.60
8LL33 Pineland RC	2017-3-46	P-10-99	32.96	4.13	44.7	0.74
8LL33 Pineland RC	2017-3-46	P-10-99	22.55	4.57	42.04	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	24.12	4.34	42.07	0.57
8LL33 Pineland RC	2017-3-46	P-10-99	30.28	4.91	43.94	0.69
8LL33 Pineland RC	2017-3-46	P-10-99	23.55	4.11	33.77	0.70
8LL33 Pineland RC	2017-3-46	P-10-99	28.56	3.45	35.26	0.81
8LL33 Pineland RC	2017-3-46	P-10-99	19.59	5.73	38.7	0.51
8LL33 Pineland RC	2017-3-46	P-10-99	17.36	2.38	34.97	0.50
8LL33 Pineland RC	2017-3-46	P-10-99	21.17	5	33.33	0.64
8LL33 Pineland RC	2017-3-46	P-10-99	18.44	3.97	34.11	0.54
8LL33 Pineland RC	2017-3-46	P-10-99	21.86	3.44	33.11	0.66
8LL33 Pineland RC	2017-3-46	P-10-99	21.2	3.3	31.76	0.67
8LL33 Pineland RC	2017-3-46	P-10-99	19.04	3.13	32.93	0.58
8LL33 Pineland RC	2017-3-46	P-10-99	22.77	2.28	28.84	0.79
8LL33 Pineland RC	2017-3-46	P-10-99	17.77	3.43	33.23	0.53
8LL33 Pineland RC	2017-3-46	P-10-99	16.36	2.99	27.41	0.60
8LL33 Pineland RC	2017-3-46	P-10-99	14.49	3.06	27.71	0.52
8LL33 Pineland RC	2017-3-46	P-10-99	14.9	1.12	16.15	0.92
8LL33 Pineland RC	2017-3-46	P-10-99	14.27	2.28	21.59	0.66
8LL33 Pineland RC	2017-3-46	P-10-99	18.41	2.58	18.59	0.99
8LL33 Pineland RC	2017-3-48	P-10-101	24.85	2.56	33.55	0.74
8LL33 Pineland RC	2017-3-48	P-10-101	24.12	2.02	33.53	0.72
8LL33 Pineland RC	2017-3-48	P-10-101	21.3	3.65	38	0.56

8LL33 Pineland RC	2017-3-48	P-10-101	22.88	1.6	24.98	0.92
8LL33 Pineland RC	2017-3-48	P-10-101	25.39	4.11	47.35	0.54
8LL33 Pineland RC	2017-3-48	P-10-101	25.49	2.49	34.15	0.75
8LL33 Pineland RC	2017-3-48	P-10-101	24.84	5	36.89	0.67
8LL33 Pineland RC	2017-3-48	P-10-101	25.65	3.13	55.76	0.46
8LL33 Pineland RC	2017-3-48	P-10-101	26.32	1.21	35.15	0.75
8LL33 Pineland RC	2017-3-48	P-10-101	23.34	3.08	39.02	0.60
8LL33 Pineland RC	2017-3-48	P-10-101	29.26	3.14	39.07	0.75
8LL33 Pineland RC	2017-3-48	P-10-101	32.28	6.17	64.67	0.50
8LL33 Pineland RC	2017-3-48	P-10-101	32.88	4.74	45.67	0.72
8LL33 Pineland RC	2017-3-48	P-10-101	24.28	3.44	36.19	0.67
8LL33 Pineland RC	2017-3-48	P-10-101	19.13	2.28	31.94	0.60
8LL33 Pineland RC	2017-3-48	P-10-101	22.68	2.15	41.69	0.54
8LL33 Pineland RC	2017-3-48	P-10-101	27.9	2.71	44.14	0.63
8LL33 Pineland RC	2017-3-48	P-10-101	31.42	4.37	49.05	0.64
8LL33 Pineland RC	2017-3-48	P-10-101	26.56	6.24	40.38	0.66
8LL33 Pineland RC	2017-3-48	P-10-101	24.11	4.09	35.12	0.69
8LL33 Pineland RC	2017-3-48	P-10-101	26.36	3.43	42.81	0.62
8LL33 Pineland RC	2017-3-48	P-10-101	28.8	3.97	41.85	0.69
8LL33 Pineland RC	2017-3-48	P-10-101	36.79	2.51	36.42	1.01
8LL33 Pineland RC	2017-3-48	P-10-101	22.16	2.15	37.19	0.60
8LL33 Pineland RC	2017-3-48	P-10-101	18.62	1.49	31.35	0.59
8LL33 Pineland RC	2017-3-48	P-10-101	29.12	4.09	56.42	0.52
8LL33 Pineland RC	2017-3-48	P-10-101	28.06	2.63	35.51	0.79
8LL33 Pineland RC	2017-3-48	P-10-101	30.58	4.48	45.82	0.67
8LL33 Pineland RC	2017-3-48	P-10-101	30.22	7.2	51.15	0.59
8LL33 Pineland RC	2017-3-48	P-10-101	25.18	5.95	45.34	0.56
8LL33 Pineland RC	2017-3-48	P-10-101	23.1	4.6	51.15	0.45
8LL33 Pineland RC	2017-3-48	P-10-101	20.57	4.63	45.34	0.45
8LL33 Pineland RC	2017-3-48	P-10-101	34.12	4.95	43.97	0.78
8LL33 Pineland RC	2017-3-48	P-10-101	22.59	3.57	37.86	0.60
8LL33 Pineland RC	2017-3-48	P-10-101	35.55	6.62	54.14	0.66
8LL33 Pineland RC	2017-3-48	P-10-101	28.98	2.6	44.5	0.65
8LL33 Pineland RC	2017-3-48	P-10-101	29.54	3.36	58.34	0.51
8LL33 Pineland RC	2017-3-48	P-10-101	26.22	4.99	36.24	0.72
8LL33 Pineland RC	2017-3-48	P-10-101	26.83	3.04	40.54	0.66
8LL33 Pineland RC	2017-3-48	P-10-101	31.79	2.32	36.1	0.88
8LL33 Pineland RC	2017-3-48	P-10-101	30.47	3.99	37.68	0.81
8LL33 Pineland RC	2017-3-48	P-10-101	33.37	2.3	41.58	0.80
8LL33 Pineland RC	2017-3-48	P-10-101	34.11	5.93	46.03	0.74
8LL33 Pineland RC	2017-3-48	P-10-101	27.99	5.86	41.74	0.67

8LL33 Pineland RC	2017-3-48	P-10-101	31.33	3.02	39.63	0.79
8LL33 Pineland RC	2017-3-48	P-10-101	26.8	5.64	37.97	0.71
8LL33 Pineland RC	2017-3-48	P-10-101	35.57	3.18	39.83	0.89
8LL33 Pineland RC	2017-3-48	P-10-101	25.53	3.8	37.65	0.68
8LL33 Pineland RC	2017-3-48	P-10-101	25.64	5.34	45.34	0.57
8LL33 Pineland RC	2017-3-48	P-10-101	32.47	3.29	39.86	0.81
8LL33 Pineland RC	2017-3-48	P-10-101	39.42	7.23	67.65	0.58
8LL33 Pineland RC	2017-3-48	P-10-101	19.18	4.93	35.5	0.54
8LL33 Pineland RC	2017-3-48	P-10-101	48.52	4.86	48.31	1.00
8LL33 Pineland RC	2017-3-48	P-10-101	30.81	3.25	37.48	0.82
8LL33 Pineland RC	2017-3-48	P-10-101	24.06	2.58	32.9	0.73
8LL33 Pineland RC	2017-3-48	P-10-101	32.23	5.07	43.7	0.74
8LL33 Pineland RC	2017-3-48	P-10-101	18.12	3.67	32.14	0.56
8LL33 Pineland RC	2017-3-48	P-10-101	20.85	3.09	30.02	0.69
8LL33 Pineland RC	2017-3-48	P-10-101	31.71	4.28	44.63	0.71
8LL33 Pineland RC	2017-3-48	P-10-101	41.19	3.73	41.38	1.00
8LL33 Pineland RC	2017-3-48	P-10-101	31.32	2.77	39.96	0.78
8LL33 Pineland RC	2017-3-48	P-10-101	31.49	2.8	38.46	0.82
8LL33 Pineland RC	2017-3-48	P-10-101	28.71	5.86	55.65	0.52
8LL33 Pineland RC	2017-3-48	P-10-101	25.91	3.27	37.08	0.70
8LL33 Pineland RC	2017-3-48	P-10-101	25.06	3.29	30.79	0.81
8LL33 Pineland RC	2017-3-48	P-10-101	25.94	4.18	35.91	0.72
8LL33 Pineland RC	2017-3-48	P-10-101	31.43	6.48	52.18	0.60
8LL33 Pineland RC	2017-3-48	P-10-101	32.46	6.61	40.57	0.80
8LL33 Pineland RC	2017-3-48	P-10-101	28.66	5.1	53.43	0.54
8LL33 Pineland RC	2017-3-48	P-10-101	20.97	4.17	43.41	0.48
8LL33 Pineland RC	2017-3-48	P-10-101	30.04	3.12	37.24	0.81
8LL33 Pineland RC	2017-3-48	P-10-101	50.72	5.73	50.7	1.00
8LL33 Pineland RC	2017-3-48	P-10-101	28.79	3.39	35.82	0.80
8LL33 Pineland RC	2017-3-48	P-10-101	22.82	4.17	45.37	0.50
8LL33 Pineland RC	2017-3-48	P-10-101	26.89	5.4	35.15	0.77
8LL33 Pineland RC	2017-3-48	P-10-101	24.38	3.36	31.38	0.78
8LL33 Pineland RC	2017-3-48	P-10-101	19.66	2.75	34.35	0.57
8LL33 Pineland RC	2017-3-48	P-10-101	31.84	4.45	39.62	0.80
8LL33 Pineland RC	2017-3-48	P-10-101	20.71	3.84	34.3	0.60
8LL33 Pineland RC	2015-16-24	P-1-103	63.9	11.22	80.84	0.79
8LL33 Pineland RC	2015-16-24	P-1-103	46.44	6.33	70.83	0.66
8LL33 Pineland RC	2015-16-24	P-1-103	43.7	7.18	66.28	0.66
8LL33 Pineland RC	2015-16-24	P-1-103	31.2	4.79	55.16	0.57
8LL33 Pineland RC	2015-16-24	P-1-103	29.65	6.61	62.71	0.47
8LL33 Pineland RC	2015-16-24	P-1-103	25.85	3.52	40.68	0.64

8LL33 Pineland RC	2015-16-24	P-1-103	28.81	2.74	38.5	0.75
8LL33 Pineland RC	2015-16-24	P-1-103	27.92	3.71	41.39	0.67
8LL33 Pineland RC	2015-16-24	P-1-103	30.08	6.61	47.66	0.63
8LL33 Pineland RC	2015-16-24	P-1-103	29.55	3.68	40.64	0.73
8LL33 Pineland RC	2015-16-24	P-1-103	23.59	2.15	29.67	0.80
8LL33 Pineland RC	2015-16-24	P-1-103	23.71	3.23	37.1	0.64
8LL33 Pineland RC	2015-16-24	P-1-103	22.3	2.34	27.27	0.82
8LL33 Pineland RC	2015-16-24	P-1-103	17.71	2.38	25.32	0.70
8LL33 Pineland RC	2015-16-24	P-1-103	19.73	3.1	28.4	0.69
8LL33 Pineland RC	2015-16-24	P-1-103	19.09	3.2	26.55	0.72
8LL33 Pineland RC	2015-16-24	P-1-103	26.06	3.43	28.63	0.91
8LL33 Pineland RC	2015-16-24	P-1-103	22.91	3.49	24.73	0.93
8LL33 Pineland RC	2017-3-52	P-10-105	36.59	4.32	26.03	1.41
8LL33 Pineland RC	2017-3-52	P-10-105	24.04	5.96	35.28	0.68
8LL33 Pineland RC	2017-3-52	P-10-105	34.17	4.46	52.57	0.65
8LL33 Pineland RC	2017-3-52	P-10-105	29.27	2.83	36.58	0.80
8LL33 Pineland RC	2017-3-52	P-10-105	29.3	3.49	45.8	0.64
8LL33 Pineland RC	2017-3-52	P-10-105	30.7	3.91	46.86	0.66
8LL33 Pineland RC	2017-3-52	P-10-105	22.91	3.5	47.7	0.48
8LL33 Pineland RC	2017-3-52	P-10-105	40.52	7.24	54.98	0.74
8LL33 Pineland RC	2017-3-52	P-10-105	33.5	8.99	51.48	0.65
8LL33 Pineland RC	2017-3-52	P-10-105	23.88	5.64	40.41	0.59
8LL33 Pineland RC	2017-3-52	P-10-105	39.78	7.71	63.34	0.63
8LL33 Pineland RC	2017-3-52	P-10-105	44.18	7.68	52.29	0.84
8LL33 Pineland RC	2017-3-52	P-10-105	22.26	1.4	29.03	0.77
8LL33 Pineland RC	2017-3-52	P-10-105	24.15	3.7	44.37	0.54
8LL33 Pineland RC	2017-3-52	P-10-105	19.49	3.65	24.45	0.80
8LL33 Pineland RC	2017-3-52	P-10-105	22.65	4.03	43.96	0.52
8LL33 Pineland RC	2017-3-52	P-10-105	20.56	2.82	30.13	0.68
8LL33 Pineland RC	2017-3-52	P-10-105	33.41	11.06	80.9	0.41
8LL33 Pineland RC	2017-3-52	P-10-105	21.13	4.48	45.57	0.46
8LL33 Pineland RC	2017-3-52	P-10-105	18.77	2.63	27.07	0.69

APPENDIX D - OXCAL CODE FOR PINELAND UNIT P-10 BAYESIAN CHRONOLOGICAL ANALYSIS

```
Plot(“Operation P Stratigraphic Chronology”)
{
 Sequence()
 {
  Boundary("Start 8LL33P10");
  Sequence("8LL33P10")
   {
   D_Sequence("Level 105")
   {
    R_Date("UGAMS-37407",1060,20);
    Gap(10);
    R_Date("UGAMS-37406",1050,20);
   };
   D_Sequence("Level 104")
   {
    R_Date("UGAMS-37405",850,20);
    Gap(8);
    R_Date("UGAMS-37404",780,20);
   };
   Phase("Level 103")
   {
    R_Date("UGAMS-37403", 800, 20);
    D_Sequence("Level 103")
    {
     R_Date("UGAMS-37402",800,20);
     Gap(7);
     R_Date("UGAMS-37401",760,20)
     {
      Outlier();
     };
    };
   };
   D_Sequence("Level 102")
   {
    R_Date("37399r", 790, 20);
    Gap(8);
    R_Date("37400r", 810, 25);
   };
```

```
    D_Sequence("Level 101")
    {
     R_Date("37397r", 550, 20)
     {
      Outlier();
     };
     Gap(8);
     R_Date("37398r", 600, 25);
    };
    D_Sequence("Level 100")
    {
     R_Date("UGAMS-37396",560,20);
     Gap(5);
     R_Date("UGAMS-37395",570,20);
    };
    Boundary("Level 99");
    D_Sequence("Level 98")
    {
     R_Date("UGAMS-37392",620,20);
     Gap(11);
     R_Date("UGAMS-37391",590,20);
    };
    D_Sequence("Level 97")
    {
     R_Date("UGAMS-37390",470,20);
     Gap(8);
     R_Date("UGAMS-37389",480,20);
    };
   };
   Boundary("End 8LL33P10");
  };
};
```

APPENDIX E - OXCAL CODE FOR BAYESIAN ANALYSIS OF HARD CLAM RADIOCARBON DATES

```
Plot(Mound Key Isotope Hard Clam Shells)
 {
 Curve("Marine20","marine20.14c");
 Delta_R("LocalMarine",-44,49);
 Sequence()
 {
  Sequence()
  {
   Boundary("Start Shell 1");
   D_Sequence("Shell 1")
   {
    R_Date("45668", 1300, 20);
    Gap(10);
    R_Date("45667", 1240, 20);
    Gap(10);
    R_Date("45666", 1240, 20);
   };
   Boundary("End Shell 1");
  };
  Sequence()
  {
   Boundary("Start Shell 2");
   D_Sequence("Shell 2")
   {
    R_Date("45671", 1220, 20);
    Gap(10);
    R_Date("45670", 1160, 20);
    Gap(10);
    R_Date("45669", 1120, 20)
    {
     Outlier();
    };
   };
   Boundary("End Shell 2");
  };
  Sequence()
```

```
  {
   Boundary("Start Shell 3");
   D_Sequence("Shell 3")
   {
    R_Date("45674", 1140, 20);
    Gap(10);
    R_Date("45673", 1160, 20);
    Gap(10);
    R_Date("45672", 1110, 20);
   };
   Boundary("End Shell 3");
  };
 };
};
```

APPENDIX F - STABLE OXYGEN ISOTOPE MEASUREMENTS ON HARD CLAM (*MERCENARIA CAMPECHIENSIS*) USED FOR ANALYSIS

Site	**Unit**	**Level**	**Shell Sample ID**	**^{13}C vs VPDB, ‰**	**^{18}O vs VPDB, ‰**	**Associated Modelled Radiocarbon Date**
8LL2	L-1	7	8LL2L170332SHE2S1XX	-0.01	1.07	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1WW	-0.32	1.20	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1VV	0.10	0.90	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1UU	0.03	0.55	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1TT	0.24	-0.09	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1SS	0.10	0.31	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1RR	0.08	0.45	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1QQ	0.14	0.14	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1PP	0.05	-0.93	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1OO	0.11	-1.61	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1NN	-0.31	-0.73	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1MM	-0.45	-1.57	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1LL	-0.63	-0.62	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1KK	-0.48	0.04	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1JJ	-0.51	-0.11	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1II	-0.20	1.27	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1HH	-0.35	0.91	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1GG	-0.23	0.91	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1FF	-0.02	0.55	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1EE	-0.23	0.95	*AD 1185 - 1300 (68% probability)*

8LL2	L-1	7	8LL2L170332SHE2S1DD	-0.11	0.03	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1CC	-0.20	-0.60	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1BB	-0.26	-0.38	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1AA	-0.61	-0.59	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1Z	-0.86	-0.39	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1Y	-1.15	-0.65	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1X	-0.88	-0.58	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1W	-0.87	-0.56	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1V	-0.55	0.53	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1U	-0.09	0.47	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1T	-0.07	-0.05	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1S	-0.54	-0.83	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1R	-0.62	-0.48	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1Q	-0.36	0.39	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1P	-0.50	0.13	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1O	-0.30	1.28	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1N	-0.07	1.89	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1M	-0.38	0.95	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1L	-0.35	1.01	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1K	-0.07	1.59	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1J	-0.08	1.69	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1I	-0.18	0.64	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1H	-0.10	0.29	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1G	-0.10	0.32	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1F	-0.21	-0.15	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1E	-0.47	-0.13	*AD 1185 - 1300 (68% probability)*

8LL2	L-1	7	8LL2L170332SHE2S1D	-0.91	-0.46	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1C	-1.02	0.41	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1B	-0.57	0.79	*AD 1185 - 1300 (68% probability)*
8LL2	L-1	7	8LL2L170332SHE2S1A	-0.31	0.03	*AD 1185 - 1300 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1XX	-0.03	-0.15	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1WW	-0.12	-0.19	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1VV	-0.25	-0.84	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1UU	-0.41	-1.71	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1TT	-0.69	-1.09	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1SS	-0.91	-1.30	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1RR	-1.08	-0.50	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1QQ	-0.93	0.53	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1PP	-0.51	0.97	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1OO	-0.32	1.33	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1NN	-0.44	0.88	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1MM	-0.23	0.83	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1LL	-0.24	0.74	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1KK	-0.18	1.28	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1JJ	0.09	-0.34	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1II	0.11	-0.56	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1HH	-0.04	-0.22	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1GG	-0.08	-0.05	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1FF	-0.23	-0.09	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1EE	-0.38	-1.52	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1DD	-0.75	0.36	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1CC	-0.97	-0.24	*AD 1265 - 1370 (68% probability)*

8LL2	O-1	85	8LL2O1851006SHES1BB	-0.90	0.72	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1AA	-1.01	-0.95	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1Z	-0.81	0.27	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1Y	-0.41	1.26	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1X	-0.24	-0.58	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1W	-0.48	0.41	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1V	-0.44	0.41	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1U	-0.78	-0.37	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1T	-1.10	-0.36	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1S	-1.09	-0.47	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1R	-1.05	-1.12	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1Q	-0.99	-1.16	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1P	-0.93	-0.59	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1O	-0.78	0.90	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1N	-0.83	0.58	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1M	-0.82	-0.69	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1L	-0.82	-0.01	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1K	-0.76	0.47	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1J	-0.62	0.49	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1I	-0.38	0.91	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1H	-0.50	-0.36	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1G	-1.38	-1.15	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1F	-0.88	0.33	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1E	-0.47	0.45	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1D	-0.09	-0.34	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1C	0.38	-0.33	*AD 1265 - 1370 (68% probability)*

8LL2	O-1	85	8LL2O1851006SHES1B	0.10	-0.30	*AD 1265 - 1370 (68% probability)*
8LL2	O-1	85	8LL2O1851006SHES1A	-0.41	-1.05	*AD 1265 - 1370 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1YY	0.88	-1.82	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1XX	1.02	-1.33	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1WW	0.72	-2.09	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1VV	0.73	-0.10	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1UU	0.79	-0.58	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1TT	0.60	0.33	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1SS	0.37	-1.19	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1RR	0.44	-1.11	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1QQ	0.29	-2.17	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1PP	0.52	-1.07	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1OO	0.32	-1.12	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1NN	0.42	-0.78	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1MM	0.46	-0.60	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1LL	0.40	-0.06	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1KK	0.46	-0.17	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1JJ	0.40	-0.47	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1II	0.20	-1.17	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1HH	0.28	-1.16	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1GG	0.45	-0.54	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1FF	0.46	1.17	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1EE	0.61	0.82	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1DD	0.39	0.31	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1CC	0.03	-1.21	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1BB	0.03	-1.61	*AD 1345 - 1445 (68% probability)*

8LL2	N-3	75	8LL2N3751661SHE3S1AA	0.39	-0.04	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1Z	0.61	-0.25	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1Y	0.30	-2.18	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1X	0.29	-0.79	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1W	-0.31	-0.61	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1V	-0.38	-0.89	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1U	0.06	-0.44	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1T	0.49	-0.64	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1S	0.54	-0.92	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1R	0.35	0.37	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1Q	0.68	-0.90	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1P	0.31	-1.74	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1O	0.47	-0.24	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1N	0.54	1.13	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1M	0.62	-0.08	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1L	0.55	-1.13	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1K	0.46	-0.42	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1J	0.68	0.84	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1I	0.71	1.04	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1H	0.56	-0.33	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1G	0.56	-0.92	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1F	0.62	-0.69	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1E	0.60	-0.29	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1D	0.29	0.10	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1C	-0.01	-1.69	*AD 1345 - 1445 (68% probability)*
8LL2	N-3	75	8LL2N3751661SHE3S1B	0.10	0.02	*AD 1345 - 1445 (68% probability)*

8LL2	N-3	75	8LL2N3751661SHE3S1A	0.27	0.33	*AD 1345 - 1445* *(68% probability)*