

THE USE OF TAPHONOMIC AND STABLE ISOTOPIC ANALYSIS IN
ARCHAEOLOGICAL SCALLOP DEPOSITS AS A KEY TO HOW NATIVE COASTAL
COMMUNITIES' HARVESTING PRACTICES WERE AFFECTED BY CLIMATIC
CHANGE (A.D. ~850 – 1500), GULF COAST OF FLORIDA

by

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(Under the Direction of Sally E. Walker)

ABSTRACT

The Calusa and Tocobaga were groups native to the Gulf Coast of Florida, who lived primarily on a marine diet and deposited the remains in extensive midden-mounds along the coast. The purpose of my study is to understand their harvesting methods and season of collection through taphonomic and stable isotopic analysis in the context of environmental change. Archaeological assemblages of Bay Scallop shells (*Argopecten irradians*) deposited between A.D. 850 – 1500 were analyzed, which spans the transition from the Medieval Warm Period (MWP) through the start of the Little Ice Age (LIA). My results indicate that there was environmental variation between the MWP and the LIA, likely inducing a shift in harvesting methods from bulk collection to individual collection. However, the season of collection remained consistent as it was likely influenced by the Bay Scallop's ecological response to seasonal change.

INDEX WORDS: Scallops, Taphonomy, Stable Isotopes, Calusa, Tocobaga, southwest Florida, Paleoenvironment, Archaeology, Little Ice Age, Medieval Warm Period

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CHAPTER 1.

INTRODUCTION

The Calusa and the Tocobaga were cultural groups that lived along the Gulf Coast of Florida. They were sedentary fisher-hunter-gatherers that subsisted on a marine-based diet. During their occupation they adapted to various environmental changes. My research focuses on the time period from A.D. 850 – 1500, which includes the climatic interval of the Medieval Warm Period (MWP; A.D. 850 – 1200) and the beginning of the Little Ice Age (LIA; A.D. 1200 – 1850). I conducted taphonomic and stable isotopic ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) analysis on archaeological and modern Bay Scallop (*Argopecten irradians*) shell assemblages. The Bay Scallop is a quick-growing mollusk adapted to living in the highly variable estuary and bay ecosystems.

My research uses taphonomic and stable isotopic analysis to determine the harvesting strategies that were used to collect Bay Scallops with respect to climate-driven resource viability. My objective was to describe the environmental conditions, potential harvesting methods used, and season of collection for each site/climate. I focused on Pineland (8LL33) during the MWP, Bayshore Homes (8PI41) during the MWP, and Pineland during the start of the LIA.

I used taphonomic analysis such as body size and live/dead ratios that provide evidence for harvesting methods. Taphonomic analysis also included age determination at collection for the scallops and their environmental conditions. Stable isotopic analysis provided more robust inferences on the scallop's environmental conditions, age, and season of collection for the two climatic periods.

Past work in archaeology using taphonomic and stable isotopic analyses commonly focusing on season of collection or paleoenvironmental reconstruction. I highlight the benefit of approaching the question of harvesting methods or season of collection through the lens of climatic change.

CHAPTER 2. BACKGROUND

CULTURAL CONTEXT

Evidence of unique and elaborate Native American cultural groups can be found along the coast of Florida dating to over 10,000 years ago (Austin et al., 2008). My research focuses on the Calusa (Southwestern Florida) and the Tocobaga (West-Central Florida). During their time of occupation, the Calusa and Tocobaga built structures and left behind artifacts that can inform archaeologists about their culture and way of life (Thompson et al., 2016). It is essential that these sites are preserved, studied, and documented as the threat of a rising sea level and the demand to urbanize these areas continues to rise (Walker, 2013).

The Calusa and Tocobaga subsisted on a diet that included a variety of marine resources such as bony fish, hard clams, oysters, and scallops (Bullen, 1955; Austin et al., 2008; Marquardt, 2013; Quitmyer, 2013; Savarese et al., 2016). Food refuse like bones and shells were preserved in large midden-mounds that can still be seen today in some locations (Austin et al., 2008; Marquardt, 2013; Austin & Mitchem, 2015). The deposits within these midden-mounds reveal details about cultural aspects such as site use, area of occupation, seasonal harvesting practices, and migration patterns through time in response to climate change (Walker, 2013). There is variability in harvesting strategies across cultural boundaries and climatic intervals due to systematic seasonal resource utilization and controlling environmental conditions (Quitmyer, 2013; Walker, 2013). Factors such as storminess, habitat degradation, water salinity, and temperature can all influence the productivity of food resources through cyclic fluctuations and

long-term climatic shifts (Quitmyer, 2013; Walker, 2013). Productive estuarine environments along the western coast of Florida could be exploited year-round allowing the inhabitants to be generally sedentary (Marquardt and Walker, 2013). These fisher-hunter-gatherers likely employed harvesting strategies on their proximal resources that optimized seasonal fluctuations in resource type and availability within the vicinity of their residence (Marquardt, 2013; Quitmyer, 2013; Thompson et al., 2016).

My research uses bay scallops that were excavated from two sites located on the western coast of Florida: The Pineland Site Complex (Calusa) and Bayshore Homes (Tocobaga; Fig. 1). These cultural groups share many similarities, as they were both fisher-hunter-gatherers with complex social and political organization (Thompson et al., 2016). Throughout their occupation, these groups adapted and evolved in response to cultural and environmental shifts such as population growth or climatic change (Marquardt and Walker, 2013; Austin and Mitchem, 2015; Savarese et al., 2016; Thompson et al., 2016). Archaeologists have identified and defined a cultural chronology for these native groups (Austin et al., 2008; Marquardt and Walker, 2013). The scope of my research specifically focuses on the cultural chronology at Pineland (Calusa) and Bayshore Homes (Tocobaga) within the time interval A.D. 850 – 1500.

ARCHAEOLOGY OF THE CALUSA AT PINELAND

The Pineland Site Complex is in Southwestern Florida on the eastern coast of Pine Island Sound. The site has an area of 2.4 km² in Lee County, Florida and was the heartland of the Calusa between 500 B.C. – A.D. 1710 (Walker, 2013; Savarese et al., 2016). Charlotte Harbor/ Pine Island Sound connects to the Gulf of Mexico through a network of barrier islands and is fed by three rivers (Peace, Myakka, and Caloosahatchee; Walker, 2013). The shallow nature of this

inshore bay, with mangrove forest, mudflats, and extensive seagrass meadows, made Pine Island Sound ideal for supporting a central native population (Marquardt and Walker, 2013; Quitmyer, 2013). The Pineland Site Complex is understood to be one of two central hubs for the Calusa, second to the capital, Mound Key (Thompson et al., 2016). My research used scallops that were excavated from the Pineland site 8LL33 (Fig. 2). Within Pineland there are two multi-mound complexes: Randell Complex (RC) and Browns Complex (BC) separated by the Pine Island Canal (8LL34; Fig.2). The scallop assemblages were excavated from two proveniences within RC, Mound 1 (RCM1) and the Operation P midden excavation site (OP; Fig.2).

The cultural history of the Calusa at Pineland is divided into six periods which, together, make up the Caloosahatchee (Cal.) sequence and include Cal. I, IIA, IIB, III, IV, and V (500 B.C – A.D. 1710; Marquardt, 2013). My study focused on Cal. periods IIB, III, and IV (A.D. 800 – A.D. 1500; Table 1).

Caloosahatchee IIB (A.D. 800 – 1200)

Prior to Cal. IIB, the sea level was relatively low and the Pinelanders had temporarily moved westward to gain access to better fishing grounds (Marquardt and Walker, 2013). In the beginning of Cal. IIB, the climate began to warm, and sea level began to rise, and as a result, Pinelanders moved their settlement landward to drier ground and small regional polities were established (Marquardt and Walker, 2013). The Cal. IIB midden deposits include a high diversity of both finfish and shellfish indicating high productivity in Pine Island Sound (Marquardt and Walker, 2013). More specifically, the midden assemblages from Cal. IIB had lower crown conch numbers and higher eastern oyster numbers than the previous period suggesting that the conditions were more advantageous for oyster populations (Marquardt and Walker, 2013).

Additionally, crested oysters (a non-food mollusk that favors high-salinity waters that encrusted the shells of the eastern oyster) were common, indicating that the waters of Pine Island Sound had higher salinity during Cal. IIB (Marquardt and Walker, 2013). During this time, the Pinelanders used long seine nets, fine-meshed square dip nets and other similar techniques in the shallow seagrass beds to harvest aquatic resources (Marquardt and Walker, 2013).

The Cal. IIB period was also a time of reorganization. In response to a rising sea level and increased storms, the Pinelanders began building linear mounds that ran perpendicular to the shoreline, likely to prevent excessive damage from storms (Marquardt and Walker, 2013). Rising sea level likely promoted the landward expansion of the central canal system by the Calusa for efficient transportation of goods and resources with neighboring communities in central and southern Florida (Marquardt and Walker, 2013). The productive estuarine environment and increased trade established Pineland as a central hub (Marquardt and Walker, 2013). By the end of Cal. IIB, smaller villages were abandoned, and populations began to centralize at Pineland (Marquardt and Walker, 2013). Overall, Cal. IIB was a time of high productivity due to the generally warm climate, which ultimately led to reorganization and initiated centralization (Marquardt and Walker, 2013).

Caloosahatchee III and IV (A.D. 1200 – 1500)

Over the years at Pineland, natural weathering and modern private land development resulted in the loss of archaeological deposits (Marquardt and Walker, 2013). It is likely that deposits associated with Cal. III and IV fell victim to this as they were not well represented at Pineland. The Cal. III (A.D. 1200 – 1350) and Cal. IV (A.D. 1350 – 1500) periods were similar and were associated with a generally cooling climate with less large storm events and a lowered

sea level (Walker and Surge, 2006; Walker, 2013). Assemblages from this time interval reflect a decrease in crested oysters suggesting lowered salinity (Marquardt and Walker, 2013). The Cal. III and IV midden-mound deposits suggest that the marine productivity remained mostly stable with only a slight decrease in diversity (Marquardt and Walker, 2013).

During Cal. III and IV Pinelanders remained year-round inhabitants and built on the centralization that began in IIB (Marquardt and Walker, 2013). The Spanish arrived in the early 1500's marking the end of Cal. IV (Marquardt and Walker, 2013). The Calusa remained inhabitants of Pineland until A.D. 1710 (Marquardt and Walker, 2013).

ARCHAEOLOGY OF THE TOCOBAGA AT BAYSHORE HOMES

Bayshore Homes Site Complex is a 14.16-hectare area off Boca Ciega Bay in West-Central Florida, Pinellas County (Fig. 3; Austin et al., 2008; Austin and Mitchem, 2015). Within this complex, there are three recorded sites: Bayshore Homes (8PI41), Abercrombie Park (8PI58), and Kuttler Mound (8PI10650; Austin et al., 2008). My research focuses on the Bayshore Homes (8PI41) site. Bayshore Homes has four main features: three mounds (mounds A, B, and C), and a large shoreline midden-ridge (Austin and Mitchem, 2015; Fig.3). Bayshore Homes has a complex depositional and occupational history that has been the focus of many studies (Austin and Mitchem, 2015).

The greater Tampa Bay area is associated with the Tocobaga, and their occupation can be categorized into many cultural phases (Austin et al., 2008). Bayshore Homes (8PI41) was occupied twice, separated by a ~300-yr hiatus (Austin and Mitchem, 2015). The first occupation occurred during the Weeden-Island phase of the Manasota (A.D. 140 – 565, Middle Woodland; Bullen 1955; Austin et al., 2008; Austin and Mitchem, 2015). The Weeden-Island phase was

associated with a large, centralized population (Austin et al., 2008). After a ~300-yr site hiatus, Bayshore Homes was reoccupied for a second period during the Englewood phase of the Safety Harbor Period (A.D. 890 – 1390, early Mississippian; Austin and Mitchem, 2015). Safety Harbor is associated with large platform mounds and nucleated villages; it was the cultural climax for the Tampa Bay populations (Bullen, 1955). The scallops in my research were excavated from the shoreline midden ridge and represent the Safety Harbor Period.

The Tocobaga relied primarily on estuarine resources as there is little evidence that extensive agriculture was practiced (Austin et al., 2008). Faunal assemblages indicate that the Tocobaga subsisted on fish, shellfish, and some birds, mammals and reptiles (Austin et al., 2008). The most common food items in midden-mound deposits consisted of mullet, oysters, and scallops with additional invertebrates such as quahogs, lightning whelks and ark shells (Austin et al., 2008). Shell artifacts are the most numerous nonceramic artifact at Bayshore Homes, with shells being used as tools and for ornamentation (Austin et al., 2008). Projectile points, shell weights, and cordage were also recovered from Tocobaga sites, indicating the use of spears and fishing nets to harvest resources (Bullen, 1955).

COLLECTIONS USED IN THE PRESENT STUDY

My study spans 650 years from A.D. 850 – 1500, examining the harvesting practices that two cultural groups, the Calusa (Pineland) and the Tocobaga (Bayshore Homes) used to obtain a common estuarine resource, the Bay Scallop (*Argopecten irradians*). A total of 278 scallops were used for taphonomic analysis (n=10 modern, n=77 Pineland, and n=191 Bayshore Homes). Of the 278 total scallops, 20 were used for stable isotopic analysis (n=1 modern, n=11 Pineland, and n=8 Bayshore Homes). The ten modern scallops were taken live from Tampa Bay in

September 2018 (collected by S. Gieger, Florida Fish and Wildlife). The Pineland Site Complex scallops were excavated from two proveniences within the Randell Complex: Mound 1 (8LL33; RCM1-MWP; n=39) and shoreline Operation P (OP) excavation (8LL33; OP-MWP n=13 and OP-LIA n=25) (Fig.2; Table 1).

The RCM1 scallops were excavated from the slope of Mound 1 referred to as Operation A that took place between 1988 and 1992 (Walker and Marquardt, 2013). The scallops are from A-profile-63 strat 7 (Fig. 4). Radiocarbon age dating (AMS) of marine shell from the same stratigraphic unit revealed the scallops were deposited between A.D. 990 – 1025 during the Cal. IIB Period (Marquardt, 2013; Table 1).

The Operation P scallops were collected from the shoreline of RC in a 4 x 1 x 1 m excavation (Fig. 5). Scallops from strat 2 and 3 were in a non-waterlogged environment, while scallops from strat 4 and 5 were in a waterlogged environment (Fig. 5). The waterlogged environment was an interaction of the midden with the modern water table in the area; the water was brackish. Radiocarbon (AMS) age dating of charred botanicals within OP indicated that the scallops were deposited between A.D. 950 – 1500 representing the transition from Medieval Warm Period into the Little Ice Age (Cal. IIB-IV period; Marquarat, 2013). Scallops from strat 2 – 4 (levels 96 – 104) represent the LIA and are called OP-LIA (n=25; Table 1). Scallops from strat 5 (level 105) represent the MWP and are referred to as OP-MWP (n=13; Table 1).

The Bayshore Homes (BSH) scallops were excavated from test unit 2 (TU2) on the landward side of the shoreline midden ridge in 2008 – 2009. The test pit was dug in 10-cm intervals, where the maximum depth was 101 cm in the west half and 90 cm in the east half of the unit (Austin et al., 2008). Four radiocarbon dates were taken from charred botanicals and bone deposits throughout the test unit. Results indicate that the dates were not chronologically

ordered indicating that this portion of the shoreline midden was likely reworked at some point in the past. However, all dates fall within the MWP. The BSH TU2 scallop shells were all excavated from a non-waterlogged environment and will be referred to as BSH-MWP (Table 1).

ENVIRONMENTAL CONTEXT

Estuarine and bay ecosystems along the coast of Florida like Pine Island Sound and Boca Ciega Bay were the main source for food for native inhabitants. However, these water bodies were highly vulnerable to environmental variability which can change the ecosystemic balance and influence cultural change such as site occupation/use, resource utilization, or harvesting strategies (Walker et al., 2013; Walker, 2013). Throughout their occupation, the Calusa and Tocobaga experienced various climatic episodes. My research focuses on the two climatic intervals that occurred between A.D. 850 and A.D.1500, the Medieval Warm Period (MWP; A.D. 850 – 1200) and the beginning of the Little Ice Age (LIA; A.D. 1200 – 1850). Evidence of these two climatic intervals is generally widespread throughout the North Atlantic region (Walker, 2013).

To understand past climate variability, it is helpful to first understand the relationships ecosystems in Florida have with climate throughout the 20th and 21st century. In present day Florida there are three distinct climatic regions or ecotones based on life-zone mapping of natural vegetation (Walker, 2013). Ecotonal boundaries are defined by regional climate within Florida which grades from a warm temperate/moist forest (north-northwestern Florida) to a subtropical/moist forest (south-southeastern Florida; Walker, 2013; Fig. 6). In Central Florida there is a transitional region that has mostly northern/temperate vegetation in the north grading into more southern/tropical vegetation in the south (Walker, 2013; Fig. 6). As climate changes

(warming/cooling), the boundaries between these regions migrate. A warming climate results in the north/northwest migration of boundaries, and when it cools there is a south/southeastern migration of the boundaries (Walker, 2013). Figure 6 is modified from Walker (2013) to illustrate the predicted ecotonal migration in a warming climate (+2° C, +200 mm precipitation; Fig. 6A) and a cooling climate (-2°C, -200 mm precipitation) compared to the location and temperature/precipitation of modern-day Florida (Fig. 6B). Figure 6 reflects the ecotonal migration with respect to temperature and precipitation changes. However, temperature is the predominant force behind ecotonal migration as changes in precipitation have a comparatively minimal effect (Walker, 2013). This is important to note because even if the climatic change is consistent throughout the entire state, patterns of precipitation can be latitudinally variable and difficult to predict (Walker, 2013). For example, by the end of the 21st century (a warming climate) it is predicted that there will be a 20% increase in precipitation in northern Florida, however, in southwestern Florida, a 5 – 10 % decrease is predicted (Walker, 2013). Therefore, the effects of past climate variability may have had a much different effect on the ecosystems at Boca Ciega Bay (in the north) than it did on the ecosystems at Pine Island Sound (in the south).

The MWP is associated with being generally warm with temperatures peaking around A.D. 1000 associated with an interval of maximum solar activity between A.D. 1000 – 1300 (Walker, 2013). However, the MWP had intermittent short-term cooling events (Walker, 2013). The overall warming was paired with a sea level transgression reaching levels up to 0.3 m above current MSL (La Costa High; Stapor et al., 1991; Walker, 2013). The La Costa High resulted in a ~0.9 – 2.3 m rise in sea level from the previous low during the Vandal Minimum (A.D. 550 – 850). The MWP assemblages at Pineland (Cal. IIB) were diverse and had a high number of crested oysters suggesting the waters of Pine Island Sound had a relatively high salinity

(Marquardt and Walker, 2013). An increase in sea level and solar activity likely resulted in more saline estuarine waters related to increased evaporation (Walker, 2013). While the precipitation data for the MWP is not conclusive for western Florida, there is evidence of increased storminess (Walker, 2013).

The climate at the beginning of the LIA between A.D. 1200 – 1500 was generally cool, interrupted by short-term warmer events (Walker, 2013). The Wolf Minimum (A.D. 1280 – 1340) and the Spörer Minimum (A.D. 1410 – 1510) were periods of low solar activity. These relatively cool temperatures were paired with sea level regressions that culminated around A.D. 1400 (Sanibel II; Stapor et al., 1991; Walker, 2013). Sanibel II resulted in a sea level that dropped 0.3 – 0.6 m below today's MSL which was around 0.6 – 0.9 m lower than it was during the MWP (Stapor et al., 1991; Walker, 2013). The lowest salinity recorded in Puerto Rico during the LIA occurred at around A.D. 1400 (Walker, 2013). The LIA assemblages of Pineland (Cal. III and IV) suggest lower salinity was also the case for Pine Island sound based on the decrease in crested oysters (Marquardt and Walker, 2013). The water freshening was likely a result of the regression and decrease in solar activity causing a seaward shift in the salinity gradient and less evaporation (Walker, 2013). Although, the regional patterns for precipitation along the western Florida are not conclusive, there is no evidence of extreme storminess during the LIA (Walker and Surge, 2006; Walker, 2013).

Overall, there was a shift from a warm saline environment during the MWP to cooler, fresher conditions in the LIA (Walker and Surge, 2006; Marquardt and Walker, 2013; Walker, 2013). Today, Pine Island Sound has a subtropical climate while Boca Ciega Bay is in the transitional zone between subtropical and temperate climate (Walker, 2013). According to Walker's ecotonal model, a warming climate like the MWP would have resulted in a subtropical

climate at Pine Island Sound, similar to present conditions in the region (Walker, 2013; Fig. 6). However, in the LIA, Pine Island Sound would have been a transitional climate suggesting a less defined wet-summer/dry-winter seasonality (Walker, 2013). Boca Ciega Bay would have been in a more sub-tropical climate during the MWP than it is currently, resulting in a more defined wet-summer/dry-winter climate during the MWP than it does today (Walker, 2013). As the climate cooled in the LIA, Boca Ciega Bay would have transitioned completely to a temperate climate. This climate-driven ecotonal migration paired with changes in sea level, salinity gradients, and patterns of storminess likely altered the ecosystem in Pine Island Sound and Boca Ciega Bay (Walker, 2013). Therefore, any resulting change in the distribution and composition of valuable food resources within these water bodies would have required the Calusa and Tocobaga to adapt their resource utilization and harvesting strategies to remain year-long residents or abandon their site in search of more productive fishing grounds.

BAY SCALLOP BIOLOGY

The Bay Scallop (*Argopecten irradians*) is a bivalved mollusk that lives along the eastern coast of the United States (Brand, 2016). Along the Gulf Coast of Florida, they are commonly found protected within the shallow-waters (<12 m) of bay and estuarine environments with a sandy substrate where seagrass is common (Brand, 2016). They live for 1 – 2 years and grow rapidly during that time reaching sizes up to 90 mm (Brand, 2016). However, in Florida, while it's possible for the Bay Scallop to live up to two years it is not common, as they typically die after spawning around 12 – 15 months (Quitmyer, 2013).

Bay Scallops are hermaphrodites and spawn once in their lifetime (Brand, 2016). In northern Florida, they spawn in August, but in southern Florida, they spawn later, between October and December (Brand, 2016). They start out as planktonic larvae and then grow into juveniles that secrete a byssus to attach to seagrass or other surfaces within the bay (Brand, 2016). This attachment allows the new generation from being swept away by currents. In areas with strong currents, the spat survival rate into adulthood was less than in areas with less current (Brand, 2016). Juveniles will detach and settle to the bottom around 20 –30 mm in length (Brand, 2016).

Bay Scallops live at the sediment-water interface and are not likely to recess into the sediment as they are quite mobile as adults (Brand, 2016). They are filter feeders, commonly subsisting on organic matter that is deposited on the surface of the sediment or suspended in the near-bottom water and are also known to resuspend surface sediments by vigorously clapping their valves (Brand, 2016).

Mobility and metabolic activity for the Bay Scallop is dependent on water temperature and salinity. Water temperatures above 32°C are lethal to the scallop, and they may die if salinity drops below 10 PSU in warm weather, but they can withstand lower than 10 PSU during cooler months (Brand, 2016). However, larvae will not attach to seagrass if the salinity is below 11.7 PSU or above 35 PSU, which greatly affects their survival and dispersal (Brand, 2016).

Seagrass beds are critical to the scallop's survival. Not only do seagrass beds offer protection from predators and heavy storms, but they also slow down water currents in normal conditions allowing for higher fertilization rates during spawning (Brand, 2016).

In the gulfs and bays off the Florida coast, the Bay Scallop regularly experiences predation which can negatively impact its overall health. Common predators include gastropods, crabs, and rays (Brand, 2016).

In warmer, more acidic waters, the Bay Scallop's calcium carbonate shell is weaker and the rate at which bioeroding sponges or polychaetes erode their shells increases (Duckworth and Peterson, 2012). Bay Scallops commonly have oysters or other bioencrusters such as slipper limpets (*Crepidula*) or barnacles on their shells which are more common during the hot summer months (Lu and Blake, 1997). While bioencrusters are not necessarily lethal, they can weigh the scallop down making them more susceptible to predation (Lu and Blake, 1997).

Bay Scallops are economically valuable because of their relatively large body size, quick growth rate, and wide distribution along the eastern coast of North America (Brand, 2016). However, dredging practices that destroy seagrass beds and nutrient loading through runoff have had an adverse effect on the once plentiful scallop populations along the Gulf Coast of Florida (Brand, 2016). The population size has decreased to almost zero near heavily urbanized areas where freshwater exchange is low (Lu and Blake, 1997). Efforts are being made to increase the population through the use of monitored artificial estuaries and metapopulation transplantation, but the current state of water quality and the impacts of overharvesting could have lasting adverse effects (Lu and Blake, 1997; Marelli and Arnold, 2001).

Table 1. Overview of the five proveniences (OP-MWP, RCM1-MWP, BSH-MWP, OP-LIA, and Modern) and their associated cultural and climatic contexts.

PROVENIENCES	CULTURE	SHELL AGE	CLIMATE	SEA LEVEL	ARCHAEOLOGY
OP-MWP n=13	Calusa	A.D. 1000 – 1200	MWP (A.D. 850 – 1200) Warm/wet High storminess High Salinity Subtropical moist forest	La Costa High (2.3 – 0.9 m rise in sea level)	Cal. IIB (A.D. 800 – 1200) High crested oyster ratio Thriving fisheries Very diverse faunal assemblages Reorganization Central canal construction complete. Onset of centralization Cal. IIB
RCM1-MWP n=39	Calusa	A.D. 990 – 1025	SAME AS OP-MWP	SAME AS OP-MWP	SAME AS OP-MWP Englewood phase of Safety Harbor (early Mississippian) Large platform mounds and nucleated villages Cultural climax
BSH-MWP n=191	Toocobaga	A.D. 890 – 1270	SAME AS OP-MWP	SAME AS OP-MWP	Cal. III (late) – Cal. IV (A.D. 1200 – 1500) Low ratio of crested oyster similar faunal diversity Stable fisheries No migratory ducks Year-round residency Continued centralization. Presence of foreign stone (trade)
OP-LIA n=25	Calusa	A.D. 1200 – 1500	LIA (A.D. 1200 – 1850) Cool/dry Low storminess Lowered Salinity Transitional: Warm temperate/ =Subtropical moist forest	Sanibel II Low (0.9 – 0.6 m drop in sea level) Major drops at A.D. 1350 and A.D. 1450	
MODERN n=10	Modern	Sept. 2018	Modern	Modern	Modern

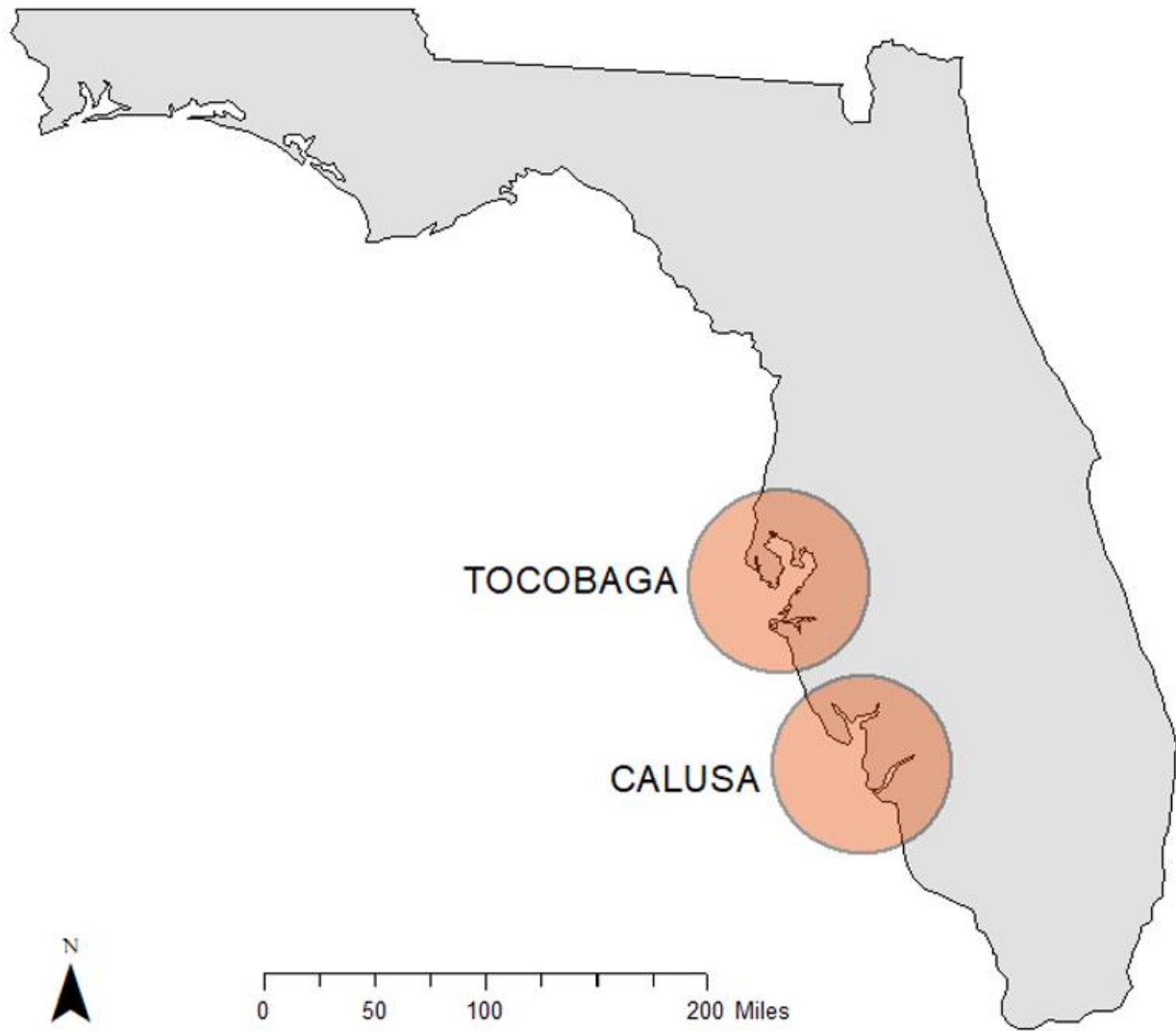


Figure 1. The Tocobaga lived in the Tampa Bay region (West-Central Florida) and the Calusa lived in the Charlotte Harbor region (Southwest Florida).



Figure 2. The Pineland Site (8LL33) includes the Randell Complex and Brown's Complex separated by a central canal (8LL34). Shells from the two Pineland proveniences come from RCM1 (blue oval on the slope of M1) and OP (orange oval on the shore of RC; Modified from Marquardt and Walker, 2013).

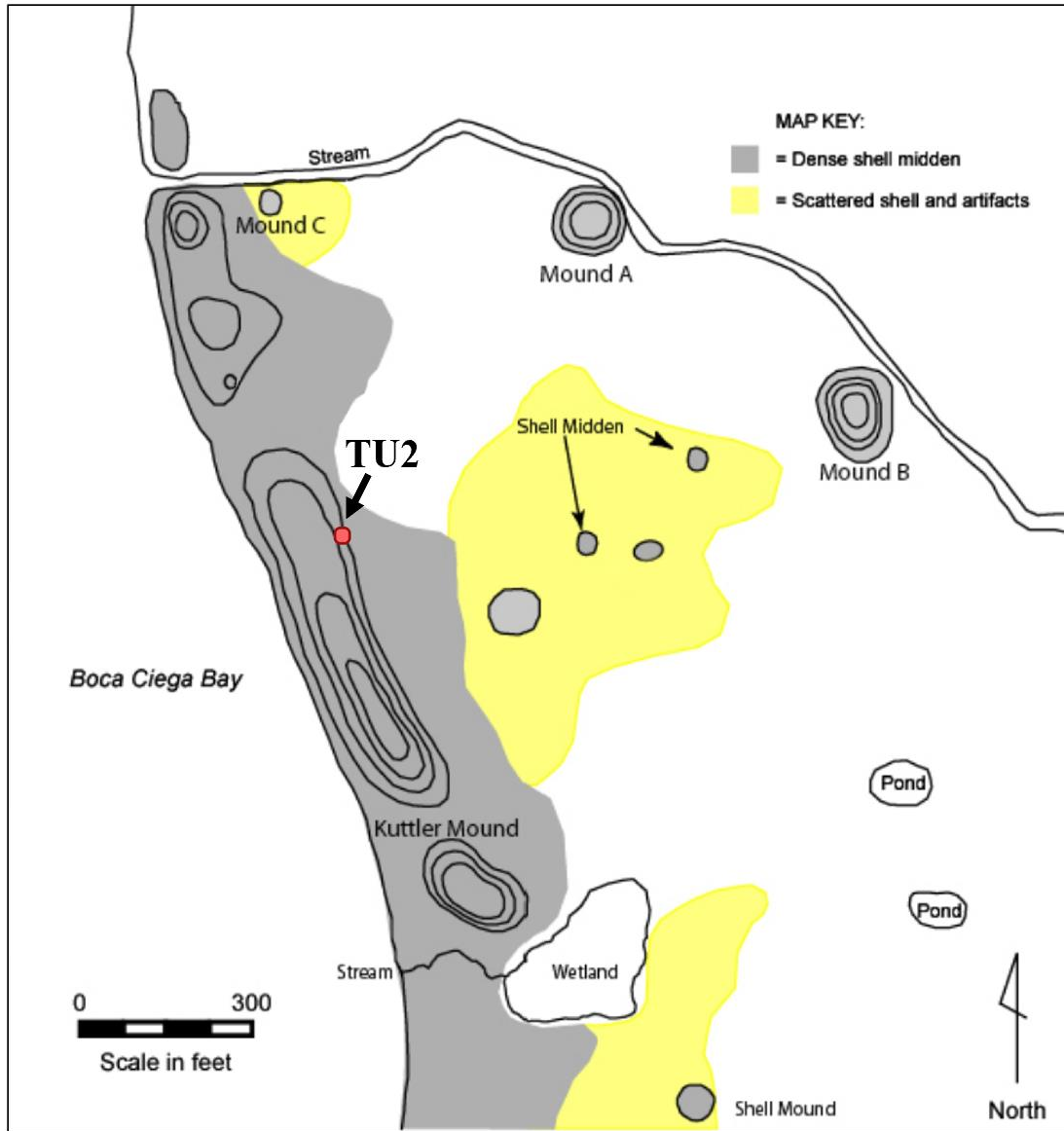


Figure 3. Bayshore Homes is located on the coast of Boca Ciega Bay and the shells used in this study were excavated from TU2 (red dot; modified from Austin et al., 2008).

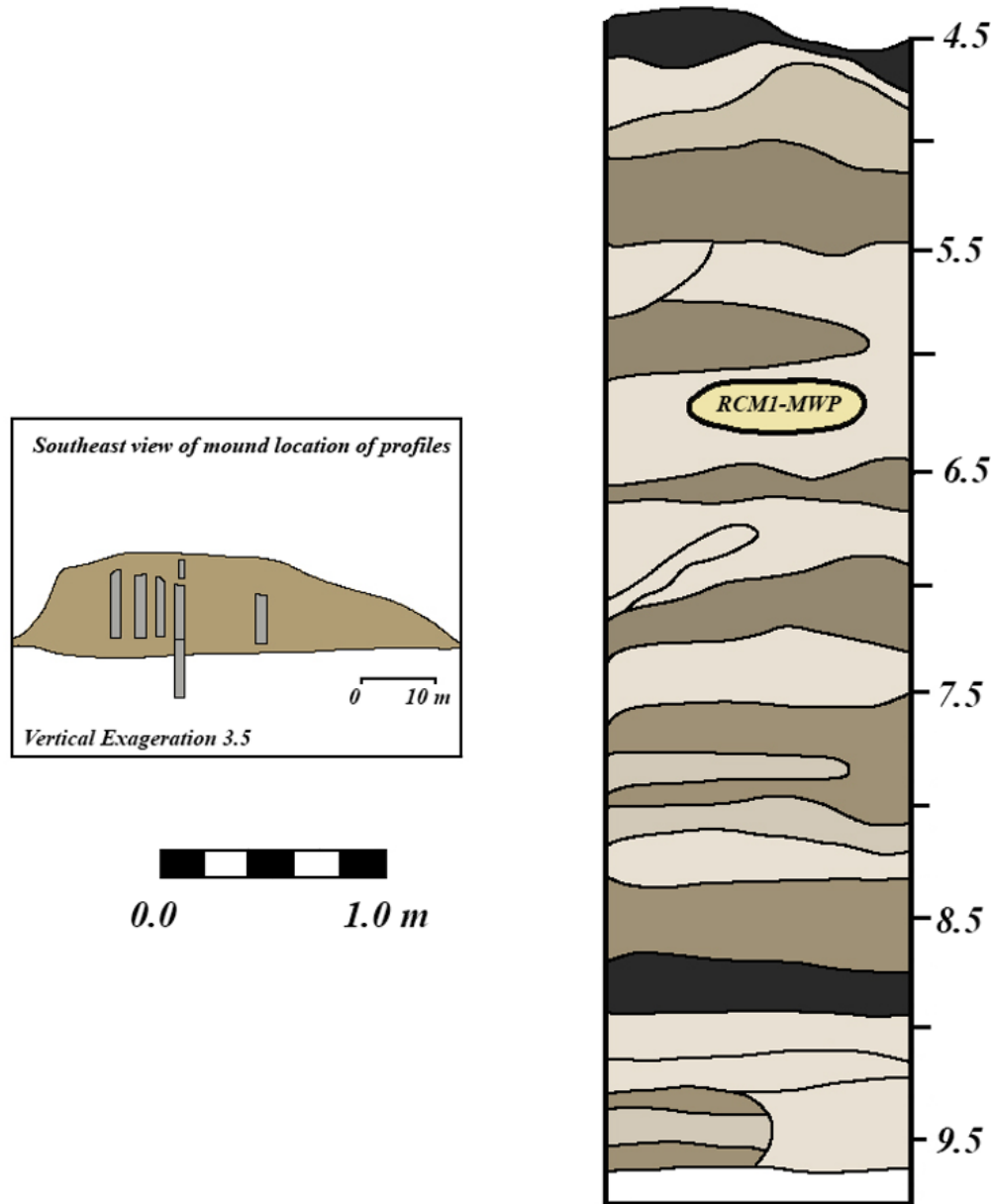


Figure 4. The Pineland RCM1 assemblage (n=39) were excavated from RCM1 (see figure 2), The longest grey bar on the profile view is magnified in the cross-section. RCM1- MWP were excavated from the yellow oval. The colorations within the cross-section indicate grain color (modified from Marquardt and Walker, 2013).

Operation P: East Profile

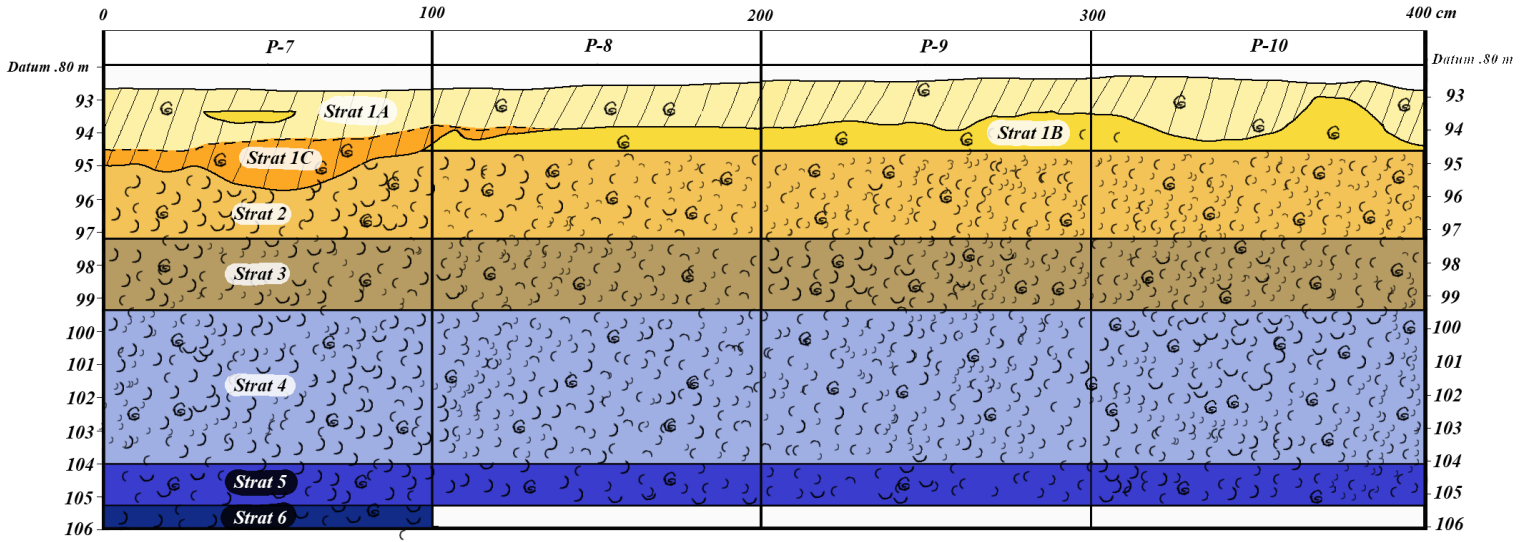


Figure 5. The Pineland OP assemblages were excavated from Operation P on the edge of RCM1 (see figure 2). The numbers along the side indicate 10 cm levels. OP-LIA scallops were excavated from levels 96 – 104 (strat 2 – 4), while OP-MWP scallops were excavated from levels 105 (strat 5). Strat 4 and 5 were waterlogged (indicated in blue; modified from a sketch by Karen Walker, 2020).

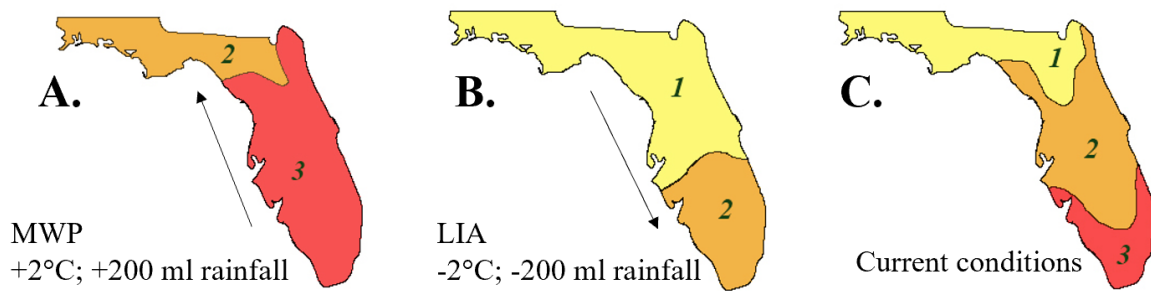


Figure 6. Florida ecotones (Ecotone 1: warm temperate moist forest [yellow]; 2: transitional warm temperate/ subtropical moist forest [orange]; 3: Subtropical moist forest [red]) migrate north with warmer-wetter conditions and down with cooler drier conditions [A. Warmer climate (MWP); B. Cooler climate (LIA); C. Modern climate; modified from Walker, 2013].

CHAPTER 3. TAPHONOMIC ANALYSES

INTRODUCTION

During the MWP and LIA, the Calusa and Tocobaga lived along the Gulf Coast of Florida, leaving behind extensive shell midden-mounds within their sites of occupation (Thompson et al., 2016). The shells and other food refuse found in these structures represent the diet at the time of deposition (Quitmyer, 2013). Common food resources included oysters, hard clams, gastropods, and scallops (Quitmyer, 2013). However, scallop shells are fragile and commonly found as fragments and do not appear in quantities as great as other mollusks. Therefore, they are studied less frequently, so little is known about what they can reveal about a community's diet and harvesting strategies.

This chapter focuses on the taphonomic analysis of Bay Scallop shells excavated from archaeological deposits to understand the harvesting strategies used by the Calusa (Pineland) and Tocobaga (Bayshore Homes). For my research, harvesting strategies encompasses two variables: the season of collection and the method of collection. I define the season of collection to be either: a year-round harvest (throughout all seasons of the year) or a specific season (i.e. spring or summer, for instance). I define the method of collection to be either: bulk collection (using seine or large net, targeting scallop beds with minimal field culling) or individual collection (using hand or small handheld nets, targeting scallop individuals with field culling).

My research focuses on three approaches to taphonomic analysis using body size/age, biotic interactions, and chemical-physical weathering to determine harvesting strategies. For

each assemblage, body size and age analyses were dedicated to examining mean body size, size range, and estimating age. For biotic interactions I looked at the presence/absence of bioeroders and bioencrusters on the shells to determine if the shells were dead at time of collection. For weathering patterns, I looked at physical damage to the shell such as chips or cracks, and for chemical weathering analysis I assigned each shell a taphonomic grade based on chalkiness of the shell related to weathering.

BACKGROUND

Little is known about the specific harvesting strategies used by the Calusa and Tocobaga because there are little to no written historical accounts representing the periods prior to the 16th century (Quitmyer, 2013). Therefore, the use of proxies must be applied to draw reasonable conclusions about the complex human-climate-ecosystem relationship of these native communities. Taphonomic analysis is frequently used in archaeological, biological, and paleoecological studies and can be used to determine relative climatic and marine conditions of the past (Wells et al., 1962, 1964; Wheeler et al., 1975; Ordzie and Garofalo, 1980; Lu and Blake, 1997; Duckworth and Peterson, 2012).

BODY SIZE AND AGE

Body size and age estimates can be used to understand the harvesting strategies of an assemblage. Mean body size of a scallop assemblage can be used to suggest the season of collection. Because they are short-lived and semelparous, Quitmyer (2013) used the body size of the Bay Scallop to determine season of capture. Using a one-year-old scallop, he modeled a seasonal growth curve and suggested scallop assemblages at Pineland with larger mean body

sizes were harvested later in the year than those with smaller mean sizes. Although, variations in growth rate and body size could also indicate over exploitation or poor scallop growth during suboptimal conditions. It has been suggested that native inhabitants will sometimes switch away from procurement if a population begins to show signs of overexploitation (Andrus and Thompson, 2012). My research focuses on more than just body size to determine season of capture.

Body size range of a scallop assemblage can suggest the season of collection as well as the method used to collect the scallops. Quitmyer (2013) suggested that scallop assemblages with a larger age range were likely collected for a longer duration than those assemblages with a smaller size range. However, if comparing the season of collection between two assemblages was solely based on body size, it would have to be assumed that both assemblages spawned at the same time and grew at the same rate. The size range of a scallop assemblage can also indicate the collection method used. Water vessels and tidal processes made exploitation and transportation of large volumes of food resources possible (Andrus and Thompson, 2012). The ability to travel greater distances allowed native inhabitants to target productive ecosystems rather than a specific taxon, so finfish and shellfish would be targeted simultaneously (Andrus and Thompson, 2012). Because they could carry large volumes of food resources, the need for field culling decreased and a wide range of species of all different sizes in all different conditions were brought to residential sites for processing (Savarese et al., 2016). Therefore, if bulk collections were used, then the assemblage would likely have a larger range of sizes than if individuals were selected by hand.

Most Florida Bay scallops die after spawning and as a result only live a year, but it is possible for them to live to be two years old (Quitmyer, 2013; Brand, 2016). Scallops with 2+

annual bands could indicate 2 years of growth and are considered near maximum body size. Therefore, the body size of scallops can suggest collection methods and relative environmental conditions. Scallops deposit an annual line on their shell once a year, so age of the individual can be estimated by counting the number of annual lines on the shell (Barber, 1984). The Bay Scallop grows quickly within the first year to two years of its life, growing faster to larger sizes if the environmental conditions are favorable (Barber, 1984). Scallops that have 2+ annual lines are likely near or at their maximum body size. Scallops near their maximum body mass would be sought after as they would offer the most protein to native inhabitants (Quitmyer, 2013). Therefore, a high frequency of scallops with 2+ annual lines in an assemblage could indicate that the Calusa or Tocobaga were hand selecting individuals for collection during that time. Additionally, the mean body size of scallops with 2+ annual lines from an assemblage could indicate favorable environmental conditions for growth. If conditions are favorable, the mean body size of fully-grown scallops would likely be larger than if the conditions were not conducive for optimal growth (Barber, 1984; Brand, 2016).

ENCRUSTING AND BIOERODING ORGANISMS AND LIVE: DEAD ANALYSIS

Biota preserved on the shells of the Bay Scallop can help illustrate when and how the Calusa and the Tocobaga were harvesting them. Within the bays and estuaries off the gulf coast of Florida the season when scallop's mortality rates are highest from heavy fouling is the hot and rainy summer months (Lu and Blake, 1997). Fouling could influence a higher mortality rate during warm climatic periods like the MWP. Additionally, some fouling/encrusting species are more common in certain environmental conditions. Marquardt and Walker (2013) suggest that a high presence of eastern oysters encrusted with crested oysters indicate higher salinity waters.

Duckworth and Peterson (2012) found that the rate in which *Cliona celata* (a boring sponge) bored into scallop shells doubled in acidic water (low pH causing thinner scallop shells). Excessive boring can cause fatality directly or cause the shell to lose integrity and strength leaving it vulnerable to predation (Duckworth and Peterson, 2012). Another form of bioerosion that can weaken the shells of the Bay Scallop are spionid polychaetes (Wells and Wells, 1962). Spionid borings can cause irritation to the mantle of the scallop, which forms interior mud blisters. Formation of mud blisters inhibits the growth and reproduction of scallops, and if extensive, can cause mortality (Wells and Wells, 1962). Predatory gastropods have a higher rate of attack during the warmer months and on average cause ~75% of attacked scallops to die (Ordzie and Garofalo, 1980). If a high frequency of individuals within an assemblage has multiple taxa of interacting biota on their shells and shells have more predatory drill holes in an archaeological deposit, then it is likely the shells were collected in the summer or during a warmer more saline climate overall like in the MWP.

Interior borings on the shells of scallops, like the ones caused by a successful predatory snail attack, indicate that the individual was dead at the time of capture (Quitmyer, 2013). These live/dead ratios can indicate the harvesting method as dead shells within an assemblage were likely bycatch, a common effect of bulk collection (Savarese et al., 2016).

TAPHONOMIC GRADE

Once deposited, the midden-mound shells are subject to post-depositional weathering. Exposure to air and water might both physically and chemically damage the shell that could alter its composition and luster (Savarese et al., 2016). If weathering is severe, critical taphonomic data such as encrusters or annual lines can be compromised leading to an inconclusive analysis.

However, shells protected in an anaerobic environment like a dense shell midden or waterlogged conditions will likely not be subjected to loss and have a better preservation state (Surge and Walker, 2006; Marquardt and Walker, 2013). That is to say, if an assemblage is heavily weathered, the lack of preserved biota or young age could be explained by a poor post-depositional environment and not as a result of harvesting strategies or the environmental conditions during growth and further analysis would be necessary.

RESEARCH OBJECTIVES

Objective 1: To compare scallops from the same climatic interval but different sites to understand harvesting methods across a cultural/demographic barrier and to compare the MWP scallops from Pineland to the MWP scallops from Bayshore Homes to determine method of harvesting.

Predictions for objective 1: During the MWP, conditions would have been favorable for the scallop population at Pine Island Sound and Boca Ciega Bay (Brand, 2016). The warm saline waters predicted for the MWP would result in a healthy scallop population that reached large sizes at maturity (Barber, 1984; Marquardt and Walker, 2013; Walker, 2013). The warm waters of the MWP would also promote heavy fouling, bioerosion, and predator activity during its increased summer seasonality (Wells and Wells, 1962; Ordzie and Garofalo, 1980; Lu and Blake, 1997; Duckworth and Peterson, 2012). Because of this, I predict that there will be a larger mean body size of scallops with a high diversity of biotic encrusters and bioeroders present within assemblages at Pineland and BSH deposited during the MWP.

The MWP would foster environmental conditions conducive for a healthy scallop population. As a result of healthy scallop populations in productive fishing grounds like seagrass

meadows, I predict that the Calusa and Tocobaga were both employing a bulk harvesting method, targeting scallop beds with seine or drag nets, and not prioritizing field culling (throwing back bycatch) during the MWP. By targeting productive scallop fishing grounds with large drag nets, the Calusa and Tocobaga likely caught a wide range of sizes including juveniles that were still byssally attached to seagrass (<30 mm) or dead shells as bycatch. Therefore, I expect to see a wide range in body sizes with the presence of dead shells in MWP deposits at Pineland and Bayshore Homes.

Objective 2: To understand if the Pinelanders changed their harvesting method as the warm MWP climate transitioned into the cooler LIA.

Prediction for objective 2: As previously stated in prediction one, the MWP is projected to be a productive time for the Pinelanders with a warm, subtropical climate, saline waters and a healthy scallop population (Barber, 1984; Marquardt and Walker, 2013; Brand, 2016). I predicted that the Pinelanders were able to target healthy scallop beds using bulk collection nets resulting in a wide variety of body sizes and the presence of dead shells in deposition during the MWP.

As the climate shifted to the cooler LIA, the shoreline regressed seaward, waters became generally cooler and less saline than they were in MWP (Walker and Surge, 2006; Walker, 2013). Ecotonal migration models also suggest that the LIA resulted in Pineland falling into a transitional zone associated with a less defined wet-summer/dry-winter seasonality (Walker, 2103). I predict that because of the cooler climate and dampened seasonality in the LIA, scallop assemblages will have less encrusting/bioeroding taxa than scallops deposited in the MWP.

Unlike the MWP, there were far fewer scallops deposited during the LIA than the MWP at the location of the OP excavations. This could be a result of scallop population decline in Pine

Island Sound or simply that the Pinelanders were processing and depositing the scallops in an alternate location. With such a small sample size representing the LIA, it is challenging to determine the cause of depositional decline. However, if there was a decline in scallop productivity due to less favorable conditions in the LIA, I predict that Pinelanders would not use bulk collection to target declining populations in the LIA. Instead, I suggest that they collected individuals by hand or by using hand-held small square nets, targeting live, epibenthic scallops, of a specific large size. For scallops collected individually, I would expect that they will have a smaller range in body size (no scallops smaller than 30 mm and possessing a large mean body size compared to the MWP scallops that are predicted to be collected in bulk), and that there will be no dead shells in collection. These results are based on only eight shells, all that were available for the LIA from to OP excavations.

METHODS

BODY SIZE AND AGE

Body size was based on shell height that was measured from the umbo of the shell to the margin that represents when scallop died (measured using an electronic digital caliper with accuracy ± 0.03 mm; Fig. 7). Measurements were taken three times and then averaged; the average was recorded as the final shell height. Some scallops were chipped and damaged to an extent where a reliable height measurement could not be recorded, in which case, the shell length measurement was taken (which is measured perpendicular to the axis of height at the widest point of the shell). The height and length of the shells were highly correlated ($r=0.94$), therefore, length was also a reasonable estimate for body size (Fig. 8). The age of each scallop was

estimated by counting the major annual growth bands recognized by a condensed or raised ridge on the exterior of the shell indicative of a year of growth (Merrill, 1967; Wang et al., 2012; Fig. 7). This method of determining scallop age is an estimate and further investigation using isotopic analysis is necessary to confirm visual age estimations. Environmental disturbance can also cause growth disruptions (shock rings) on scallops and at times can be confused as annual bands (Merrill, 1967). Finally, the valve type of the scallop (left or right) was determined by the characteristic non-symmetrical auricles to ensure that scallops of the same size were not from the same animal (Fig. 7).

BIOLOGICAL TAPHONOMIC ANALYSIS

Biological taphonomic features on shells were recorded including bioencrusters, bioeroders, and evidence of predation (shell repair, drill holes). Bioencrusters attach to the surface of scallop shells usually without eroding the shell. Bioeroders are classified as any type of biota that erodes into the shell leaving permanent cavities. The presence/or absence of bioencrusters and bioeroders was recorded. Scallops with interior drill holes were considered dead at time of collection (Fig. 9).

CHEMICAL-PHYSICAL TAPHONOMIC ANALYSIS

The physical and chemical taphonomic conditions were observed for each scallop. Chemical weathering results in a chalky texture, loss of color, and less defined growth striae (Fig. 10). The extent of weathering for each shell was approximated using visually-assessed percentages and assigned a taphonomic grade (TG). Taphonomic grades ranged from 1 – 5 based

on the percentage of weathering (TG1: 0 – 20% weathering, TG2: 21 – 40% weathering, TG3: 41 – 60% weathering, TG4: 61 – 80% weathering, and TG5: 81 – 100% weathering; Fig. 10).

RESULTS

BODY SIZE/AGE

Mean body size for each of the four archaeological assemblages and modern samples were ranked as follows based on largest to smallest mean body size (shell height): OP-LIA (51.14 mm; largest), OP-MWP (50.55 mm), RCM1-MWP (50.46 mm), Modern (45.5 mm), and BSH-MWP (44.73 mm; smallest; Fig.11). The mean body size for BSH-MWP and OP-MWP were significantly different (t-score= 3.08; d.f.=201; $p < 0.01$). BSH-MWP was also significantly different than OP-LIA (t-score=3.34; d.f.=27; $p < 0.01$).

The range of body size based on shell heights for the five assemblages are as follows: OP-LIA (24.29 – 64.66 mm), Modern (30.91 – 59.97 mm), BSH-MWP (29.56 – 64.24 mm), RCM1-MWP (23.3 – 59.41 mm), and OP-MWP (36.67 – 50.61 mm).

BIOLOGICAL TAPHONOMIC ANALYSIS

Scallops had evidence of encrusters, bioeroders and predation. Bioencrusters included oysters, barnacles, slipper limpets, and worm tubes (Fig. 12). Bioeroders that were commonly seen on the scallops included *Entobia*, spionids, and root traces (Fig. 12). Traces of predation included shell repair and gastropod drill holes (Fig. 12).

BIOENCRUSTERS

All encrusters were absent in OP-LIA, while all four encrusters (oysters, barnacles, slipper limpets, and worm tubes) were present in RCM1-MWP and BSH-MWP assemblages (Fig. 13). Oysters were present in all the MWP assemblages and the modern assemblage; barnacles were present in RCM1-MWP, BSH-MWP, and Modern assemblages; slipper limpets were present in all three MWP assemblages, while worm tubes were present in RCM1-MWP, BSH-MWP, and the Modern (Fig. 13).

BIOERODERS

All of the MWP assemblages had evidence of all three bioeroders (*Entobia*, spionid, and gastropod bore holes), while the LIA assemblage had only spionid and gastropods. The modern assemblage only had spionid present. *Entobia* was present in all MWP assemblages; RCM1-MWP, OP-MWP, BSH-MWP (Fig. 13). Spionid burrows were present in all five assemblages: OP-LIA, OP-MWP, BSH-MWP, RCM1-MWP, and Modern. Gastropod drill holes (both complete and non-complete) were present in all four archaeological assemblages: RCM1-MWP, OP-LIA, OP-MWP, and BSH-MWP.

All three assemblages associated with the MWP had complete gastropod drill holes (indicating mortality prior to collection): RCM1-MWP, BSH-MWP, and OP-MWP (Fig. 14). The OP-LIA assemblage and the live-caught modern shells did not have any interior bore holes indicating mortality prior to collection.

PHYSICAL-CHEMICAL TAPHONOMIC WEATHERING

The four archaeological assemblages had shells assigned to three or more taphonomic grades. RCM1-MWP was the most weathered with a mean of 4.18, OP- LIA had a mean of 4.00, BSH-MWP a mean of 2.76, and OP-MWP had a mean of 2.03 (Fig. 15).

Based on their mean TG, RCM1-MWP and OP-LIA were not significantly different (t-score= -0.64; d.f.= 45; p=0.52). All of the other sites based on mean TG were significantly different from each other: RCM1-MWP and OP-MWP (t-score= -8.73; d.f.= 45; p < 0.00); RCM1-MWP and BSH-MWP (t-score= 10.31; d.f.= 75; p <0.001; OP-MWP and BSH-MWP (t-score= -3.47; d.f.= 218; p <0.001); OP-MWP and OP-LIA (t-score= 4.42; d.f.= 36; p <0.001; BSH-MWP and OP-LIA (t-score= 3.33; d.f.= 196; p= 0.001). The modern shell assemblage has a pristine state of weathering with all of its shells assigned a taphonomic grade of TG1 as they were all collected live.

CONCLUSION/ DISCUSSION

My first objective was to compare scallops from the same climatic interval (MWP) but different sites (Pineland vs. Bayshore Homes) to determine harvesting methods (bulk or individual collection) and season of collection (warm summer/fall or cool winter/spring).

I found that encrusters and bioeroders that favor warmer seasons/climates were frequent in both Pineland and Bayshore Homes MWP assemblages which suggests that the Calusa and Tocobaga shared a similar warm subtropical climate and collected the scallops during or after the hot summer months. Additionally, the MWP assemblages from both sites contained dead shells, which were likely bycatch. Savarese et al., 2013 explains that this kind of bycatch is seen with

clusters of oysters that were collected from intertidal oyster bars. However, if a drag net was used in seagrass meadows it is likely that this same kind of scallop bycatch would end up in deposition. Therefore, I suggest that both the Calusa and Tocobaga were targeting productive seagrass meadows with seine nets to collect both shellfish and finfish during the warm summer/late fall months. The scallop populations in the area would be scooped up along with any bycatch suspended in the seagrass (dead shells).

While scallops from both Pineland and Bayshore Homes suggest a productive, warm, subtropical environment during the MWP, the TU2 excavations at Bayshore Homes retrieved more than three times the number of scallops than OP-MWP and RCM1-MWP combined. The large assemblage from Bayshore Homes could be attributed to a larger scallop population in Boca Ciega Bay than Pine Island Sound during the MWP or that the Tocobaga were placing greater emphasis on scallop procurement during that time.

While the Bayshore Homes assemblage had a greater depositional frequency, the scallops at BSH were significantly smaller than the scallops from OP-MWP. Quitmyer (2013) suggests that scallops of a smaller size indicate an earlier season of harvest. However, both sites had a high frequency of bioeroders and bioencrusters present on the shell indicating that the Calusa and Tocobaga were harvesting during or after the warm summer/fall months. Therefore, it is unlikely that the Bayshore Homes scallops are smaller due to an earlier harvesting season. The smaller size at Bayshore Homes could be due to environmental conditions resulting in slower growth, metapopulation morphology due to overharvesting, or a shorter life span leaving scallops less time to develop prior to collection. If stable isotopic analyses through ontogeny suggests the scallops from Pineland and Bayshore Homes had a similar season of collection, then that would suggest the smaller body size at Bayshore Homes was not due to an earlier season of harvest, but

rather a difference in life span, over harvesting causing population morphology, or unfavorable growth conditions.

My second objective was to understand if scallop assemblages from Pineland exhibit differences in harvesting methods used by the Calusa as the climate putatively shifted from a warm climate in the MWP to a cooler climate in the LIA.

My results indicate that there was no significant difference in body size between the MWP and the LIA scallops, suggesting the conditions for growth were similar during the MWP and early LIA. The lack of diversity in encrustation and bioerosion within the OP-LIA could be indicative of a cooler climate with less acidic waters than what was experienced during the MWP. Although, OP-LIA was heavily weathered, so it may be possible that some of the once existing encrusting biota weathered away over the scallop's depositional history. Not only was there a lack of diversity in biota, but there were also no dead shells present in the OP-LIA assemblage, which suggest the Calusa were employing an individual harvesting method, avoiding bycatch.

The LIA is generally understood to have a cooler climate and lower sea levels than what was experienced during the MWP in Southwest Florida. The lowered sea level may have caused the Pinelanders to experience greater difficulty transporting bulk catch from productive seagrass meadows back to Pineland. Therefore, I suggest that climatic change may have induced a shift from bulk collection during the MWP to a more selective method of harvesting during the LIA, such as individual collection, to avoid unnecessary weight and bulk of bycatch. Stable isotopic analyses will be necessary to confirm if the environmental conditions changed during the transition from the MWP to the LIA.

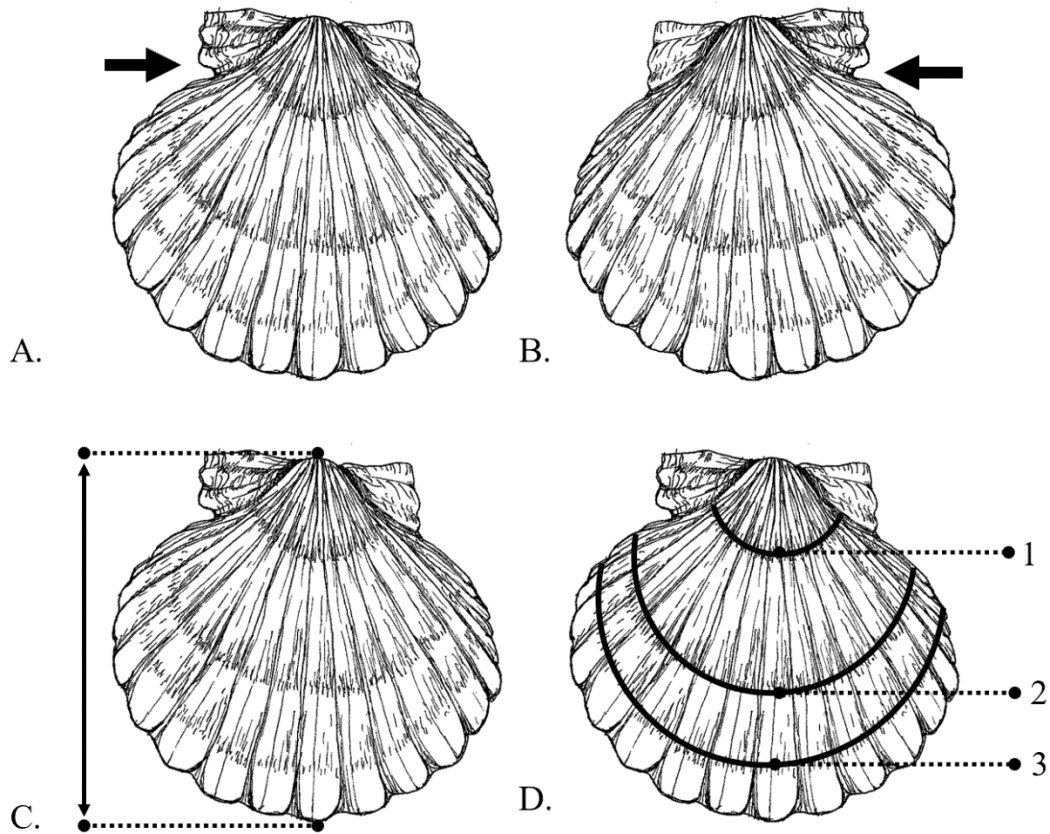


Figure 7. *A. irradians* valve type, body size, and age measurements. **A.** left (top) valve; **B.** right (bottom) valve; **C.** shell height measured from the umbo to the final season of growth; **D.** age estimated by counting the number of annual growth lines.

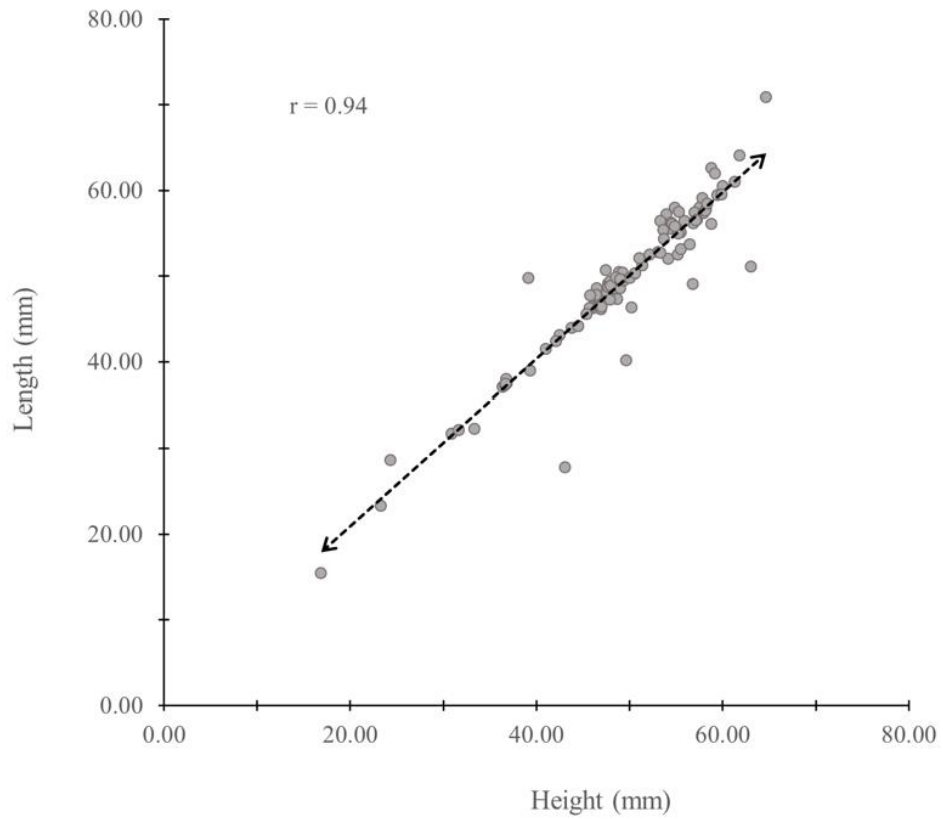


Figure 8. Linear regression to compare shell height to length for *A. irradians*.

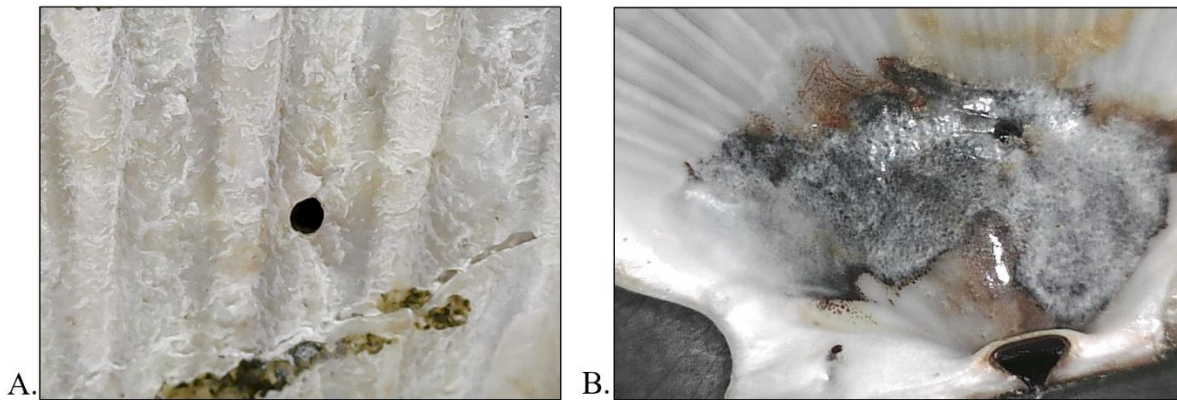


Figure 9. Live vs. dead was based on: **A.** complete gastropod bore hole (dead); **B.** mud blister/ non-fatal interior scarring (live).

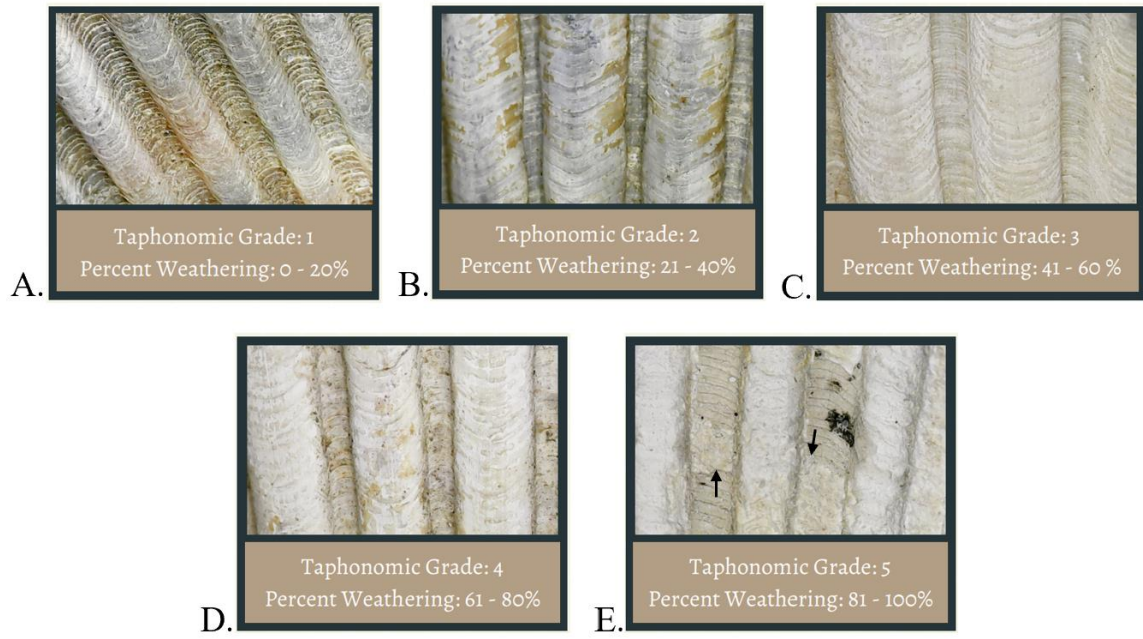


Figure 10. The five taphonomic grades for shell weathering. Black arrows point to dissolution.

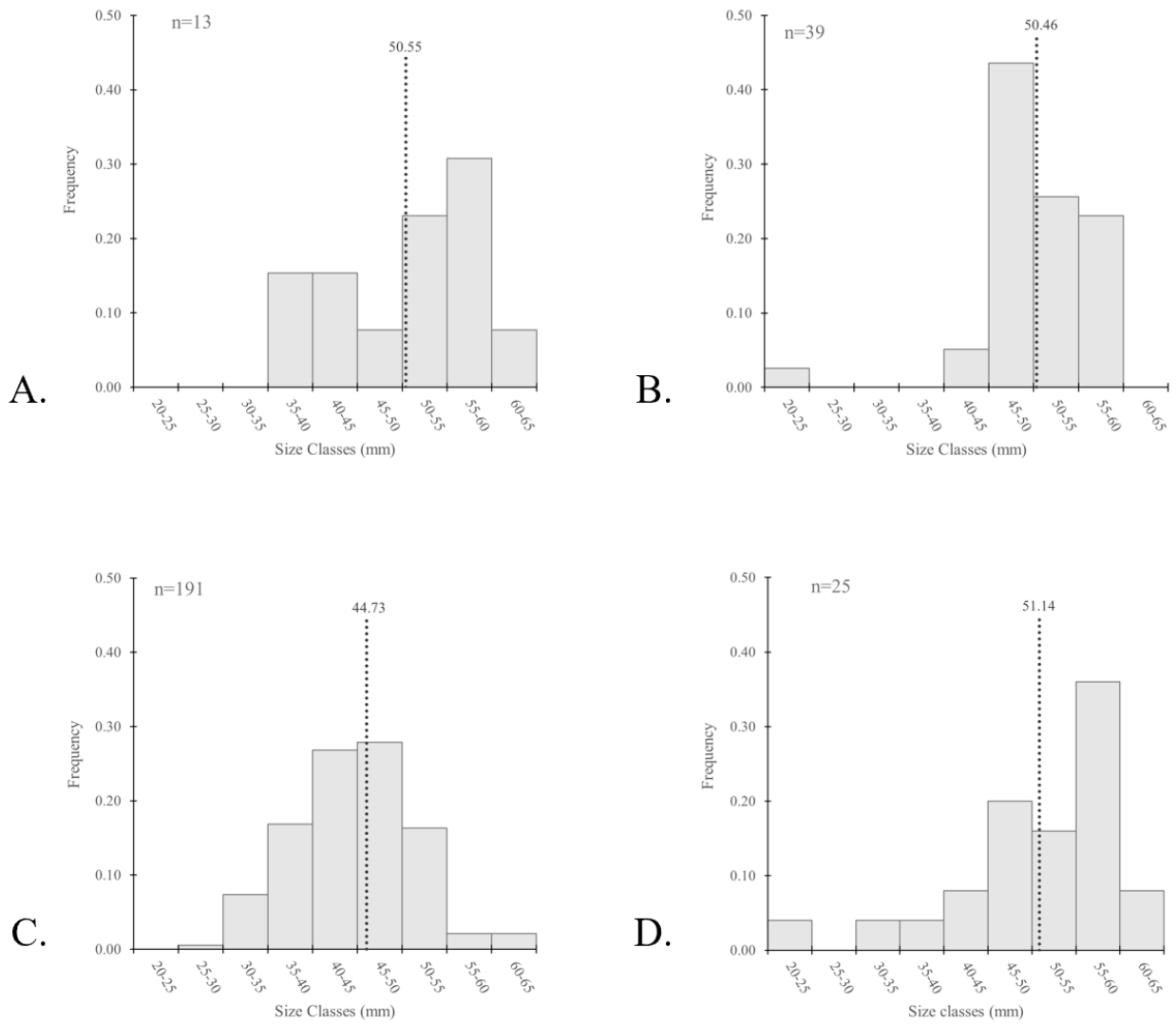


Figure 11. Body size frequency distribution and mean body size for the Medieval Warm Period (A-C) and the Little Ice Age (D): (A) OP-MWP; (B) RCM1-MWP; (C) BSH-MWP; (D) OP-LIA.

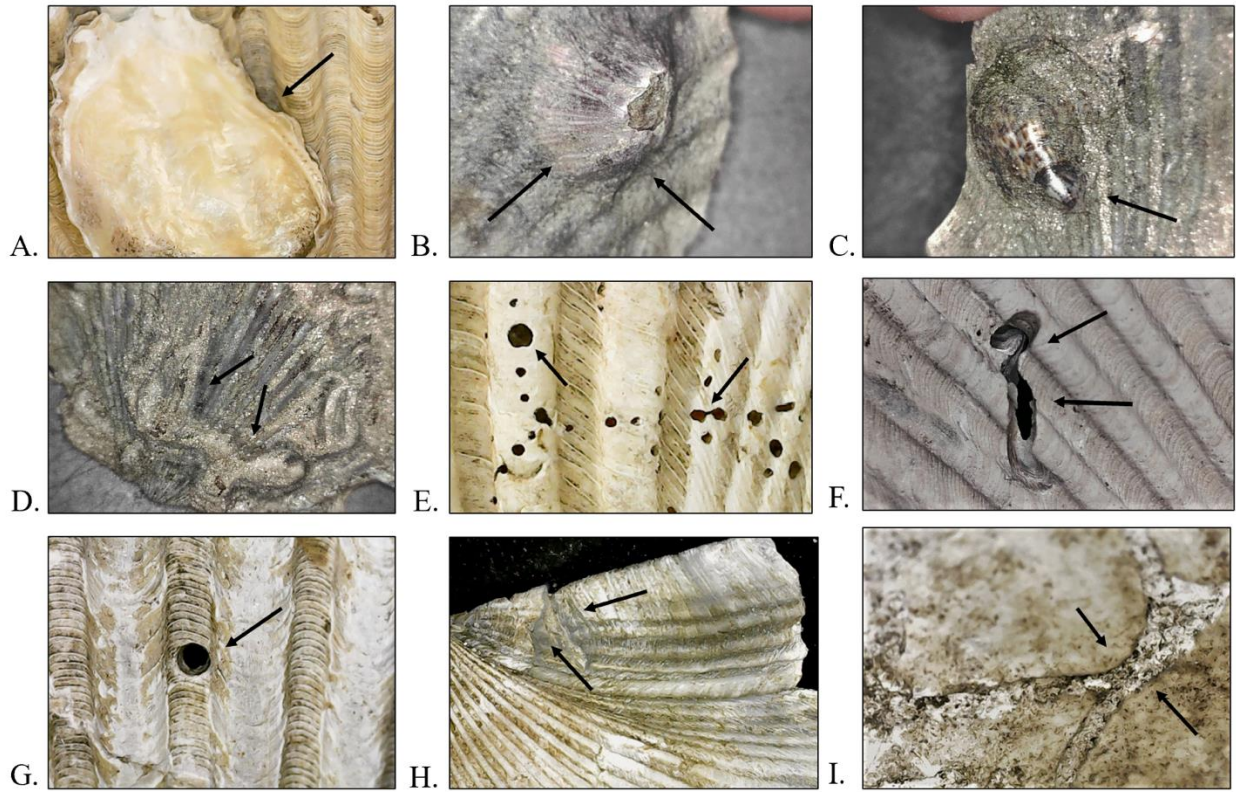


Figure 12. Biota and predation marks on *A. irradians*: **A-D** are encrusters (**A.** oyster, **B.** barnacle, **C.** *Crepidula*, **D.** worm tubes). **E-I** are bioeroders (**E.** *Entobia*, **F.** spionid, **G.** gastropod, **H.** shell repair, **I.** root traces).

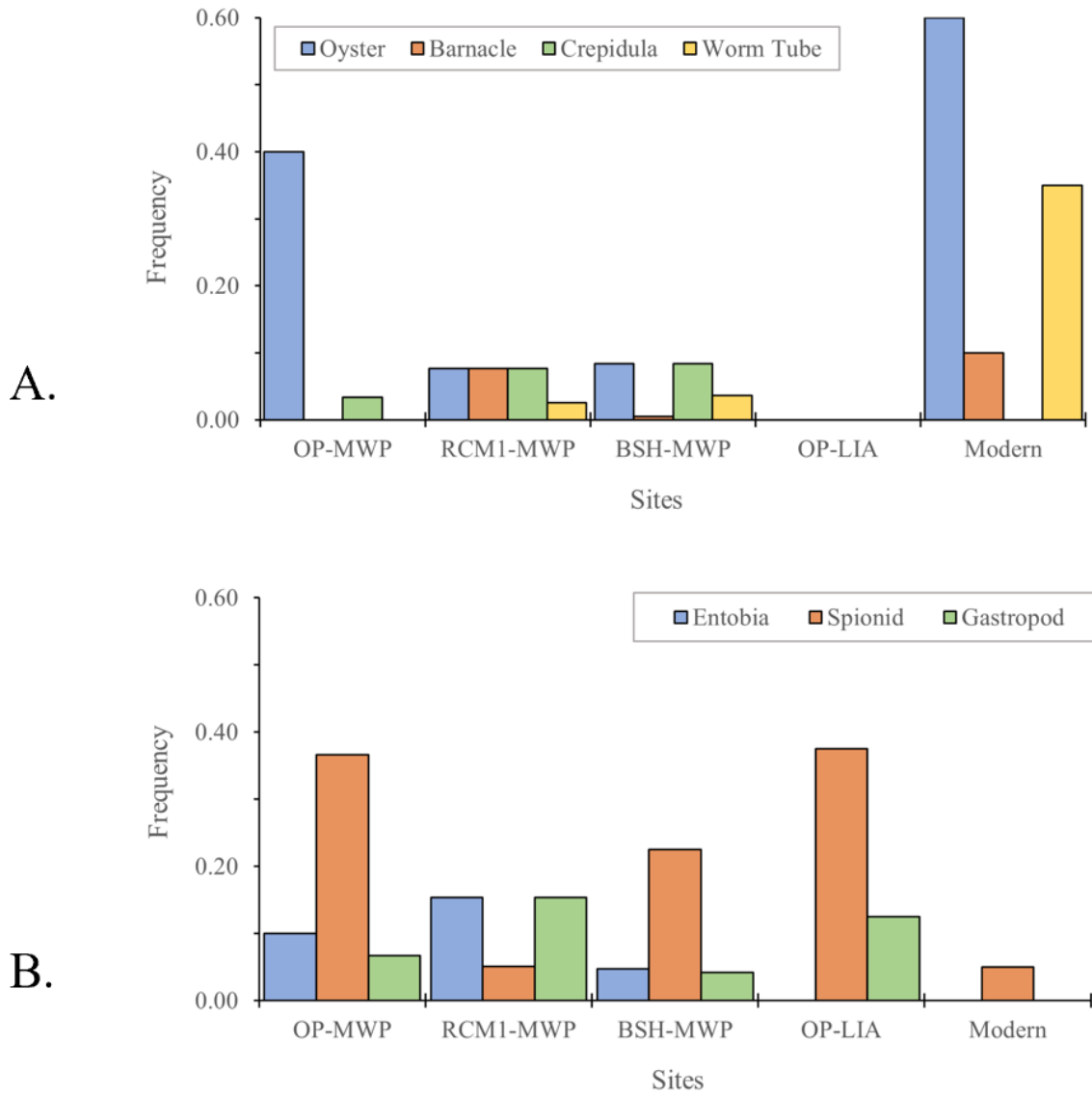


Figure 13. Frequency of shells with bioencrusters (**A**) and bioeroders (**B**).

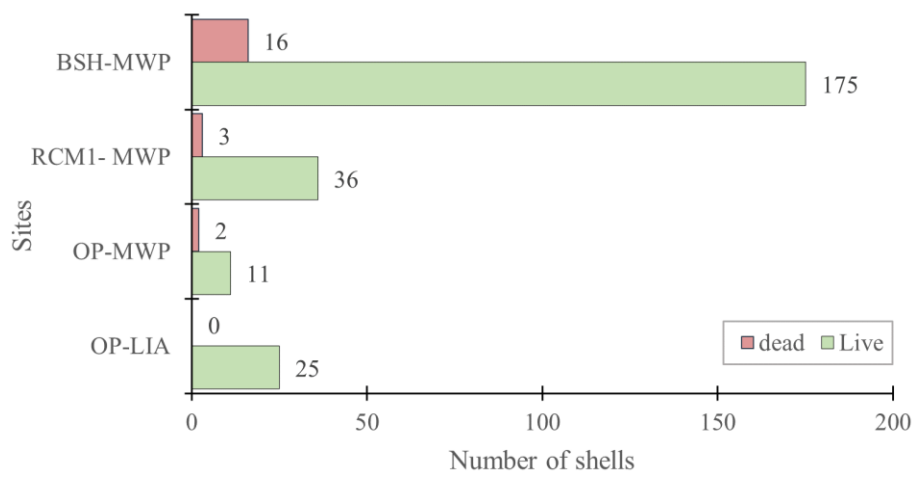


Figure 14. Live/dead ratios for each archaeological assemblage (numbers next to bars indicate number of shells).

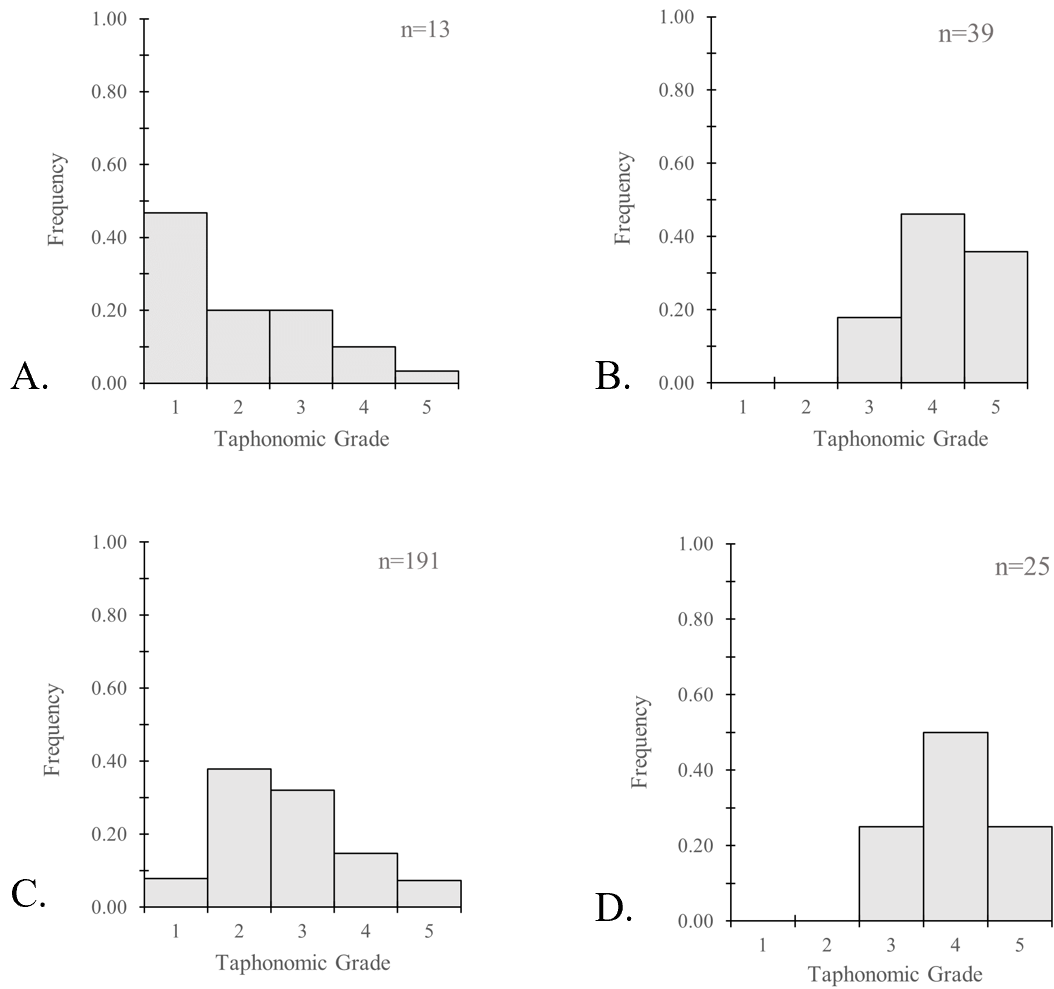


Figure 15. Taphonomic grade frequency distribution of *A. irradians* for each of the archaeological assemblages. **(A)** OP-MWP; **(B)** RCM1-MWP; **(C)** BSH-MWP; **(D)** OP-LIA.

CHAPTER 4.

STABLE ISOTOPIC ANALYSIS

INTRODUCTION

Native coastal hunter-gatherers from Florida, like the inhabitants of Pineland and Bayshore Homes, commonly exploited mollusks from the shallow intertidal zones or seagrass meadows near their site of occupation. The remains of these mollusks end up preserved in large midden-mounds along the coast of Florida. The stable isotopic ratios of oxygen and carbon precipitated in these accretionary carbonate shells preserve paleoenvironmental conditions during their time of growth (Walker, 2013).

In archaeology and paleoclimate studies, oxygen stable isotopes are frequently used to determine relative temperature, seasonality, season of capture, and age of an individual while carbon can be used to assess general metabolic activity and/or marine productivity (Owen et al., 2002; Lorrain et al., 2004; Chauvaud et al., 2005; Gillikin et al., 2006; Prendergast and Stevens, 2006; Walker and Surge, 2006; Andrus and Thompson, 2012; Wang et al., 2013; Leng and Lewis, 2016). Stable isotopic data is used to help understand how native inhabitants procured their resources on a seasonal to centennial scale (Andrus and Thompson, 2012). I applied stable isotopic analysis ($\delta^{18}\text{O}_{\text{shell}}$ and $\delta^{13}\text{C}_{\text{shell}}$) to determine if there was a difference between the Calusa and Tocobaga in season of capture and age the Bay Scallop. Further, while I did not do temperature studies as they are difficult to do for environments with fluctuating salinity (Wang et al. 2013), I did do relative comparisons between warm and cooler climatic trends between the LIA, MWP and modern Bay Scallop.

Within the realm of Florida archaeology, the two bivalves used most often in pre-historical paleoclimate reconstruction are *Mercenaria spp.* (hard clam) and *Crassostrea virginica* (eastern oyster; Andrus and Thompson et al., 2012; Wang et al., 2013). Their abundance in archaeological assemblages, wide temperature and salinity tolerances, and relatively consistent incremental growth are useful for paleoclimate reconstruction. Additionally, the Bay Scallop (*A. irradians*) is also found in midden-mound deposits, but unlike hard clams and oysters who live intertidally, these scallops live fully submerged for the duration of their life and therefore may be more useful for determining seawater conditions.

The Bay Scallop's rate of growth depends on water temperature and food availability. Along the western coast of Florida, they typically grow 3.8 mm to 8 mm per month and can reach sizes of 50 mm in 6 to 8 months (Barber, 1984). They have adapted to a wide range of salinity (15 – 35 PSU; optimal is 23 – 32 PSU) and temperatures (15 – 32°C; optimal ~ 30° C) which allows them to live in variable estuarine ecosystems year-round. In general, scallops make excellent high-resolution paleoclimate indicators (Owen et al., 2002; Chauvaud et al., 2005).

OXYGEN STABLE ISOTOPIC ANALYSIS

The $\delta^{18}\text{O}$ ratios of carbonate shells can be used to reconstruct paleoenvironmental conditions during the scallop's life. $\delta^{18}\text{O}$ is the ratio between the heavy ^{18}O

and the lighter ^{16}O and is determined as follows:

$$\left(\left(\left(\frac{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{sample}}}{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{Standard}}} \right) - 1 \right) \times 1000\text{‰} \right)$$

It has long been understood that oxygen isotopes in CaCO_3 marine shells are a promising tool for paleotemperature and paleoenvironmental analysis especially within an archaeological context (Hickson et al, 1999; Owen et al, 2002; Wang et al, 2013; Leng & Lewis, 2016). The $\delta^{18}\text{O}_{\text{shell}}$ is influenced by water temperature and the isotopic chemistry of the water ($\delta^{18}\text{O}_{\text{water}}$; Prendergast and Stevens, 2006).

My research focuses on using $\delta^{18}\text{O}_{\text{shell}}$ of the Bay Scallop to characterize the relative temperature (warmer/colder), seasonality, age, season of capture for scallop assemblages deposited during the MWP and LIA to reconstruct inferences about the environmental productivity, harvesting methods and season of collection employed by the Calusa and Tocobaga.

In subtropical regions like Florida, $\delta^{18}\text{O}_{\text{shell}}$ has an inverse relationship with temperature. That is, a more negative ratio for $\delta^{18}\text{O}_{\text{shell}}$ occurs for hot summer months and a more positive $\delta^{18}\text{O}_{\text{shell}}$ ratio occurs for cooler winter months (Prendergast and Stevens, 2006). The $\delta^{18}\text{O}_{\text{water}}$ has a positive correlation with salinity; as the water becomes more saline, the $\delta^{18}\text{O}_{\text{water}}$ becomes more positive therefore making the $\delta^{18}\text{O}_{\text{shell}}$ become more positive (Owen et al., 2002; Prendergast and Stevens, 2006; Walker and Surge, 2006; Wang et al., 2013); the opposite occurs when seawater is freshened by rain water or freshwater runoff.

The overall mean of $\delta^{18}\text{O}_{\text{shell}}$ will reveal the relative temperature of the water during time of growth for that individual (Andrus and Thompson, 2012). For estuarine environments, it is difficult to determine the exact paleotemperature considering the high temporal variability of salinity fluctuations (Walker and Surge, 2006; Andrus and Thompson, 2012; Wang et al., 2013). Even when modern water temperature and salinity data are available, pre-historic climatic shifts could have altered sea level, position of the saltwater wedge, or rate/frequency of precipitation

which all affect $\delta^{18}\text{O}$ (Wang et al., 2013). Consequently, these unknown variables of past climate can skew the outcome of temperature equations by amplification or dampening the $\delta^{18}\text{O}_{\text{shell}}$ (Walker and Surge, 2006; Wang et al., 2013). Reconstructing past temperature variability is outside of the scope of my research, but I aim to generally interpret more positive or more negative $\delta^{18}\text{O}_{\text{shell}}$ ratios to determine cooler and warmer intervals, respectively.

Regions where there is seasonal temperature fluctuation like at Pineland and Bayshore Homes, the $\delta^{18}\text{O}_{\text{shell}}$ ratios reflect seasonal variation (seasonality; Walker and Surge, 2006; Andrus and Thompson, 2012; Wang et al., 2013; Quitmyer, 2013). If multi-seasonal analysis is done, the $\delta^{18}\text{O}_{\text{shell}}$ will reflect a sinusoidal curve where summer is represented by more negative ratios and winter by more positive ratios (Prendergast and Stevens, 2006; Wang et al., 2013). For Pine Island Sound and Bayshore Homes the water temperature within the bays ranges from 10 – 35° C annually. Assuming the salinity range is negligible, the $\delta^{18}\text{O}_{\text{shell}}$ could have an amplitude (peak to trough) of 5‰ (0.2‰/°C; Wang et al., 2013). Therefore, the average amplitude of an assemblage ($\delta^{18}\text{O}_{\text{shell}}$) should represent the seasonal variation in temperature and salinity experienced during that time interval. Conversely, if salinity was variable, it could cause an amplified or dampened seasonality. For example, if you had dry winters the $\delta^{18}\text{O}_{\text{shell}}$ would appear more positive, or wet summers, the $\delta^{18}\text{O}_{\text{shell}}$ would reflect more negative values. Therefore, a subtropical climate, with strong wet-summer/dry-winter seasonality, the $\delta^{18}\text{O}_{\text{shell}}$ would appear amplified.

Wanamaker et al. (2011) suggests that bivalve fossils (*Arctica islandica*) from the MWP had a decreased seasonal amplitude than those from the early LIA indicating cooler summers and warmer winters during the MWP in the Gulf of Maine, USA. This could indicate that scallop assemblages from Pineland and Bayshore Homes deposited during the MWP may have a smaller

amplitude than those from the LIA. However, Walker and Surge (2006) suggest that the northern latitudes of the US experienced more severe cooling impacts during the LIA than compared to southern Florida. They applied stable isotopic analysis to *Mercenaria* shells and catfish otoliths and suggested that during the LIA, Pinelanders experienced mild but consistently cooler temperatures (Walker and Surge, 2006). In addition, modeled patterns of ecotonal migration suggest that the transitional climate currently experienced in Central Florida likely moved south during the LIA resulting in a less defined wet-summer/dry-winter seasonality at Pineland (Walker, 2013). Furthermore, LIA faunal assemblages at Pineland do not include migratory bird bones suggesting the winters were not extreme (Marquart and Walker, 2013) Therefore, the increased LIA seasonality experienced in Maine was likely not the case in Southern Florida, and seasonality can vary across latitudes.

The $\delta^{18}\text{O}_{\text{shell}}$ derived relative temperature (that is, warmer or cooler) and seasonality (dampened or amplified) can demonstrate the paleoclimate throughout an individual's interval of growth. Relative temperature and seasonality coupled with physical indicators of growth (or growth cessation) on the shell (annual or shock lines) can be matched with corresponding isotopic records illustrating the environmental parameters that potentially influenced an ecological response in the scallop (stunted or accelerated growth; Wheeler et al., 1975).

Paleoclimate information offers insight about the temporal patterns of growth so long as carbonate samples are taken at consistent increments following the axis of shell growth (Prendergast and Stevens, 2006). For example, age estimates can be made by identifying how many seasons the scallop lived through (Prendergast and Stevens, 2006). The position of annual lines along a $\delta^{18}\text{O}_{\text{shell}}$ curve can indicate the season in which the scallop altered growth rate or if shock lines are associated with unfavorable short-term environmental conditions (Hollyman et

al., 2013). Barber (1984), suggest that on the onset of spring when waters begin to warm the Florida Bay Scallop will deposit a spring ridge on its shell during a period of rapid growth.

The topic of interest in many archaeological studies is season of collection. For an individual, the $\delta^{18}\text{O}_{\text{shell}}$ sampled from the final edge of growth represents the season of procurement (Prendergast and Stevens, 2006). Seasonal extremes like summer or winter are typically associated with the minimum and maximum intervals on a $\delta^{18}\text{O}_{\text{shell}}$ curve, respectively (Walker and Surge, 2006; Wang et al., 2013; Prendergast and Stevens, 2006; Leng and Lewis, 2016). However, if the final growth occurs during a marginal season (fall/spring) then the analyst must determine the direction of change approaching the final edge (Prendergast and Stevens, 2006). If $\delta^{18}\text{O}_{\text{shell}}$ from the weeks or months prior to fatality progressively become more negative, it is likely a spring collection, while becoming more positive suggests cooling and a likely fall season of capture.

If all the shells in an assemblage are collected during the same season, it is probable that the native inhabitants during that time were employing a seasonal harvesting strategy.

Determining the time of harvest can be helpful to understand resource exploitation. For scallops at Pineland, Quitmyer (2013) proposed they were being harvested during late summer/early fall at near peak body mass prior to natural population mortality induced by annual spawning.

Therefore, the $\delta^{18}\text{O}_{\text{shell}}$ sample associated with the final season of growth would be the most negative ratios (summer) to ratios slightly more positive (early fall) for Pineland assemblages.

Overall, the $\delta^{18}\text{O}_{\text{shell}}$ of Bay Scallops have the potential to be a high-resolution paleoclimatic indicators. The inferred paleoclimate data such as relative temperature (warmer or cooler) and seasonality (dampened or amplified) can be used to reconstruct the age and identify

the conditions resulting in non-optimal growth (annual or shock lines). The increment of final growth in relationship to its position on the curve indicates the season of capture.

CARBON STABLE ISOTOPIC ANALYSIS

$\delta^{13}\text{C}$ is a ratio between the lighter 12-carbon and the heavier 13-carbon and is determined as follows:

$$\left(\left(\left(\frac{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{sample}}}{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{Standard}}} \right) - 1 \right) \times 1000\text{‰} \right)$$

The partitioning of carbon stable isotopes in marine shells is quite complex but generally can be related to the environmental $\delta^{13}\text{C}_{\text{DIC}}$ and metabolic $\delta^{13}\text{C}$ (Lorrain et al., 2004). For my analysis, I will be using $\delta^{13}\text{C}_{\text{shell}}$ as an indicator of metabolic activity. As scallops age their growth rate slows down resulting in $\delta^{13}\text{C}_{\text{shell}}$ progressively becoming more negative (Lorrain et al., 2004). For *A. irradians* populations near Tampa Bay, there are distinct periods of energy storage, reorganization, and expenditure as a genetic response to their environment (Barber, 1984). The Bay Scallop's rate of growth, development, respiration, feeding volume, and reproduction are dependent on temperature, salinity, and food availability (Barber, 1984; Kirby-Smith and Barber, 1974; Lorrain et al., 2004; McConnaughey and Gilikin, 2008). Therefore, it is possible that juvenile scallops grow fast (have higher metabolic activity) and thus more positive $\delta^{13}\text{C}_{\text{shell}}$ in their shells compared to older scallops after spawning indicative of more negative $\delta^{13}\text{C}_{\text{shell}}$. These changes could indicate changing environmental conditions, as well if coupled with $\delta^{18}\text{O}_{\text{shell}}$ comparisons.

OBJECTIVES/PREDICTIONS FOR STABLE ISOTOPIC ANALYSIS

Objective 1: To determine season of capture during the MWP at Pineland and Bayshore Homes for the Calusa and the Tocobaga, respectively.

Predictions 1: During the MWP, both Pineland and Bayshore Homes would have had subtropical climate (Walker, 2013). As a result, I predict that the overall mean and amplitude $\delta^{18}\text{O}_{\text{shell}}$ will not show any significant difference between the two sites. I predict that the assemblages from both sites will have generally large amplitudes because of the strong wet-summer/dry-winter seasonality (high seasonality) and generally indicate warm waters because of the increased solar activity during the MWP (low/more negative $\delta^{18}\text{O}_{\text{shell}}$; Walker and Surge, 2006; Walker et al., 2013; Walker, 2013)

Modern scallops in subtropical South Florida spawn when temperatures drop in fall/winter, have slower growth through the winter, and increase growth and development in the spring as temperatures increase (will deposit a spring ridge; Barber, 1984). As summer turns into fall and temperature drops, the scallop population will begin to spawn with most scallops dying after spawning (Barber, 1984). The native inhabitants of Florida likely collected scallops near their peak body mass right before or at the beginning of spawning season to avoid animals that were too small or already dead (Quitmyer, 2013).

Therefore, I predict that both the Calusa and Tocobaga were collecting scallops in the warm summer/early fall months prior to cooling-induced spawning. I expect the final growth increments on BSH-MWP and OP-MWP scallops to have $\delta^{18}\text{O}_{\text{shell}}$ values that are near minimum values (warm months). In present day Florida, scallops in more northern regions

spawn earlier in the year (August) than scallops in southern Florida (October-December). Therefore, I also expect that the season of juvenile recruitment (based on the early shell growth near the umbo) may also have been similar between the two sites during the MWP. I predict that the season of recruitment for Bayshore Homes and Pineland was similar to today's southern Florida populations, occurring during the cool fall/winter months. I expect to see the initial $\delta^{18}\text{O}_{\text{shell}}$ values to be approaching more positive values.

The highly adaptable Bay Scallop would be able to live in a wide range of temperature and salinity tolerances, however, they favor warm, saline water (Sastry, 1963; Barber, 1984; Leverone, 1993; Brand, 2016). For that reason, I anticipate that scallops at Bayshore Homes and Pineland were productive during the MWP. I am predicting that the initial decline of $\delta^{13}\text{C}_{\text{shell}}$ will occur once the scallop settles to the bottom (20 – 30 mm in size) and begins to dedicate its energy to the development of its reproductive organs in late spring/early summer (Barber, 1984). Therefore, starting at 20 – 30 mm I expect that the $\delta^{13}\text{C}_{\text{shell}}$ will become progressively more negative corresponding to the onset of more negative $\delta^{18}\text{O}_{\text{shell}}$ values (warming spring/summer).

Objective 2: To determine the environmental conditions and season of capture during the MWP and LIA for the Pineland site.

Prediction 2: At Pineland, the MWP was likely warmer compared to the LIA. Furthermore, during the LIA, Pineland was likely subject to an ecotonal migration which could dampen seasonality (Walker, 2013). Therefore, I predict that the $\delta^{18}\text{O}_{\text{shell}}$ values for the MWP assemblage will have a more negative mean indicating warmer climates and larger amplitude indicating greater seasonality than the LIA assemblage at Pineland. I predict that the dampened seasonality and overall cooler climate will result in a later season of collection during the LIA.

For the LIA, I suggest that the Pinelanders collected in the fall with the final $\delta^{18}\text{O}_{\text{shell}}$ value approaching more negative values. I predict that the initial decline in $\delta^{13}\text{C}_{\text{shell}}$ will occur as $\delta^{18}\text{O}_{\text{shell}}$ begins to become more negative due to slower carbon turn over due to reallocation of energy to the production of reproductive organs induced by warming temperatures (Barber, 1984). during the MWP and the LIA as the warming.

METHODS

SHELL SELECTION

A total of 20 *A. irradians* shells were sampled to undergo stable isotopic analysis associated with four assemblages (Table 2). All shells chosen for stable isotopic analysis were at least 40 mm in length with one or more presumed annual band present. When possible, shells with minimal weathering and bioerosion were selected.

SAMPLE PREPARATION

Shells were cleaned with deionized water to clear the surface of excess dirt and were dried for 48 hours. Using a dry soft bristle brush and compressed air, the shell was cleaned of any remaining sediment and mounted on a glass plate for ease of drilling. Each shell was sampled along the longest axis from the final season of growth to the umbo every 1 – 1.5 mm. Sampling was done using a handheld Dremel at low speed with a 0.8 mm dental burr. Samples were collected with X-acto® knives then weighed on a microbalance and placed into 4.5ml borosilicate round bottom indigo cap Exetainers®. All tools were cleaned using a combination of compressed air and dry Kimwipes™ in between samples of the same shell. In between different

shell samples, all tools were cleaned using an isopropyl alcohol (70%) wipe, allowed to dry completely, and then wiped with a dry KimwipesTM. Shells usually yielded up to 45 samples, however smaller shells produced fewer samples.

LABORATORY ANALYSIS

A total of 827 samples were sent to the Stable Isotope Laboratory at the University of Alabama for analysis. Samples were analyzed using a Thermo Gas Bench II coupled to a Thermo Delta Plus isotope ratio mass spectrometer in continuous flow mode. Samples were reacted with orthophosphoric acid at 50°C. Data is expressed in parts per mil (‰) relative to them VPBD standard. At least one blank and multiple standards were included in each run to assess analytical precision and drift. Blanks and standards were run in 4.5 borosilicate round bottom indigo cap Exetainers from the same case as shell samples.

RESULTS

$\delta^{18}\text{O}_{\text{shell}}$ RESULTS

Overall Mean $\delta^{18}\text{O}_{\text{shell}}$

Mean $\delta^{18}\text{O}_{\text{shell}}$ are reported for the Pineland site in Table 3. The mean $\delta^{18}\text{O}_{\text{shell}}$ for OP-LIA (mean= -0.16 ‰) was significantly different than all the other sites tested: BSH-MWP (mean= 0.65 ‰; t-score= -13.02; d.f.=586; p < 0.001); OP-MWP (mean= 0.75 ‰; t-score= -8.27; d.f.= 384; p < 0.001); and Modern (mean= 0.37 ‰; t-score= -3.45; d.f.= 343; p < 0.001).

Amplitude, Minimum, and Maximum $\delta^{18}\text{O}_{\text{shell}}$

The average seasonality (mean amplitude $\delta^{18}\text{O}_{\text{shell}}$) or total difference between the minimum and maximum values for BSH-MWP (2.18 ‰) was significantly smaller than the amplitude for OP-MWP (3.18 ‰; t-score= 2.53; d.f.= 11; p= 0.02) and OP-LIA (2.96 ‰; t-score= 2.42; d.f.= 12; p= 0.03). The Modern assemblage had an $\delta^{18}\text{O}_{\text{shell}}$ amplitude of 3.45‰ with a minimum value of -1.12‰ and a maximum value of 2.33‰.

Initial Recruitment and Season of Capture

The age estimates and $\delta^{18}\text{O}_{\text{shell}}$ values for the umbo (first season of growth) and final season of growth can be found in Table 3. The average $\delta^{18}\text{O}_{\text{shell}}$ value for the first and final season of growth for OP-MWP was 0.27‰ and -0.45‰ which can be interpreted as ~cooler fall recruitment stage and a summer season of capture (Fig. 17). The average $\delta^{18}\text{O}_{\text{shell}}$ value for the first and final season of growth for BSH-MWP was 1.03‰ and -0.27‰ which can be interpreted as a ~fall/winter recruitment stage and a late summer season of capture (Fig. 16).

The average $\delta^{18}\text{O}_{\text{shell}}$ value for the first and final season of growth for OP-LIA was 0.99‰ and -1.00‰ which indicates a late fall recruitment stage and a fall season of capture (Fig. 18). The $\delta^{18}\text{O}_{\text{shell}}$ value for the first and final season of growth for the modern shell was 0.68‰ and -0.80‰ which suggests a fall recruitment stage and corresponds with a known collection in September of 2018 from Tampa Bay (Fig19). The oxygen stable isotopes suggest that none of the sampled scallops were over a year old.

Growth Lines (annual lines/shock lines)

The position of annual lines (and/or shock lines from disturbance) are in Table 3. All shells had at least one growth interruption line. The one closest to the umbo is referred to as the first, and if the shell had two lines, the one farthest away from the umbo is referred to as the 2nd. On average, the first growth band for OP-MWP appeared 18.00 mm away from the umbo and had a $\delta^{18}\text{O}_{\text{shell}}$ of 1.16‰ (Fig. 17). On average for BSH-MWP, the first growth band appeared 14.78 mm away from the umbo and had a $\delta^{18}\text{O}_{\text{shell}}$ of 1.09‰ (Fig. 16). On average for OP-LIA, the first growth band appeared 25.83 mm away from the umbo and had a $\delta^{18}\text{O}_{\text{shell}}$ of 0.20‰ (Fig. 18). The Modern shells first growth band appeared 13.31 mm away from the umbo and had a $\delta^{18}\text{O}_{\text{shell}}$ of 2.33‰ (Fig. 19). In general, for all the assemblages, the first growth band appears to be a response to a declining $\delta^{18}\text{O}_{\text{shell}}$ indicating warming.

The second growth band was not present on all of the sampled shells: 80% of OP-MWP assemblage had a second growth line at ~ 44.06 mm away from the umbo with a $\delta^{18}\text{O}_{\text{shell}}$ value of 0.43‰ on average; 0.63% of BSH-MWP assemblage had a second growth line at 39.49 mm away from the umbo with a $\delta^{18}\text{O}_{\text{shell}}$ value of 0.93‰ on average; 50% of OP-LIA assemblage had a second growth line at ~ 36.89 mm away from the umbo with a $\delta^{18}\text{O}_{\text{shell}}$ value of -0.27‰ on average. The second growth line appears to be associated with unusual positive or negative spikes in $\delta^{18}\text{O}_{\text{shell}}$, indicating a change in temperature or salinity.

$\delta^{13}\text{C}_{\text{shell}}$ RESULTS

The average $\delta^{13}\text{C}_{\text{shell}}$ for OP-MWP is 1.58‰, which was significantly more negative than BSH-MWP (-0.89‰; t-score= -9.44; d.f.= 311; p< 0.001) and OP-LIA (-0.87‰; t-score= -8.37; d.f.= 405; p< 0.001). There was no significant difference between BSH-MWP and OP-LIA

(t-score= -0.05; d.f.= 479; p= 0.96). The modern shell had an average of -3.47‰ which was significantly more negative than OP-MWP (t-score= -13.66; d.f.= 61; p<0.001), BSH-MWP (t-score= -22.56; d.f.=345; p< 0.001), and OP-LIA (t-score= 20.13; d.f.= 50; p< 0.001).

The distance away from the umbo in which a steady negative decline starts for each assemblage was visually approximated using the isotopic plots (Fig. 16 – 19). The average $\delta^{13}\text{C}_{\text{shell}}$ for the start of the presumed metabolic decline occurred at 31.63 mm from the umbo for OP-MWP; for BSH-MWP it occurred at 28.75 mm and for OP-LIA it started at 24.33 mm. The presumed metabolic decline for modern shell started occurred 27.74 mm from the umbo. Therefore, all four assemblages began to show decline between 20 – 30 mm of growth, around the size that the scallops would have settled to the bottom.

DISCUSSION/ CONCLUSION

Objective 1: To determine season of capture during the MWP at Pineland and Bayshore Homes for the Calusa and the Tocobaga, respectively.

My first objective was to determine if the $\delta^{18}\text{O}_{\text{shell}}$ values of scallops deposited during the MWP at Bayshore Homes and Pineland reflected similar sub-tropical environmental conditions and determine if there was any variability in the season of capture between the sites. I found that the mean $\delta^{18}\text{O}_{\text{shell}}$ for both sites indicate similar conditions. The $\delta^{18}\text{O}_{\text{shell}}$ for both assemblages had a seasonal curve indicative of a wet-summer/dry-winter as should be expected for the sub-tropical climate they were in (Walker, 2013). The Pineland assemblage (OP-MWP) did however, have a greater amplitude between its maximum and minimum values suggesting Pineland had a greater seasonality than the Bayshore Homes assemblage. This increased

seasonality at Pineland is expected due to a more defined wet-summer/dry-winter seasonality to the south.

Visual approximation of the initial and final position of $\delta^{18}\text{O}_{\text{shell}}$ values relative to the curve represent the season of recruitment and collection, respectively. The Bayshore Homes assemblage suggest that recruitment of the juvenile scallops began in the cooler winter months and collection took place in the warmer summer months potentially going into early fall. The MWP Pineland assemblage $\delta^{18}\text{O}_{\text{shell}}$ curves suggest recruitment began earlier in warmer summer months and that the Pinelanders were collecting the scallops in the following summer. None of the shells that were isotopically analyzed indicate that they lived longer than a year. Therefore, the warmer (more negative $\delta^{18}\text{O}_{\text{shell}}$) season of recruitment for OP-MWP would have occurred earlier in the year than the cooler (more positive $\delta^{18}\text{O}_{\text{shell}}$) season of recruitment at Bayshore Homes. However, the season of collection for both sites during the MWP was similar, BSH-MWP and OP-MWP have terminal $\delta^{18}\text{O}_{\text{shell}}$ at or recovering from the most negative value, suggesting that the Calusa and Tocobaga both were collecting scallops in the warm summer/fall months. The later season of recruitment for the Bayshore Homes assemblage could explain their overall smaller body size and earlier appearance of spring growth bands, possibly indicating a shorter period of growth. However, both assemblages exhibit some variability in the interpreted seasons of recruitment and further analysis would need to be done to distill a pattern.

Both assemblages were likely still byssally attached to seagrass when they deposited their initial annual lines which appear <30 mm from the umbo. A fraction of scallops from both assemblages had a second growth interruption present, possibly caused by extreme summer temperatures reaching near maximum levels or an influx of summer storms lowering the salinity or increasing turbidity which can be harmful to these filter feeders (Walker, 2013). The Florida

Bay Scallop will begin to reallocate energy to the production of reproductive organs as temperatures begin to rise slowing down the rate of carbon turn over. The initial decline in $\delta^{13}\text{C}_{\text{shell}}$ began at a larger size for Pineland scallops than Bayshore Homes, again likely because the Pineland scallop's recruitment occurred earlier in the year and therefore experienced the spring/summer temperatures at an older age.

Overall, it appears that both Pineland and Bayshore Homes experienced similar warm climates, but the seasonal variation at Pineland was greater. Additionally, during the MWP the season of juvenile recruitment occurred earlier in the year at Pineland than at Bayshore Homes. As a result, the Pineland scallops had a longer life span and were able to grow larger. During the larval and juvenile stage of life the Bay Scallop benefits from lower water temperatures (20 – 28°C) and higher salinities of (20 – 30 PSU) which would have made the early development in the cool/dry winters optimal for growth (Barber, 1984; Brand, 2016). Therefore, in South Florida during the MWP the dry-winter could have been an optimal growth period for the Bay Scallop with high salinities (low rainfall) and temperatures that did not reach fatal levels. My findings suggest that during the MWP Pineland and Bayshore Homes experienced a similar warm sub-tropical climate and that the native inhabitants were collecting scallops at near peak body mass prior to spawning in the warm summer/fall months.

Objective 2: To determine the environmental conditions and season of capture during the MWP and LIA for the Pineland site.

My second objective was to explore how environmental conditions affected scallop productivity and thus season of collection at Pineland during the MWP transitioning into the LIA. The LIA assemblages were significantly more negative $\delta^{18}\text{O}_{\text{shell}}$ than the assemblages

deposited during the MWP. This is contradictory to what I expected for a cooler climate predicted for the LIA compared to the MWP.

The unconventional negative mean $\delta^{18}\text{O}_{\text{shell}}$ for the LIA could be explained by salinity. Salinity has a positive relationship with $\delta^{18}\text{O}_{\text{water}}$ so when salinity drops, $\delta^{18}\text{O}_{\text{water}}$ becomes more negative, and as a result $\delta^{18}\text{O}_{\text{shell}}$ will also reflect more negative ratios. For southwestern Florida, the climatic change experienced as the MWP shifted into the LIA was relatively mild. However, there is evidence of a sea level regression and resulting drop in salinity. If salinity and water level were the primary variables, this could be the cause of the unconventional pattern in $\delta^{18}\text{O}_{\text{shell}}$ between the MWP and the LIA. If there was substantial salinity variation coinciding with climatic change for MWP to LIA but remained relatively consistent throughout the climatic interval (that is, low in the LIA), then it could overshadow the influence of temperature and the overall $\delta^{18}\text{O}_{\text{shell}}$ values would reflect more freshening of the estuarine habitats for the scallops during this time and not a temperature change.

The water levels and salinity for modern day Pine Island Sound and Boca Ciega Bay are thought to be similar to what was experienced during the MWP. Even if the overall climate was warmer or cooler between the Modern and MWP the mean and amplitude for $\delta^{18}\text{O}_{\text{shell}}$ would be similar if salinity was similar. In fact, the Modern and MWP have similar $\delta^{18}\text{O}_{\text{shell}}$ means (Modern: 0.37‰ MWP: 0.75 ‰) and amplitudes (Modern: 3.45 ‰ and MWP: 3.18‰). Additionally, the $\delta^{18}\text{O}_{\text{shell}}$ curves for both the Modern and MWP assemblages have a fall juvenile development period and a summer collection. Therefore, it is arguable that salinity, a controlling factor of scallop survival and spatial distribution, was similar for the Modern shell and the MWP assemblage. Furthermore, the seasonal fluctuation between a hot summer and a cool winter are represented as expected on the $\delta^{18}\text{O}_{\text{shell}}$ curve having an inverse relationship with

relative temperature for all of the assemblages. However, in the LIA the $\delta^{18}\text{O}_{\text{shell}}$ mean and amplitude was significantly more negative than the MWP assemblage from Pineland.

There is reasonable evidence suggesting that in southwest Florida the temperature during the LIA was not drastically different than the MWP (Marquardt and Walker, 2013; Walker; 2013). However, there are multiple lines of evidence that suggest a sea level regression and drop in salinity. Sedimentary records and the appearance of sea catfish in midden deposits indicate that there was a drop in sea level which could have resulted in a salinity gradient regression from Pine Island Sound and a behavioral change of the Calusa to catch catfish in the open ocean. This drop in sea level, coupled with a decrease in solar activity may have resulted in less evaporation, may have lowered salinity in the shallow waters of Pine Island Sound. Within the LIA assemblages there is a decrease in the appearance of saline-favoring fauna (crested oysters) supporting this.

If the salinity in Pine Island Sound during the MWP was in fact, similar to today it would have been near normal marine levels which explains the more positive $\delta^{18}\text{O}$ values overall. Therefore, it is reasonable to suggest that the unusually negative $\delta^{18}\text{O}_{\text{shell}}$ mean associated with the LIA is affected by lowered salinity. I speculate that this salinity-affected $\delta^{18}\text{O}_{\text{shell}}$ mean for the LIA supports a negligible temperature change model which explains the continued diversity within the midden deposits and the lack of migratory birds during a 'cool' climate. My findings correspond with past paleoclimate studies which have represented overestimation of reconstructed paleotemperature due to salinity (Walker and Surge, 2006; Wang et al., 2013).

The Bay Scallop prefers more saline waters, and waters < 16 PSU could result in new generation recruitment failure or even mass population migration to more suitable conditions.. The $\delta^{18}\text{O}_{\text{shell}}$ values for the LIA indicate a late fall juvenile development and a fall season of

collection indicating that the scallops only lived for one year, but their reproductive cycle is later in the year than the MWP. The Bay Scallops from the LIA also suggest a rapid growth during the winter stage as their spring ridges appeared when they were much larger than the MWP scallops even though the MWP had more time to grow. This could be due to winter being the drier season potentially increasing salinity to more productive levels.

The initial decline in $\delta^{13}\text{C}_{\text{shell}}$ for the LIA corresponds with the increasingly more negative $\delta^{18}\text{O}_{\text{shell}}$ (warming spring/summer). Additionally, as temperatures continue to rise, and more energy is allocated towards developing reproductive organs or storing energy to exploit during spawning the rate of $\delta^{13}\text{C}_{\text{shell}}$ decline increases. The Florida Bay Scallop only spawns once in its lifetime and rarely survives after spawning resulting in a relatively short life span. However, if they have favorable conditions they grow rapidly. Their rate of respiration and feeding as well as reproductive timing are all controlled by environmental factors. Therefore, it is reasonable to suggest that through the Florida Bay Scallops ontogeny the $\delta^{13}\text{C}_{\text{shell}}$ decline is associated with environmental controls.

Table 2. The four assemblages used for stable isotopic analysis (BSH- MWP [orange], OP- MWP [yellow], OP-LIA [blue], and Modern [green]) are listed below with their associated climate.

ASSEMBLAGE	SITE	CLIMATE	SHELL ID	# OF SAMPLES
BSH-MWP	Bayshore Homes	MWP	BSH2S1	45
BSH-MWP	Bayshore Homes	MWP	BSH3S1	41
BSH-MWP	Bayshore Homes	MWP	BSH4S1	45
BSH-MWP	Bayshore Homes	MWP	BSH5S1	33
BSH-MWP	Bayshore Homes	MWP	BSH6S1	41
BSH-MWP	Bayshore Homes	MWP	BSH7S1	35
BSH-MWP	Bayshore Homes	MWP	BSH8S1	39
BSH-MWP	Bayshore Homes	MWP	BSH9S1	36
OP-MWP	Pineland	MWP	P105S4	42
OP-MWP	Pineland	MWP	P105S10	35
OP-LIA	Pineland	LIA	P103S2	45
OP-LIA	Pineland	LIA	P104S3	45
OP-LIA	Pineland	LIA	P104S9	45
OP-LIA	Pineland	LIA	P99S2	45
OP-LIA	Pineland	LIA	P99S3	42
OP-LIA	Pineland	LIA	P99S4	45
Modern	Modern	Modern	M	35
				Total=827

Table 3. Results of $\delta^{18}O_{shell}$ for the four assemblages regarding paleoclimate indicators and growth patterns of the Bay Scallop (*A. irradians*).

	BSH-MWP	OP-MWP	OP-LIA	MODERN
$\delta^{18}O$ Overall Mean (‰)	0.65	0.75	-0.16	0.37
Seasonality ($\delta^{18}O$ amplitude; ‰)	2.59	3.18	2.96	3.45
$\delta^{18}O$ First season of growth (‰)	1.02	0.13	0.99	0.68
$\delta^{18}O$ Season of Capture (‰)	-0.27	-0.45	-1.00	-0.80
Estimated Season of Capture	summer/fall	summer	summer/fall	summer
1st growth line position (mm from umbo)	14.78	18.00	25.83	13.31
$\delta^{18}O$ 1st Growth Line (‰)	1.09	1.16	0.21	2.33

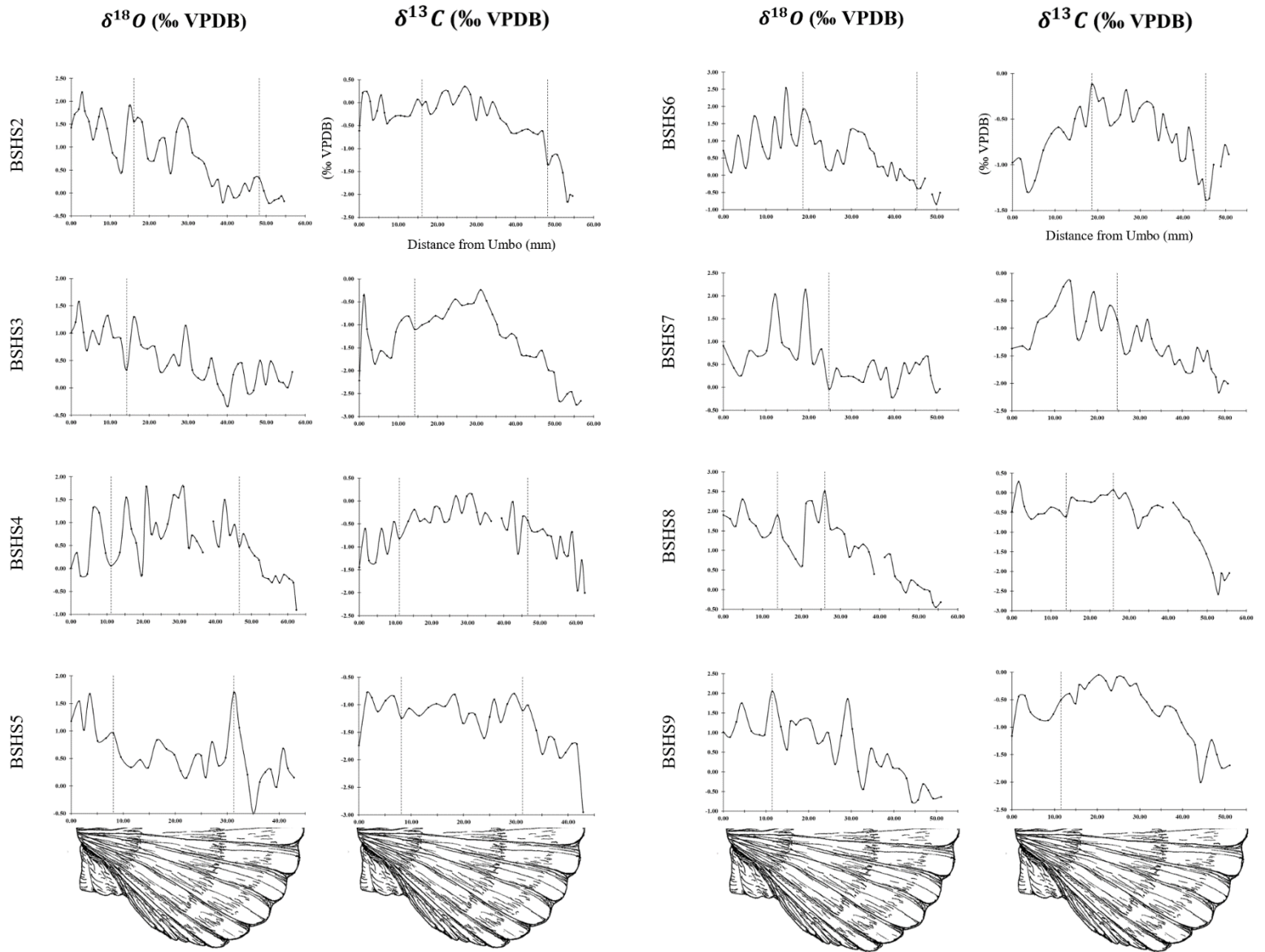


Figure 16. Stable isotopic plots for Bayshore Homes (BSH-MWP) for $\delta^{18}O_{shell}$ and $\delta^{13}C_{shell}$ from the umbo to the final season of growth for sampled *A. irradians*. The vertical dashed lines are the location of presumed growth lines (annual lines or shock lines).

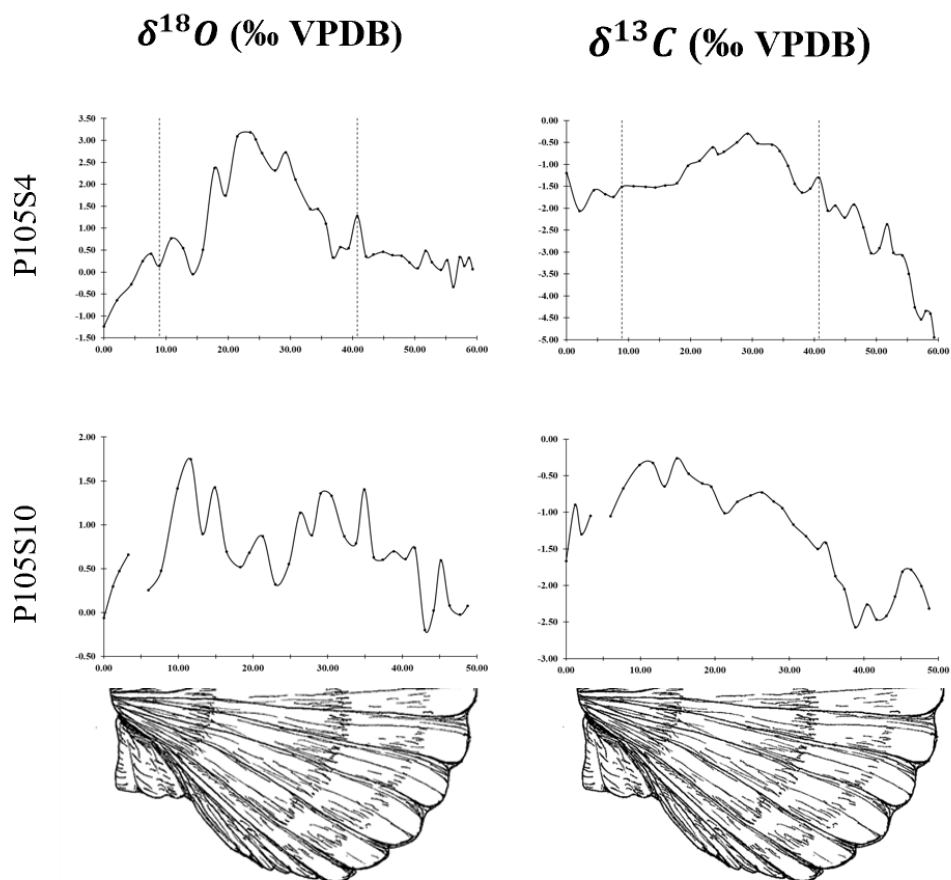


Figure 17. Stable isotopic plots for Pineland during the MWP (OP-MWP) for $\delta^{18}O_{shell}$ and $\delta^{13}C_{shell}$ from the umbo to the final season of growth for sampled *A. irradians*. The vertical dashed lines are the location of presumed growth lines (annual lines or shock lines).

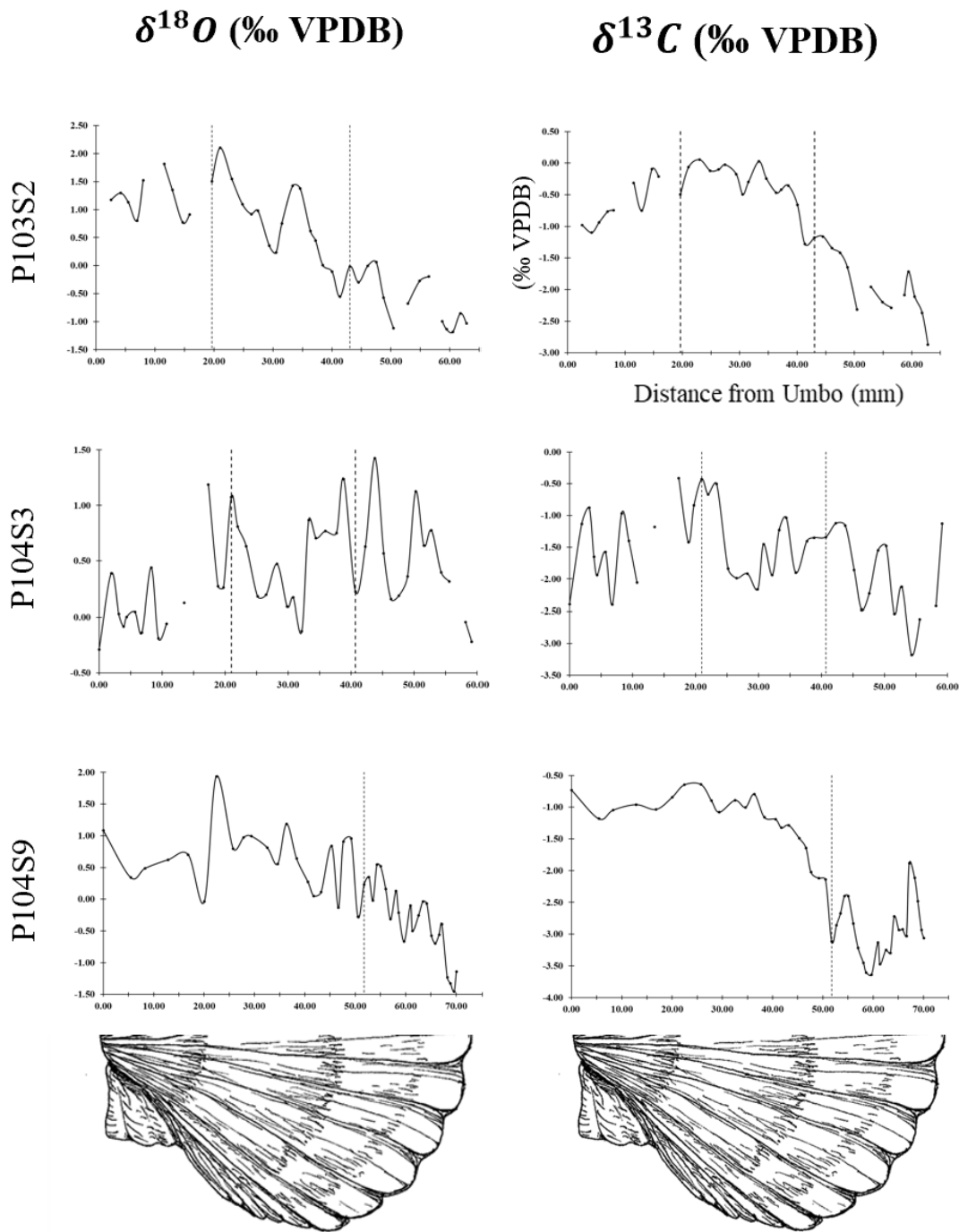


Figure 18a. Stable isotopic plots for Pineland during the LIA (OP-LIA) for $\delta^{18}O_{shell}$ and $\delta^{13}C_{shell}$ from the umbo to the final season of growth for sampled *A. irradians*. The vertical dashed lines are the location of presumed growth lines (annual lines or shock lines).

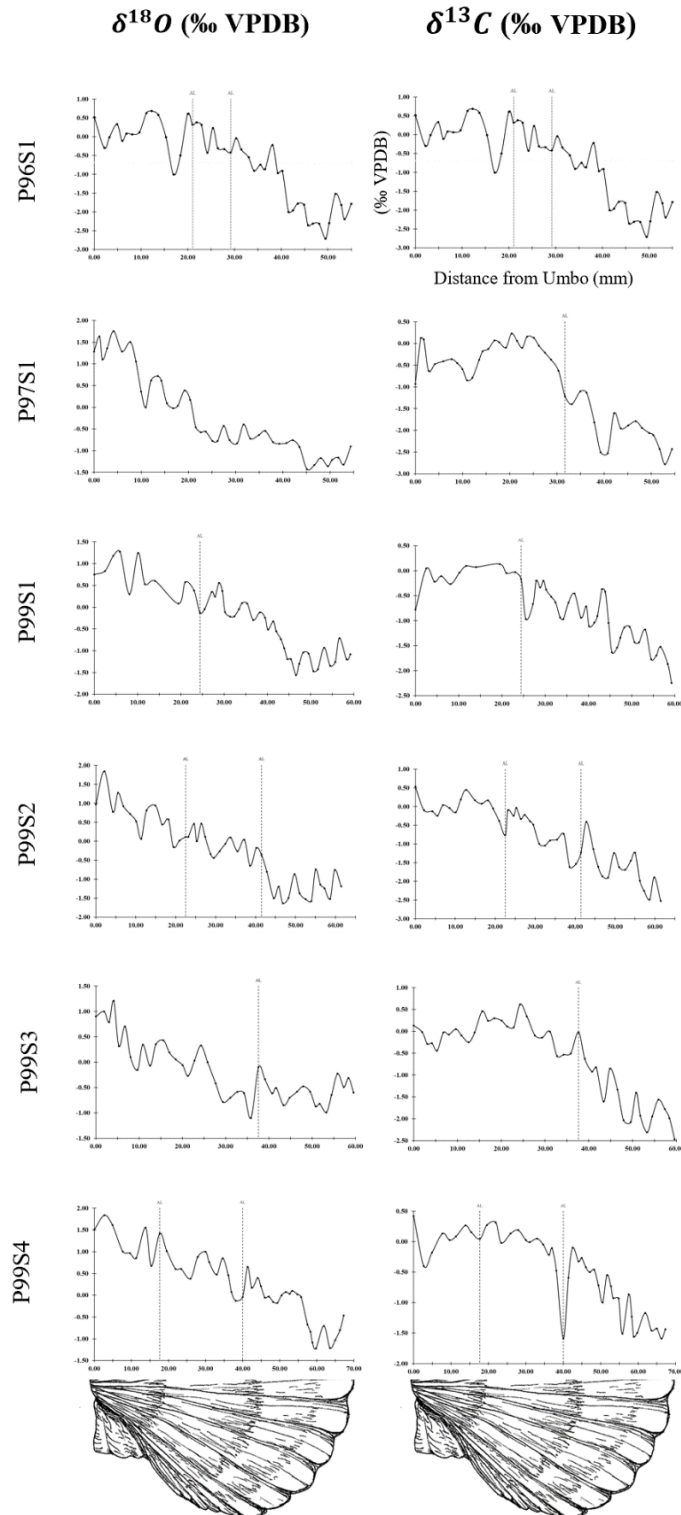


Figure 18b. Stable isotopic plots for Pineland during the LIA (OP-LIA) for $\delta^{18}O_{shell}$ and $\delta^{13}C_{shell}$ from the umbo to the final season of growth for sampled *A. irradians*. The vertical dashed lines are the location of presumed growth lines (annual lines or shock lines).

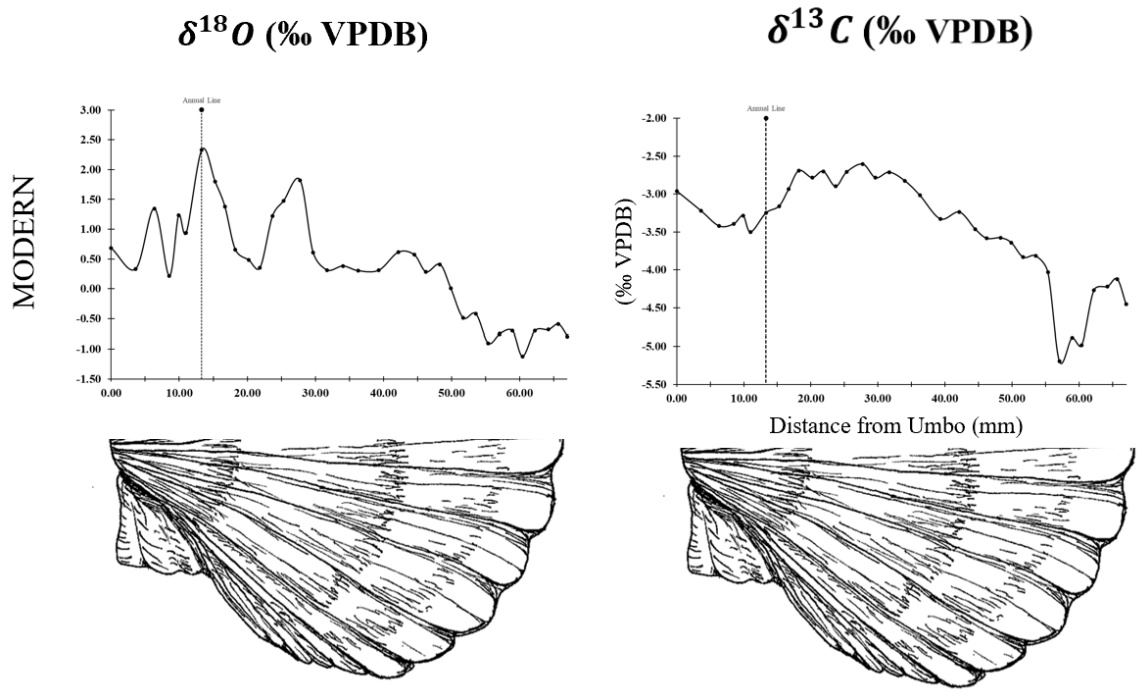


Figure 19. Stable isotopic plots for the Modern shell for $\delta^{18}O_{shell}$ and $\delta^{13}C_{shell}$ from the umbo to the final season of growth for sampled *A. irradians*. The vertical dashed lines are the location of presumed growth lines (annual lines or shock lines).

CHAPTER 5.

SUMMARY

My research combined the methodology of taphonomic analysis and stable isotopic analysis ($\delta^{18}\text{O}_{\text{shell}}$ and $\delta^{13}\text{C}_{\text{shell}}$) to understand the role that past climate variability may have had on the harvesting practices of native inhabitants that use the Bay Scallop (*Argopecten irradians*) as a food resource. Taphonomic analyses of body size, encrusting/bioeroding organisms on the shell, live/dead ratios helped determine harvesting method, season of capture, and environmental conditions. Isotopic analyses ($\delta^{18}\text{O}_{\text{shell}}$ and $\delta^{13}\text{C}_{\text{shell}}$) supported the taphonomic interpretations and also provided more robust data on climatic variability between the MWP and LIA, the conclusions of which I will discuss next.

I found that during the MWP, the inhabitants of Pineland (Calusa) and Bayshore Homes (Tocobaga) were employing a similar bulk collection method to harvest scallops likely targeting productive scallop beds within sea grass meadows during the interval of peak body mass prior to natural mortality induced by spawning. The $\delta^{18}\text{O}_{\text{shell}}$ results for MWP scallop-shell assemblages from both Pineland and Bayshore Homes indicate that both cultures experienced a sub-tropical climate with wet summers and dry winters.

Overall, the $\delta^{18}\text{O}_{\text{shell}}$ trends for MWP scallop assemblages at Pineland and Bayshore Homes were relatively positive, likely as response to increased salinity in the estuarine waters where the scallops lived during a time of increased solar radiation. However, as the MWP transitioned into the LIA, $\delta^{18}\text{O}_{\text{shell}}$ became more negative, likely due to reduced salinity. The salinity drop may have stemmed from a decrease in solar activity (resulting in decreased

evaporation from estuarine waters) or a sea-level regression that results in the seaward migration of the salinity gradient during the transition to the LIA (Walker, 2013).

The climatic transition into the LIA did not affect the season of collection for Pinelanders because the $\delta^{18}\text{O}_{\text{shell}}$ results indicate that they continued to harvest the Bay Scallop in the warm summer/fall months. However, the associated drop in sea level and freshening waters may have made it more difficult for the Calusa to transport large bulk catch from productive fishing grounds. Indeed, the taphonomic analyses suggested that they switched from bulk collection in the MWP to individual harvesting methods in the LIA in an effort to minimize unnecessary weight from bycatch.

My research provides evidence that the Calusa and Tocobaga were practicing seasonal harvesting strategies that collect scallops during an optimal period of growth during the MWP. During this time, they were likely using a bulk collection method in productive estuarine areas to increase harvesting efficiency. The shift into LIA for the Calusa suggests a more selective harvesting method focused on individual scallop collection to minimize sorting through unwanted bycatch.

Archaeological studies have highlighted some of the many ways these coastal communities do not fit into the typical hunter-gatherer model of resource procurement. My research demonstrates a methodology for delineating harvesting methods through the lens of climatically-dictated resource viability. Harvesting methods, however, are not dictated solely by resource availability, they are also controlled by many other factors such as resource proximity, mechanical advances, political hierarchy, site infrastructure, geographic limitations, socio-cultural structure, and inherited knowledge. Therefore, continued research is necessary before

conclusive statements about the cause-and-effect relationships concerning harvesting methods and resource procurement for the Calusa and Tocobaga can be made.

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APPENDIX A

Taphonomic data for *A. irradians*

Table A. Taphonomic data for the five assemblages listed in order from OP-LIA (n=25), OP-MWP (n=13), RCM1-MWP (n=39), BSH-MWP (n=191), and Modern (n=20). Biotic interactions are listed as a present (1) or absent (0).

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8LL33OP	Pineland	P-8-96	LIA	8LL33OP96S1	56.45	R	2	2	4	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-9-97	LIA	8LL33OP97S1	57.95	R	2	2	5	1	0	0	9	0	0	0	0	0
8LL33OP	Pineland	P-9-98	LIA	8LL33OP98S2	47.42	R	1	1	4	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-10-98	LIA	8LL33OP98S1	55.87	L	2	2	3	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-99	LIA	8LL33OP99S4	49.96	R	2	2	4	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-99	LIA	8LL33OP99S3	39.35	R	2	2	5	1	0	0	7	0	0	0	0	0
8LL33OP	Pineland	P-8-99	LIA	8LL33OP99S2	54.66	R	2	2	4	0	0	0	0	0	1	0	0	0
8LL33OP	Pineland	P-10-99	LIA	8LL33OP99S1	55.3	L	2	2	3	1	0	0	7	0	0	0	0	0
8LL33OP	Pineland	P-8-103	LIA	8LL33OP103S4	58.8	R	2	2	4	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-103	LIA	8LL33OP103S3	46.41	R	-	1	2	0	0	0	2	0	0	1	0	0
8LL33OP	Pineland	P-8-103	LIA	8LL33OP103S2	50.01	L	2	2	1	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-9-103	LIA	8LL33OP103S1	64.66	R	2	2	4	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-103/104	LIA	8LL33OP104S13	43.08	R	1	1	2	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-104	LIA	8LL33OP104S12	58.12	R	-	-	4	0	0	1	4	0	0	0	0	0
8LL33OP	Pineland	P-8-104	LIA	8LL33OP104S11	44.46	L	2	2	1	0	0	0	0	0	1	1	0	0
8LL33OP	Pineland	P-9-104	LIA	8LL33OP104S10	53.32	L	2	2	2	1	0	0	5	0	0	2	0	0

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8LL33OP	Pineland	P-9-104	LIA	8LL33OP104S9	48.97	R	2	2	3	1	0	0	3	0	0	13	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S8	45.79	R	-	-	5	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S7	58.35	L	1	1	1	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S6	33.35	L	1	1	1	0	0	0	4	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S5	24.29	L	-	-	1	0	0	0	1	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S4	63.06	R	2	2	2	1	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S3	59.84	R	2	2	3	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S2	55.26	R	1	1	2	0	0	0	0	0	0	1	0	0
8LL33OP	Pineland	P-7-104	LIA	8LL33OP104S1	53.71	L	2	2	1	0	0	0	1	0	0	0	0	0
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S13	36.67	L	-	-	1	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S12	49.65	R	2	2	1	0	0	0	0	0	0	1	0	0
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S11	59.14	R	2	2	3	1	0	0	0	0	0	8	0	1
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S10	39.1	L	1	1	1	1	0	0	0	0	0	1	0	0
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S9	57.25	L	2	2	2	0	1	0	15	0	0	0	0	0
8LL33OP	Pineland	P-10-105	MWP	8LL33OP105S8	57.11	L	2	2	1	0	1	0	2	0	1	0	0	0
8LL33OP	Pineland	P-8-105	MWP	8LL33OP105S7	54.86	L	1	1	1	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-105	MWP	8LL33OP105S6	56.76	L	1	1	3	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-105	MWP	8LL33OP105S5	61.83	L	2	2	3	0	0	0	0	0	0	0	0	0
8LL33OP	Pineland	P-8-105	MWP	8LL33OP105S4	42.92	L	2	2	1	1	0	1	0	0	0	8	0	0
8LL33OP	Pineland	P-7-105	MWP	8LL33OP105S3	40.99	L	2	2	1	0	0	0	2	0	0	1	0	0
8LL33OP	Pineland	P-7-105	MWP	8LL33OP105S2	50.24	R	2	2	3	0	0	1	0	0	0	7	0	0
8LL33OP	Pineland	P-7-105	MWP	8LL33OP105S1	50.61	R	2	2	1	0	0	0	1	0	0	2	0	0
8LL33-RCM1	Pineland	A-profile-63	MWP	8LL33RCM1S1	55.48	L	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM2	Pineland	A-profile-63	MWP	8LL33RCM1S2	42.09	L	1	1	4	0	1	0	0	0	1	0	0	1
8LL33-RCM3	Pineland	A-profile-63	MWP	8LL33RCM1S3	51.05	L	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM4	Pineland	A-profile-63	MWP	8LL33RCM1S4	47.71	L	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM5	Pineland	A-profile-63	MWP	8LL33RCM1S5	48.32	L	2	2	3	1	0	0	0	0	1	0	0	0
8LL33-RCM6	Pineland	A-profile-63	MWP	8LL33RCM1S6	56.96	L	2	2	3	1	0	0	0	0	0	0	0	0
8LL33-RCM7	Pineland	A-profile-63	MWP	8LL33RCM1S7	48.98	L	-	-	4	1	0	0	0	0	0	0	0	0
8LL33-RCM8	Pineland	A-profile-63	MWP	8LL33RCM1S8	49.35	L	2	2	5	0	0	0	0	0	0	0	0	0

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8LL33-RCM9	Pineland	A-profile-63	MWP	8LL33RCM1S9	23.3	L	>1	1	4	0	0	0	0	0	0	0	0	0
8LL33-RCM10	Pineland	A-profile-63	MWP	8LL33RCM1S10	47.94	L	2	2	5	1	0	0	0	0	0	0	0	0
8LL33-RCM11	Pineland	A-profile-63	MWP	8LL33RCM1S11	57.84	L	2	2	4	1	0	0	0	0	0	0	0	0
8LL33-RCM12	Pineland	A-profile-63	MWP	8LL33RCM1S12	56.84	L	2	2	3	0	0	0	0	0	0	0	2	1
8LL33-RCM13	Pineland	A-profile-63	MWP	8LL33RCM1S13	45.71	L	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM14	Pineland	A-profile-63	MWP	8LL33RCM1S14	48.79	L	-	-	4	1	0	0	0	0	0	0	0	0
8LL33-RCM15	Pineland	A-profile-63	MWP	8LL33RCM1S15	48.53	L	2	2	5	1	0	0	0	0	1	0	5	0
8LL33-RCM16	Pineland	A-profile-63	MWP	8LL33RCM1S16	45.35	L	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM17	Pineland	A-profile-63	MWP	8LL33RCM1S17	47.86	L	2	2	5	0	1	0	0	0	1	0	0	0
8LL33-RCM18	Pineland	A-profile-63	MWP	8LL33RCM1S18	48.66	R	2	2	4	0	0	0	2	0	0	0	0	0
8LL33-RCM19	Pineland	A-profile-63	MWP	8LL33RCM1S19	50.55	R	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM20	Pineland	A-profile-63	MWP	8LL33RCM1S20	54.33	R	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM21	Pineland	A-profile-63	MWP	8LL33RCM1S21	53.27	R	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM22	Pineland	A-profile-63	MWP	8LL33RCM1S22	54.47	R	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM23	Pineland	A-profile-63	MWP	8LL33RCM1S23	54.61	R	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM24	Pineland	A-profile-63	MWP	8LL33RCM1S24	46.16	R	2	2	3	0	0	0	0	0	0	0	0	0
8LL33-RCM25	Pineland	A-profile-63	MWP	8LL33RCM1S25	47.21	R	2	2	4	0	0	1	0	3	0	0	1	1
8LL33-RCM26	Pineland	A-profile-63	MWP	8LL33RCM1S26	58.79	R	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM27	Pineland	A-profile-63	MWP	8LL33RCM1S27	53.04	R	2	2	3	0	0	0	0	0	0	0	0	0
8LL33-RCM28	Pineland	A-profile-63	MWP	8LL33RCM1S28	52.17	R	2	2	4	0	0	0	0	0	0	0	0	0
8LL33-RCM29	Pineland	A-profile-63	MWP	8LL33RCM1S29	47.58	R	2	2	3	0	1	1	0	0	3	12	0	0
8LL33-RCM30	Pineland	A-profile-63	MWP	8LL33RCM1S30	53.6	R	2	2	4	1	0	0	0	0	0	0	0	0
8LL33-RCM31	Pineland	A-profile-63	MWP	8LL33RCM1S31	57.49	R	2	2	4	1	0	1	0	0	0	5	0	0
8LL33-RCM32	Pineland	A-profile-63	MWP	8LL33RCM1S32	59.41	R	2	2	5	0	0	0	0	0	0	0	0	0
8LL33-RCM33	Pineland	A-profile-63	MWP	8LL33RCM1S33	58.17	R	2	2	4	0	0	1	1	0	0	0	0	0
8LL33-RCM34	Pineland	A-profile-63	MWP	8LL33RCM1S34	51.36	R	2	2	3	0	0	0	0	0	0	1	0	0
8LL33-RCM35	Pineland	A-profile-63	MWP	8LL33RCM1S35	48.87	R	2	2	5	1	0	0	0	0	0	0	0	0
8LL33-RCM36	Pineland	A-profile-63	MWP	8LL33RCM1S36	55.47	R	2	2	5	0	0	1	0	0	0	0	0	0
8LL33-RCM37	Pineland	A-profile-63	MWP	8LL33RCM1S37	49.24	R	2	2	5	0	0	1	0	0	0	0	0	0
8LL33-RCM38	Pineland	A-profile-63	MWP	8LL33RCM1S38	46.91	R	2	2	5	0	0	0	0	0	1	0	0	0

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8LL33-RCM39	Pineland	A-profile-63	MWP	8LL33RCM1S39	44.5	R	1	1	4	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	2	MWP	8PITU2LVL2S1	51.62	R	2+	2	4	1	1	0	3	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S1	49.7	R	2+	2	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S2	49.72	L	1+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S3	45.84	R	1+	1	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S4	43.44	R	1+	0	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S5	38.14	L	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S6	37.25	L	1+	0	3	1	1	0	1	0	0	1	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S7	35.17	R	1+	0	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S8	49.57	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S9	40.11	L	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S10	51.51	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S11	36.78	R	1+	0	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S12	42.96	L	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S13	33.9	R	~1	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	3	MWP	8PITU2LVL3S14	39.09	R	1+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S1	50.19	L	2+	2	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S2	52.25	-	2+	2	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S3	40.04	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S4	43.88	L	1+	2	2	1	0	0	3	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S5	37.45	L	1+	0	2	1	1	0	22	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S6	46.5	R	2+	1	3	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S7	33.48	L	~1	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S8	46.23	L	2+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S9	44.95	L	1+	0	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S10	44.63	R	1+	0	3	1	0	0	7	0	0	0	0	3
8PI41TU2	BSH	4	MWP	8PITU2LVL4S11	35.88	R	1+	1	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S12	43.4	R	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S13	51.44	R	2+	0	2	1	0	0	3	0	0	0	0	1
8PI41TU2	BSH	4	MWP	8PITU2LVL4S14	57.11	R	2+	1	2	1	0	0	0	0	0	0	0	0

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8PI41TU2	BSH	4	MWP	8PITU2LVL4S15	46.95	R	2+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S16	52.78	R	2+	0	3	1	0	1	4	0	0	0	0	0
8PI41TU2	BSH	4	MWP	8PITU2LVL4S17	55.47	R	2+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S1	53.98	R	2+	1	3	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S2	39.94	R	1+	0	3	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S3	61.76	L	2+	1	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S4	43.71	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S5	51.58	L	2+	0	2	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S6	41.86	L	1+	0	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S7	36.97	R	1+	1	2	1	1	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S8	42.54	L	1+	1	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S9	36.28	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S10	40.86	R	1+	1	2	1	0	0	2	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S11	33.78	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S12	42.01	R	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S13	49.57	R	2+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S14	36.62	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S15	42.18	R	1+	1	3	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S16	38.95	L	1+	1	2	1	0	1	8	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S17	47.59	L	2+	1	3	1	0	0	2	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S18	48.24	L	2+	0	2	1	0	0	0	0	1	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S19	51.03	L	2+	0	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S20	44.4	L	1+	1	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S21	40.16	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S22	47.94	L	2+	1	2	1	1	0	0	0	1	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S23	47.28	L	2+	1	2	1	0	0	0	0	2	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S24	37.36	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S25	41.03	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S26	38.62	R	1+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S27	42.47	L	2+	2	2	1	0	0	0	0	0	0	0	0

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8PI41TU2	BSH	5	MWP	8PITU2LVL5S28	34.8	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S29	44.86	R	2+	2	3	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S30	45.57	L	2+	2	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S31	41.27	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S32	53.38	L	2+	2	2	1	1	1	25	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S33	50.96	R	2+	3	3	1	0	0	5	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S34	47.44	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S35	42.24	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S36	45.81	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S37	53.25	R	2+	1	3	1	1	0	0	0	2	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S38	52.14	L	2+	2	2	1	0	0	2	0	0	1	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S39	44.99	R	1+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	5	MWP	8PITU2LVL5S40	52.82	L	2+	1	4	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S1	46.9	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S2	41.79	R	1+	1	3	1	0	0	0	0	0	1	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S3	43.08	R	1+	0	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S4	45.02	R	1+	1	3	0	0	0	1	0	0	0	1	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S5	50.03	L	2+	2	3	1	0	0	3	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S6	49.85	R	2+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S7	46.06	L	2+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S8	37.87	R	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S9	58.1	L	2+	0	2	1	0	0	2	0	0	1	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S10	54.65	L	2+	0	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S11	49.47	L	2+	1	2	1	1	0	1	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S12	38.18	L	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S13	49.47	R	2+	2	3	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S14	39.95	L	1+	1	5	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S15	46.21	L	1+	0	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S16	34.87	L	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S17	54.16	R	2+	1	2	1	0	0	0	0	0	0	0	0

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8PI41TU2	BSH	6	MWP	8PITU2LVL6S18	39.94	R	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S19	44.96	L	1+	0	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S20	50.52	L	2+	2	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S21	37.69	R	1+	1	4	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S22	50.1	R	2+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S23	47	R	2+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S24	51.43	R	2+	0	3	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S25	39.13	L	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S26	42.03	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S27	44.11	L	1+	0	4	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S28	44.42	R	1+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S29	49.45	L	2+	0	3	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S30	40.72	R	1+	0	4	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	6	MWP	8PITU2LVL6S31	46.94	R	1+	1	4	0	0	0	4	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S1	43.48	R	1+	0	4	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S2	34.56	L	1+	1	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S3	43.83	R	2+	1	3	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S4	41.69	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S5	38.09	R	1+	2	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S6	48.2	R	2+	2	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S7	36.42	L	1+	0	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S8	54.01	L	2+	1	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S9	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S10	46.3	R	2+	2	2	0	0	0	0	0	0	0	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S11	46.12	L	1+	1	3	0	0	0	0	0	0	0	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S12	49.29	R	2+	0	5	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S13	42.33	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S14	44.08	R	1+	0	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S15	40.28	R	1+	1	3	1	0	0	0	0	0	0	0	2
8PI41TU2	BSH	7	MWP	8PITU2LVL7S16	55.8	R	2+	0	4	1	0	0	1	0	0	0	0	0

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8PI41TU2	BSH	7	MWP	8PITU2LVL7S17	34.85	L	1+	1	1	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S18	50.93	L	2+	1	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S19	43.81	R	1+	1	4	1	0	0	0	1	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S20	47.34	L	2+	1	2	1	0	0	0	1	0	0	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S21	47.13	L	2+	1	2	1	0	0	0	3	0	1	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S22	38.21	L	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S23	46.83	L	2+	2	2	1	0	0	2	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S24	47.94	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S25	49.71	R	2+	2	3	1	0	0	0	0	0	1	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S26	46.64	L	2+	2	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S27	45.45	L	2+	2	2	0	0	0	0	2	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S28	50.07	L	2+	2	1	1	0	0	0	0	0	3	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S29	54.06	L	2+	2	1	1	0	0	0	20	0	1	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S30	45.46	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S31	34.29	R	~1	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S32	48.58	R	2+	1	3	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S33	32.51	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S34	46.94	L	2+	2	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S35	50.49	L	2+	1	2	1	0	0	0	0	0	0	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S36	38.24	L	1+	1	2	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S37	38.94	L	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S38	47.59	L	2+	1	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S39	49.86	R	2+	1	4	1	0	0	0	4	0	4	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S40	40.61	R	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S41	31.68	R	1+	1	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S42	46.1	L	2+	1	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S43	41.93	R	1+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S44	33.88	L	1+	1	2	1	1	0	1	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S45	29.56	L	1+	0	4	0	0	0	3	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S46	41.75	R	1+	0	4	1	0	0	0	0	0	0	0	0

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8PI41TU2	BSH	7	MWP	8PITU2LVL7S47	47	L	1+	1	2	1	0	0	0	0	0	1	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S48	35.23	-	1+	1	5	0	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S49	46.29	R	2+	2	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S50	42.69	L	1+	1	2	1	0	0	0	0	0	3	0	1
8PI41TU2	BSH	7	MWP	8PITU2LVL7S51	49.45	L	2+	2	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S52	49.66	L	2+	2	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S53	39.56	R	1+	1	3	1	0	0	1	0	0	2	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S54	46.13	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S55	43.09	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S56	41.69	R	1+	1	4	1	0	0	0	0	0	1	0	0
8PI41TU2	BSH	7	MWP	8PITU2LVL7S57	39.91	-	1+	-	4	1	0	0	0	0	0	1	0	1
8PI41TU2	BSH	8	MWP	8PITU2LVL8S1	44.37	L	1+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S2	64.24	R	2+	4	3	1	0	1	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S3	39.37	L	1+	1	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S4	54.3	R	2+	0	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S5	44.85	L	1+	1	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S6	41.88	R	1+	0	4	1	0	0	0	0	0	2	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S7	30.44	L	1+	1	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S8	49.13	R	2+	2	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S9	42.61	L	1+	0	3	1	0	0	3	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S10	46.12	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S11	44.49	R	1+	2	3	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S12	33.91	R	1+	3	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S13	38.04	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S14	47.47	R	2+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S15	38.73	R	1+	2	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S16	40.63	R	1+	1	3	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S17	43.74	R	1+	1	4	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S18	51.29	R	2+	0	4	1	1	0	2	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S19	51.78	R	2+	1	2	1	0	0	0	0	0	0	0	2

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
8PI41TU2	BSH	8	MWP	8PITU2LVL8S20	32.33	L	1+	0	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S21	61	L	2+	0	1	1	1	0	9	0	1	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S22	61.22	L	2+	0	1	1	1	0	5	0	1	1	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S23	54.93	L	2+	2	2	1	0	0	1	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S24	50.28	R	2+	2	5	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S25	46.77	L	1+	3	2	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S26	42.17	L	1+	2	1	1	0	0	0	0	0	0	0	0
8PI41TU2	BSH	8	MWP	8PITU2LVL8S27	45.48	L	1+	1	2	1	1	0	2	0	0	0	0	0
8PI41TU2	BSH	9	MWP	8PITU2LVL9S1	41.21	R	1+	0	5	1	1	0	12	0	0	0	0	0
8PI41TU2	BSH	9	MWP	8PITU2LVL9S2	47.7	L	2+	1	5	1	1	0	4	0	2	0	0	0
8PI41TU2	BSH	9	MWP	8PITU2LVL9S3	53.82	L	2+	3	5	1	1	0	1	1	0	0	0	0
8PI41TU2	BSH	9	MWP	8PITU2LVL9S4	37.26	R	1+	1	5	1	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M1L	46.49	L	1+	1	1	0	0	0	0	0	0	2	0	0
Tampa Bay	TB	-	Modern	M1R	47.7	R	1+	1	1	0	0	0	0	0	0	4	0	0
Tampa Bay	TB	-	Modern	M2L	36.83	L	<1	0	1	0	0	0	0	5	0	0	0	0
Tampa Bay	TB	-	Modern	M2R	36.77	R	<1	0	1	0	0	0	0	0	0	2	0	0
Tampa Bay	TB	-	Modern	M3L	53.95	L	2+	2	1	0	0	0	0	16	0	1	0	0
Tampa Bay	TB	-	Modern	M3R	54.82	R	2+	2	1	0	0	0	0	1	0	1	0	0
Tampa Bay	TB	-	Modern	M4L	47.87	L	2+	2	1	0	0	0	0	0	0	2	0	0
Tampa Bay	TB	-	Modern	M4R	48.84	R	2+	2	1	0	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M5L	30.91	L	1+	1	1	0	0	0	0	1	0	0	0	0
Tampa Bay	TB	-	Modern	M5R	31.63	R	1+	1	1	0	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M6L	42.49	L	2+	2	1	0	0	0	0	1	0	1	0	0
Tampa Bay	TB	-	Modern	M6R	43.76	R	2+	2	1	0	0	0	0	0	0	1	0	0
Tampa Bay	TB	-	Modern	M7L	46.04	L	2+	2	1	0	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M7R	47.04	R	2+	2	1	0	0	0	0	0	0	1	0	0
Tampa Bay	TB	-	Modern	M8L	36.35	L	1+	1	1	0	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M8R	36.62	R	1+	1	1	0	0	0	0	0	0	0	0	0
Tampa Bay	TB	-	Modern	M9L	59.97	L	2+	2	1	0	0	0	0	0	0	0	1	0
Tampa Bay	TB	-	Modern	M9R	61.31	R	2+	2	1	0	0	0	0	0	0	2	0	0

Site Number	Site Name	Level	Climate	Sample ID	Height (mm)	Valve (L/R)	Age	Annulae	Taph. Grade	Root Traces	Int. Boring	<i>Entobia</i>	Spionid	Worm Tube	Gastropod	Oyster	Barnacle	<i>Crepidula</i>
Tampa Bay	TB	-	Modern	M10L	54.11	L	2+	2	1	0	0	0	0	18	0	3	1	0
Tampa Bay	TB	-	Modern	M10R	55.16	R	2+	2	1	0	0	0	1	1	0	1	0	0

APPENDIX B

Stable Isotopic data $\delta^{18}\text{O}_{\text{shell}}$ and $\delta^{13}\text{C}_{\text{shell}}$ for *A. irradians*

Table B. Stable isotopic data for the four assemblages listed by shell in order from OP-LIA (n=9), OP-MWP (n=2), BSH-MWP (n=8), and Modern (n=1). The $\delta^{18}\text{O}_{\text{shell}}$ and $\delta^{13}\text{C}_{\text{shell}}$ are listed for each shell with sample one being the final season of growth going to the umbo.

Sample #	P96S1		P97S1		P99S1		P99S2		P99S3	
	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
1	-1.7864	-3.2798	-0.9052	-2.4292	-1.0804	-2.2494	-1.1884	-2.5244	-0.5996	-2.4716
2	-2.1900	-2.9946	-1.3218	-2.7822	-1.2004	-1.8652	-0.7552	-1.893	-0.3136	-1.9892
3	-1.8154	-2.7244	-1.1614	-2.4332	-0.71	-1.5244	-1.5132	-2.4892	-0.4884	-1.7752
4	-1.5212	-2.6740	-1.2138	-2.1106	-1.258	-1.6928	-1.2388	-2.2526	-0.2258	-1.5616
5	-2.2976	-2.8694	-1.3582	-2.061	-1.3492	-1.7758	-1.139	-1.9858	-0.6480	-1.9448
6	-2.7074	-2.8892	-1.1694	-1.9434	-0.9328	-1.1802	-0.7426	-1.237	-0.9887	-2.3112
7	-2.3144	-2.4856	-1.3308	-1.79	-1.4264	-1.4352	-1.5748	-1.4478	-0.8202	-1.9312
8	-2.3072	-2.2730	-1.4268	-1.8858	-1.469	-1.427	-1.5248	-1.6892	-0.8722	-1.4014
9	-2.3538	-2.6522	-0.9162	-1.9572	-1.066	-1.1216	-1.3696	-1.6214	-0.5818	-2.0768
10	-1.8124	-2.7732	-0.7606	-1.6048	-1.0456	-1.135	-0.8654	-1.243	-0.4756	-2.0328
11	-1.7770	-3.4016	-0.8268	-2.525	-1.2994	-1.3392	-1.4914	-1.8996	-0.5824	-1.3314
12	-1.9602	-3.0348	-0.84	-2.5082	-1.5582	-1.5378	-1.6306	-1.8628	-0.7012	-0.8510
13	-2.0002	-2.1440	-0.8028	-1.8178	-1.1926	-1.6348	-1.194	-1.6084	-0.8478	-1.6042
14	-0.9116	-2.0164	-0.548	-1.1342	-1.1948	-1.0432	-1.4966	-1.1342	-0.5080	-0.8286
15	-0.9644	-2.1400	-0.6368	-1.1016	-0.9402	-0.4206	-0.8022	-0.405	-0.6160	-0.9238
16	-0.2190	-2.1210	-0.7248	-1.3986	-0.7334	-0.3676	-0.3584	-1.2296	-0.3364	-0.6316
17	-0.8616	-2.3914	-0.3984	-1.211	-0.553	-0.909	-0.176	-1.5352	-0.1030	-0.0198
18	-0.7464	-2.4340	-0.8306	-0.6254	-0.3284	-1.0376	-0.6446	-1.6144	-1.0986	-0.5040
19	-0.9064	-1.7744	-0.7622	-0.3692	-0.5142	-1.1114	0.042	-0.7354	-0.6100	-0.5316
20	-0.5506	-1.6078	-0.4318	-0.2148	-0.241	-0.7118	-0.2572	-0.8818	-0.5846	-0.5638
21	-0.3378	-0.9704	-0.7776	-0.05	-0.1172	-0.9416	0.103	-0.9072	-0.6994	-0.0044
22	-0.0418	-1.1468	-0.7768	0.1288	-0.2954	-0.4584	-0.0624	-1.0414	-0.7820	-0.1426
23	-0.4166	-1.4824	-0.5612	0.1554	0.0814	-0.6388	-0.2592	-0.9932	-0.4154	-0.0942
24	-0.3312	-1.5478	-0.5772	-0.1016	0.0938	-0.9686	-0.4376	-0.488	0.0014	0.3428
25	-0.3054	-1.1418	-0.4596	0.0594	-0.0474	-0.934	-0.3348	-0.395	0.3274	0.6160
26	0.2316	-0.4028	0.1684	0.2322	-0.2082	-0.6334	0.1196	-0.223	0.0314	0.0934
27	-0.4218	-0.5448	0.3868	-0.0918	-0.2172	-0.5234	0.4674	-0.3312	-0.2712	0.1130
28	0.3144	-0.8228	0.035	0.0304	-0.1132	-0.38	0.003	-0.0346	-0.0588	0.2434
29	0.3806	-0.8306	-0.0212	0.07	0.3694	-0.2028	0.459	-0.2424	0.0562	0.2976
30	0.3240	-1.0706	0.0936	-0.125	0.5572	-0.3358	0.1198	-0.0988	0.1932	0.2430
31	0.6050	-0.7204	0.6112	-0.1794	0.2418	-0.199	0.1164	-0.768	0.4320	0.4612

Sample #	P96S1		P97S1		P99S1		P99S2		P99S3	
	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
32	-0.4996	-1.4896	0.72	-0.378	0.3512	-0.6646	0.0186	-0.384	0.3528	-0.0258
33	-1.0066	-1.1976	0.6168	-0.7892	-0.0428	-0.9664	-0.1474	-0.0506	-0.0678	-0.2494
34	-0.0106	-0.8424	-0.004	-0.8456	-0.1308	-0.1708	0.5772	0.1662	0.3422	-0.0934
35	0.5786	-0.0810	0.361	-0.5914	0.3806	-0.0304	0.4444	0.08	-0.1534	0.0500
36	0.6818	-0.2988	1.0528	-0.4494	0.5718	-0.046	0.9442	0.1704	0.1016	-0.0726
37	0.6266	-0.3184	1.505	-0.3598	0.0804	0.1352	0.8134	0.4502	0.7034	-0.0270
38	0.1186	-1.0708	1.2868	-0.4094	0.6032	0.074	0.0662	0.1866	0.3154	-0.4408
39	0.0630	-0.9724	1.7544	-0.4748	0.5306	0.095	0.5268	-0.1542	1.2096	-0.2732
40	0.0818	-0.8816	1.3568	-0.627	1.2456	-0.0376	0.7204	-0.0418	0.7878	-0.2886
41	-0.1120	-0.8338	1.1004	0.0946	0.296	-0.2666	0.9252	0.0382	0.9982	-0.0176
42	0.3338	-0.9712	1.6322	0.1234	1.2742	-0.1068	1.2748	-0.2424	0.9008	0.1324
43	-0.0146	-0.8396	1.2862	-0.9304	1.1748	-0.2198	0.7740	-0.1246	-	-
44	-0.2956	-0.1050	-	-	0.8316	0.0458	1.8440	-0.0942	-	-
45	0.5212	0.1276	-	-	0.7476	-0.7758	0.9704	0.5344	-	-

Sample #	P99S4		P103S2		P104S3		P104S9		P105S4	
	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
1	-0.4626	-1.439	-	-	-0.2180	-1.1254	-1.1386	-3.0652	0.0664	-4.9474
2	-0.798	-1.5902	-1.0296	-2.8702	-0.0416	-2.4248	-1.4532	-2.9352	0.3270	-4.4100
3	-1.0276	-1.4242	-0.8506	-2.3676	-	-	-1.3252	-2.4812	0.1420	-4.3420
4	-1.2104	-1.4582	-1.1826	-2.1102	0.3156	-2.6216	-1.2302	-2.1132	0.3420	-4.5328
5	-0.7032	-1.172	-1.1368	-1.7168	0.3980	-3.1824	-0.391	-1.8828	-0.3358	-4.2584
6	-1.2194	-1.4932	-0.9940	-2.0840	0.7756	-2.1244	-0.5574	-3.0286	0.2700	-3.4992
7	-1.087	-1.5602	-	-	0.6394	-2.5348	-0.6962	-2.922	0.0502	-3.0788
8	-0.8374	-1.2318	-0.1960	-2.2864	1.1258	-1.4796	-0.5726	-2.9354	0.2216	-3.0208
9	-0.6702	-0.8658	-0.2750	-2.1966	0.3598	-1.5488	-0.0656	-2.7238	0.4840	-2.3692
10	-0.0422	-1.509	-0.6772	-1.9574	0.1862	-2.2258	-0.0352	-3.2988	0.0904	-2.9066
11	0.0206	-0.9318	-	-	0.1554	-2.4762	-0.2566	-3.2474	0.2212	-3.0214
12	0.1016	-0.9268	-1.1144	-2.3152	0.5692	-1.8612	-0.4988	-3.4748	0.3720	-2.4394
13	0.0316	-0.7328	-0.5694	-1.6506	1.4244	-1.1612	-0.098	-3.134	0.3820	-1.9152
14	0.0734	-0.5478	0.0602	-1.4208	0.6292	-1.1238	-0.6658	-3.6368	0.4592	-2.2146
15	-0.0044	-1.0004	-0.0032	-1.3454	0.2250	-1.3384	-0.2116	-3.6048	0.3974	-1.9418
16	-0.173	-0.7164	-0.2952	-1.1600	1.2374	-1.3492	0.1276	-3.452	0.3560	-2.0538
17	-0.1516	-0.4598	-0.0150	-1.1808	0.7514	-1.4034	-0.314	-3.2178	1.2794	-1.3058
18	-0.03	-0.5006	-0.5560	-1.2812	0.7682	-1.9004	0.1594	-2.8322	0.5474	-1.5508
19	-0.0524	-0.4216	-0.1110	-0.6592	0.7066	-1.0384	0.5164	-2.3992	0.5708	-1.6462
20	0.2096	-0.2676	0.0100	-0.3548	0.8684	-1.2294	0.5462	-2.3996	0.3313	-1.4437
21	0.3986	-0.3232	0.4492	-0.4208	-0.1232	-1.9390	-0.0194	-2.6736	1.1012	-1.0356
22	0.1738	-0.1008	0.6196	-0.4678	0.1714	-1.4528	0.3504	-2.8578	1.4372	-0.6964
23	0.6524	-0.5908	1.3746	-0.2428	0.0884	-2.1626	0.2316	-3.1142	1.4406	-0.5494
24	-0.044	-1.5886	1.4230	0.0270	0.4724	-1.9172	-0.2782	-2.1408	2.1052	-0.5242
25	-0.1256	-0.4776	0.7552	-0.2970	0.1972	-1.9878	0.9558	-2.1202	2.7280	-0.2964
26	0.0768	-0.109	0.2312	-0.4942	0.1814	-1.8382	0.907	-2.024	2.3124	-0.4952
27	0.4592	-0.2184	0.3572	-0.1742	0.6326	-0.5042	-0.133	-1.6456	2.7142	-0.7140
28	0.848	-0.047	0.9806	-0.0246	0.8100	-0.6678	0.8402	-1.4886	3.0264	-0.7660
29	0.4742	0.0502	0.9200	-0.0996	1.0732	-0.4282	0.1118	-1.2834	3.1848	-0.6114
30	0.7582	-0.0074	1.0922	-0.1196	0.2604	-0.8398	0.0516	-1.3248	3.0914	-0.9148
31	1	0.025	1.5492	0.0534	0.2730	-1.4224	0.2712	-1.1916	1.7420	-1.0324
32	0.8838	0.1892	2.1032	-0.0636	1.1888	-0.4116	0.6416	-1.1582	2.3690	-1.4264
33	0.3796	0.1336	1.5044	-0.4962	-	-	1.1862	-0.7936	0.5052	-1.4794
34	0.6034	-0.0198	-	-	0.1238	-1.1790	0.5554	-1.0018	-0.0524	-1.5256
35	0.6038	0.3152	0.9114	-0.2138	-	-	0.8138	-0.8902	0.5446	-1.5126
36	1.0156	0.2698	0.7686	-0.0962	-0.0566	-2.0582	0.9922	-1.0796	0.7640	-1.4996
37	1.4208	0.0452	1.3536	-0.7512	-0.1884	-1.4018	0.9738	-0.8986	0.1448	-1.5098
38	0.6742	0.1558	1.8168	-0.3116	0.4408	-0.969	0.799	-0.641	0.4176	-1.7408
39	1.5552	0.2646	-	-	-0.1374	-2.4042	1.9338	-0.6472	0.2510	-1.6814
40	0.856	0.0866	1.5240	-0.7458	0.0486	-1.5772	-0.0372	-0.8406	-0.2764	-1.5866
41	0.9696	0.027	0.8016	-0.7698	0.0056	-1.9406	0.703	-1.0336	-0.6442	-2.0602
42	1.0024	0.1334	1.1324	-0.9380	-0.081	-1.652	0.6218	-0.9584	-1.2404	-1.1998
43	1.6128	-0.181	1.2952	-1.1000	0.032	-0.8788	0.487	-1.0446	-	-
44	1.8372	-0.4008	1.1738	-0.9814	0.389	-1.1336	0.3416	-1.1818	-	-
45	1.5038	0.418	-	-	-0.29	-2.3984	1.083	-0.7284	-	-

Sample #	P105S10		BSH2		BSH3		BSH4		BSH5	
	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
1	0.1538	-2.9536	-0.1798	-2.0368	0.293	-2.6604	-0.904	-2.0028	0.1538	-2.9536
2	0.3192	-1.7142	-0.0656	-2.0092	0.0094	-2.7418	-0.3068	-1.2892	0.3192	-1.7142
3	0.6824	-1.7048	-0.1186	-2.1580	0.0982	-2.4634	-0.2232	-1.9528	0.6824	-1.7048
4	-0.017	-1.8684	-0.1550	-1.5270	0.1248	-2.509	-0.1354	-0.6776	-0.017	-1.8684
5	0.3026	-1.961	-0.2212	-1.1376	0.489	-2.663	-0.3104	-1.1958	0.3026	-1.961
6	0.2506	-1.6294	0.0484	-1.1660	0.0622	-2.0382	-0.1674	-1.121	0.2506	-1.6294
7	0.0736	-1.5878	0.3312	-1.3414	0.5016	-1.9848	-0.3014	-0.7768	0.0736	-1.5878
8	-0.506	-1.8976	0.3300	-0.6226	-0.0442	-1.5646	-0.2236	-1.2512	-0.506	-1.8976
9	0.2048	-1.4654	0.0462	-0.6900	-0.0968	-1.7042	-0.1622	-0.7734	0.2048	-1.4654
10	1.06	-1.0118	0.2116	-0.6544	0.4554	-1.6874	0.1814	-0.747	1.06	-1.0118
11	1.7004	-1.102	-0.0468	-0.5794	0.437	-1.6726	0.279	-0.6144	1.7004	-1.102
12	0.5136	-0.7972	-0.0964	-0.6094	0.2432	-1.6562	0.462	-0.6690	0.5136	-0.7972
13	0.3668	-0.9852	0.1576	-0.6666	-0.334	-1.2872	0.7532	-0.6512	0.3668	-0.9852
14	0.8024	-1.3176	-0.2042	-0.6520	-0.1292	-1.197	0.4844	-0.4268	0.8024	-1.3176
15	0.1566	-0.9014	0.2914	-0.4666	0.0684	-1.2898	0.9556	-0.3356	0.1566	-0.9014
16	0.552	-1.2222	0.1514	-0.3428	0.5412	-1.2192	0.7294	-1.1520	0.552	-1.2222
17	0.5616	-1.6052	0.6412	0.0152	0.371	-0.9956	1.4976	-0.0170	0.5616	-1.6052
18	0.1498	-1.1746	0.7608	-0.2740	0.1536	-0.7722	0.4746	-0.6256	0.1498	-1.1746
19	0.2758	-1.1616	0.8804	0.1170	0.1798	-0.4782	1.0266	-0.3754	0.2758	-1.1616
20	0.5694	-1.3332	1.4462	-0.3776	0.3258	-0.2396	-	-	0.5694	-1.3332
21	0.6748	-0.8148	1.6302	0.1806	1.1424	-0.5216	0.3512	-0.4406	0.6748	-0.8148
22	0.8358	-1.0266	1.3290	0.3542	0.4146	-0.5472	0.5976	-0.2594	0.8358	-1.0266
23	0.3336	-0.9814	0.4282	0.1498	0.6082	-0.5768	0.723	-0.5082	0.3336	-0.9814
24	0.4762	-1.0492	1.1952	-0.0408	0.4048	-0.4452	0.4554	-0.2448	0.4762	-1.0492
25	0.34	-1.1986	1.1484	0.2526	0.2906	-0.6602	1.7828	0.1504	0.34	-1.1986
26	0.5268	-1.0646	0.7060	0.2102	0.755	-0.8682	1.5382	0.1044	0.5268	-1.0646
27	0.9612	-1.2396	0.7504	-0.1214	0.7156	-0.8066	1.5988	-0.262	0.9612	-1.2396
28	0.871	-0.845	1.5524	-0.2492	0.7884	-0.9298	0.9668	0.1112	0.871	-0.845
29	0.8192	-0.9226	1.6486	0.0196	1.2994	-1.005	0.6472	-0.4024	0.8192	-0.9226
30	1.6722	-1.1238	1.5656	-0.0534	0.3302	-1.1008	0.9956	-0.457	1.6722	-1.1238
31	1.0174	-0.8722	1.8952	0.07	0.907	-0.8158	0.7518	-0.1632	1.0174	-0.8722
32	1.539	-0.777	0.4618	-0.278	0.9216	-0.9008	1.7856	-0.1318	1.539	-0.777
33	1.1782	-1.7412	0.768	-0.2952	1.3214	-1.1568	0.13875	0.46825	1.1782	-1.7412
34	-	-	0.8792	-0.2824	1.124	-1.7188	0.5584	-0.3872	-	-
35	-	-	1.4086	-0.2944	0.7998	-1.6754	0.8626	-0.4368	-	-
36	-	-	1.8462	-0.3856	1.0462	-1.5702	1.5482	-0.187	-	-
37	-	-	1.6636	-0.4592	0.6836	-1.8554	0.351	-0.4424	-	-
38	-	-	1.405	-0.2188	1.013	-1.548	0.0592	-0.8176	-	-
39	-	-	1.1648	0.1664	1.5764	-1.0956	0.3376	-0.4518	-	-
40	-	-	1.5608	-0.1804	1.2026	-0.3614	1.2132	-1.1536	-	-
41	-	-	1.7882	-0.3764	1.0064	-2.2142	1.3238	-0.6022	-	-
42	-	-	2.202	0.0284	-	-	-0.1212	-1.3386	-	-
43	-	-	1.828	0.2424	-	-	-0.1632	-1.2974	-	-
44	-	-	1.717	0.2132	-	-	0.3436	-0.6022	-	-
45	-	-	1.4256	-0.6146	-	-	0.0034	-1.4446	-	-

Sample #	BSH6		BSH7		BSH8		BSH9		MODERN	
	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
1	-0.5104	-0.8876	-0.0352	-2.0044	-0.318	-2.0438	-0.634	-1.6918	-0.795	-4.4534
2	-0.8424	-0.7848	-0.1116	-1.9598	-0.4444	-2.2256	-0.6766	-1.7384	-0.5924	-4.1202
3	-0.5544	-1.02	0.2602	-2.1706	-0.3298	-2.048	-0.4666	-1.499	-0.683	-4.221
4	-	-	0.6768	-1.8874	-0.0402	-2.5824	-0.3114	-1.231	-0.7036	-4.2688
5	-0.0902	-0.9998	0.6178	-1.7386	0.0074	-2.0352	-0.7132	-1.5364	-1.1192	-4.9828
6	-0.373	-1.3676	0.4976	-1.4096	0.122	-1.5514	-0.7644	-2.0012	-0.7034	-4.8862
7	-0.3774	-1.3854	0.5382	-1.5974	0.2456	-1.2106	-0.1612	-1.3206	-0.7494	-5.1946
8	-0.1542	-1.1594	0.303	-1.3544	-0.0692	-1.0178	0.0822	-1.1212	-0.8992	-4.0326
9	-0.1394	-1.211	0.5302	-1.7876	0.1906	-0.7264	0.1098	-0.9106	-0.4192	-3.8152
10	-0.0222	-0.8394	-0.0244	-1.7966	0.3442	-0.6288	0.452	-0.6942	-0.4858	-3.8322
11	0.182	-0.591	-0.2138	-1.575	0.9002	-0.4282	0.1398	-0.6208	0.0056	-3.6388
12	-0.1476	-0.9344	0.4256	-1.6528	0.8254	-0.2488	0.2566	-0.6246	0.4088	-3.5762
13	0.3664	-0.9538	0.1716	-1.3212	-	-	0.59	-0.8006	0.2836	-3.5832
14	-0.0202	-0.6656	0.5874	-1.5062	0.4004	-0.3736	-0.4394	-0.6936	0.5698	-3.4608
15	0.2454	-0.7574	0.4488	-1.399	0.9648	-0.3168	0.0098	-0.542	0.6126	-3.2366
16	0.2566	-0.5916	0.1178	-1.1876	1.1548	-0.3826	1.0926	-0.4076	0.3102	-3.3256
17	0.6354	-0.446	0.157	-0.8406	1.0578	-0.58	1.8562	-0.2096	0.303	-3.0146
18	0.7784	-0.7332	0.2296	-1.231	1.1046	-0.6294	0.924	-0.2488	0.381	-2.8242
19	1.1874	-0.3684	0.2424	-0.9566	0.8348	-0.9006	0.198	-0.097	0.3138	-2.7094
20	1.274	-0.3066	0.2418	-1.4084	1.4186	-0.4252	0.99	-0.0912	0.6084	-2.783
21	1.3222	-0.3802	0.4116	-1.4604	1.5784	-0.0108	0.7972	-0.3344	1.8226	-2.6024
22	0.3316	-0.5268	-0.0342	-0.841	1.5442	-0.1446	0.733	-0.1562	1.4754	-2.7088
23	0.7234	-0.1808	0.8328	-0.5854	2.5062	0.0710	1.3192	-0.0504	1.2174	-2.8972
24	0.1502	-0.4526	0.5246	-1.041	1.7150	-0.0500	1.321	-0.1916	0.3528	-2.6988
25	0.2422	-0.5364	2.1362	-0.3392	2.2594	-0.0636	1.2016	-0.3058	0.4824	-2.7818
26	0.9958	-0.568	0.6274	-0.8724	2.1948	-0.2116	1.2896	-0.2308	0.6578	-2.6882
27	0.9144	-0.2704	0.8412	-1.1948	0.6130	-0.2394	0.5634	-0.5738	1.3822	-2.9348
28	1.5564	-0.3024	0.977	-0.1388	0.7816	-0.2060	1.1544	-0.3916	1.7994	-3.1582
29	1.9122	-0.1204	2.0336	-0.243	1.1058	-0.1976	2.0524	-0.5072	2.3318	-3.2482
30	0.8598	-0.5806	0.7992	-0.596	1.3316	-0.1242	0.9442	-0.763	0.9364	-3.4996
31	1.1822	-0.3652	0.6776	-0.7842	1.8978	-0.6028	0.9426	-0.8768	1.2348	-3.2852
32	2.5438	-0.4962	0.7948	-0.8888	1.4470	-0.4450	1.0406	-0.864	0.2148	-3.3916
33	0.7968	-0.7232	0.2576	-1.3748	1.3368	-0.3686	1.7474	-0.7272	1.347	-3.4202
34	1.6956	-0.6446	0.4234	-1.324	1.6254	-0.5194	1.274	-0.4284	0.3332	-3.2172
35	0.4932	-0.5896	0.9104	-1.3674	1.7960	-0.5446	0.888	-0.4426	0.6824	-2.9576
36	0.8306	-0.66	-	-	2.3042	-0.6670	1.0146	-1.1588	-	-
37	1.7222	-0.841	-	-	1.6218	-0.3466	-	-	-	-
38	0.2036	-1.1734	-	-	1.8066	0.2826	-	-	-	-
39	1.1578	-1.297	-	-	1.9018	-0.4750	-	-	-	-
40	0.0808	-0.937	-	-	-	-	-	-	-	-
41	0.7164	-0.9762	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-