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Human-Environment Interactions: Sea-Level Rise and Marine Resource Use at Eleanor Betty, an Underwater Maya Salt Work, Belize

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HUMAN-ENVIRONMENT INTERACTIONS:
SEA-LEVEL RISE AND MARINE RESOURCE USE AT ELEANOR BETTY,
AN UNDERWATER MAYA SALT WORK, BELIZE

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Doctor of Philosophy

in

The Department of Geography and Anthropology

by

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December 2017

To my husband, Sean.

To those who have gone— Pappy, PopPop, MomMom, Big Nanny, Big Papaw, and Eola.

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Abstract

Dissertation excavations were performed in the spring of 2013 at the underwater site of Eleanor Betty in Paynes Creek National Park, Belize. The marine environment preserved wooden architecture associated with the salt works. Excavation goals included: 1) excavating and defining the boundaries of the submerged shell midden; 2) collecting sediment samples for paleoenvironmental analyses; and 3) recovering cultural remains to determine the site's purpose (residence versus production workshop).

Four transects were added to the existing transect from excavations performed during the 2011 field season. The shell midden measured 5 meters in length (north-to-south throughout all transects) by 0.5-to-1 meters in width (east-to-west across all transects).

Sediment samples were subjected to loss-on ignition (the burning of sediment to determine the percent of organic matter present) and microscopic identification of sediment to identify the type of organic matter present. Analyses revealed a high organic content coupled with an abundance of *Rhizophora mangle* (fine red mangrove roots), which keep pace with sea-level rise and fall. Results indicate that Eleanor Betty was built on the cleared red mangrove stands and submerged by sea-level rise.

The shell midden was determined to be a cultural midden as charcoal and archaeological material were recovered throughout all levels of the submerged midden deposit. Approximately 4,733 pieces of shell resulted from the excavations. Of the 4,733 pieces, 3,979 fragments were identified as *Crassostrea rhizophora* (red mangrove oysters). Microscopic analyses suggest the shell were part of a meal, perhaps a feasting ritual, as evidenced by the break patterns on the shells' ventral margins. Assessment of height-length ratios for predation indicates the procurement of shells was a one-time event.

An abundance of charcoal (~16,000 grams) and briquetage (~215,000 grams) – pottery used to evaporate brine over fires to make salt, was recovered from the 2013 field excavations. No household items, such as figurine whistles or pottery used for food storage, were recovered. The excavation results indicate that Eleanor Betty was a salt production workshop.

Chapter 1: Introduction

Dissertation excavations were performed in the spring of 2013 at the ancient Maya underwater site of Eleanor Betty in Paynes Creek National Park, Belize, as part of the National Science Foundation (NSF) grant “Collaborative Research: Ancient Maya Wooden Architecture and the Salt Industry.” Eleanor Betty is part of the Paynes Creek Salt Works located in Punta Ycacos Lagoon system in southern Belize (Figure 1.1). To date, over 105 underwater and terrestrial sites have been recorded in this area by Dr. Heather McKillop and her team (McKillop 2002, 2004a, 2004b, 2005a, 2007a, 2007b, 2008, 2009a, 2009b, 2010; McKillop et al. 2010a, 2010b; Robinson and McKillop 2013; Sills and McKillop 2010, 2013; Watson et al. 2013).

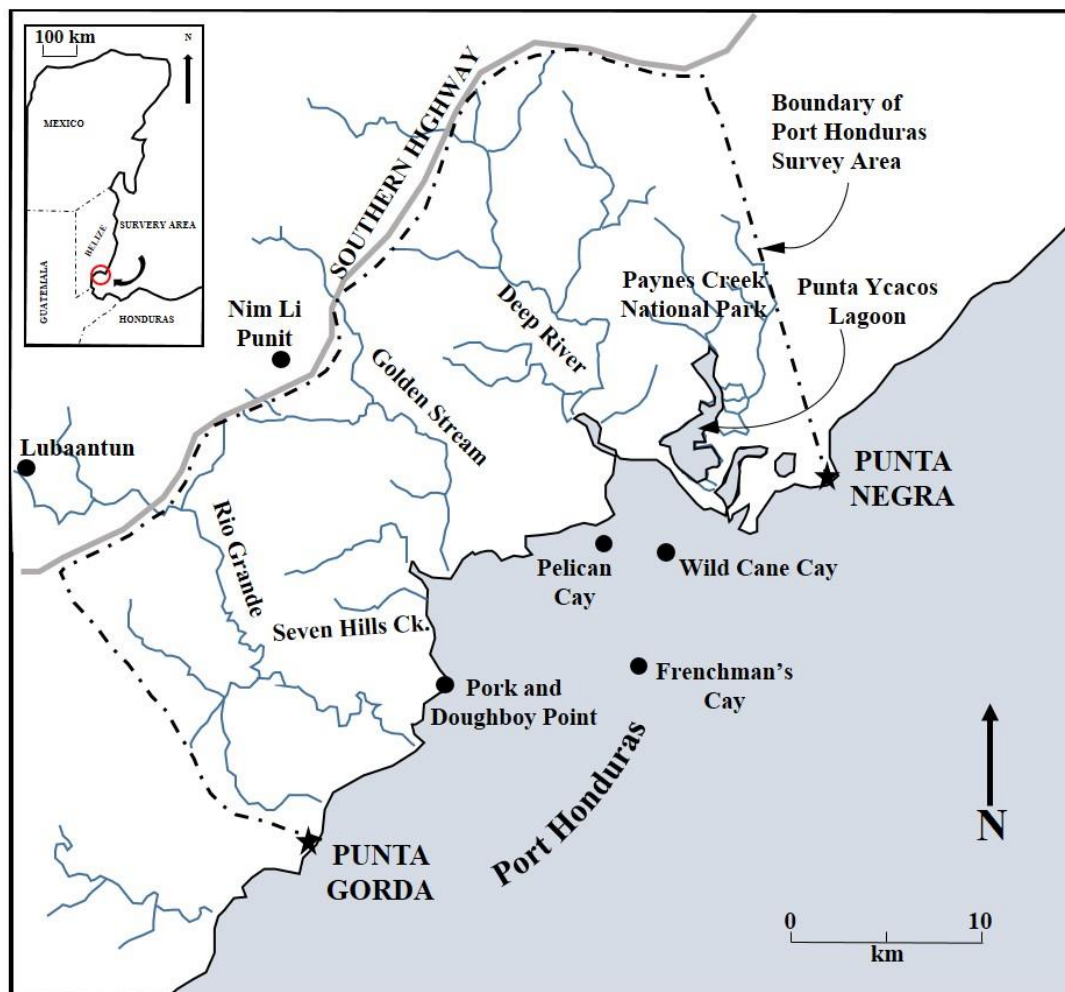


Figure 1.1. Map of survey area and research area. Adapted from McKillop (2009b: Figure 1).

2013 Field Research Goals

The main goal outlined prior to the start of the 2013 field season was excavating and establishing the extent of a submerged shell midden unexpectedly discovered during the 2011 field season. A second goal was to determine the function of the site as a household workshop, production workshop, or residence. Additional research goals included laboratory analyses to determine if the shell midden was cultural or natural, defining the purpose of the shell as utilitarian, non-utilitarian, or subsistence items, and determining if the site was once on dry land and submerged by rising seas or on platforms over the water.

Salt Production in Mesoamerica

The periodicity of salt production, along with the spatial distribution of salt works, in Mesoamerica has been widely disputed (Andrews 1983; Dillon 1975; Kepecs 2003; McKillop 2002). Evidence of salt production in the Yucatán Peninsula prior to and during the Early Formative period (1000-600 B.C.; Eaton 1978) is limited. A group of salt-making sites along the southwest coast of Guatemala provides evidence for salt production during the Late Formative period (300 BC-AD 300; Coe and Flannery 1967). Salt production continued throughout the Classic period (AD 300-900) and into the Postclassic period (AD 900-1452) at Salinas de los Nuevos Cerros in the Chixoy floodplain of Guatemala (Dillon 1977, 1981; Dillon et al. 1988; Woodfill et al. 2015) and the salt beds in the northern Yucatán Peninsula (Andrews 1983, 1984).

Salt makers throughout Mesoamerica at sites such as Sacapulas, Guatemala (Reina and Monaghan 1981) and the Lake Cuitzeo Basin, Michoacán (Williams 1999, 2002, 2004, 2010) continued to exploit salt flats for salt production during historic times. Andrews (1983) did not record salt works on the coast of Belize. He revised his original hypothesis that salt beds of the northern Yucatán supplied the inland Maya population of the southern Maya lowlands with salt

during the Classic period (Andrews 1997; Andrews and Mock 2002). McKillop (2002) hypothesized that the nearby inland lowland Maya utilized the salt production workshops of Paynes Creek National Park, Belize, for their salt needs.

Methods of Salt Production in Mesoamerica

Two common methods of salt production in Mesoamerica are solar evaporation and evaporation by fire. Methods of salt production in Mesoamerica have been documented primarily by ethnographic and ethnohistoric accounts. Other evidence of salt production can be found by analyzing broken pottery sherds primarily used with the fire evaporation method and identifying landscape modifications for the solar evaporation method (Somers 2007).

Solar Evaporation

Landscape modifications include digging salt pans (flat bottomed ponds) filled with coastal brine. The salt pans are left in the sun until the water has evaporated (Andrews 1983). The resulting crystalized salt is harvested with rakes, by hand, or with shell scrapers (Hester 1953).

Ethnoarchaeological and archaeological investigations were employed by Williams (1999, 2004, 2009, 2010) at a salt production site in Lake Cuitzeo Basin, Mexico. The salt makers at Lake Cuitzeo Basin utilized ancient salt making methods. They constructed cylindrical wooden structures, which were used as filters on top of wooden canoes used to dry brine filtered by the cylindrical wooden structures. The structures were supported by four wooden posts and crossbeams, which served to hold the structure in place (Williams 1999, 2004, 2009, 2010). Using wheelbarrows, soil was collected and placed into the cylindrical wooden structures. Spring water was then poured on the soil. The water was leached once it filtered through the soil. The salt makers gathered and packaged the crystalized salt once the brine completely evaporated (Williams 1999).

A separate salt production method, *tepesco*, involved filtering brine through salty soil in a raised wooden structure (Andrews 1983; Williams 1999). Once filtered, the brine was placed into solar pans and evaporated. Williams (1999) described a very similar method known as *tapeite*.

Evaporation by Heating Brine Over Fires, Creating “Briquetage”

The evaporation of brine over fire to make salt involves placing saline-rich brine in ceramic vessels and placing the vessels over a controlled fire for an extended period of time until the water in the vessels evaporates, leaving loose salt (Andrews 1983; Kepecs 2003; Santley 2004; Somers 2007). The ceramic vessels used in this salt-making process are called briquetage. Two periods of salt production occurred at El Salado in Veracruz, Mexico: one during the Early Formative and the other, more intense production, during the Late Classic (A.D. 600-900; Santley 2004). The methods of production changed from solar evaporation in the Early Formative to evaporation by fire in the Late Classic. The salt makers of El Salado employed mainly Coarse Brown, Coarse Brown with Quartz Temper, and Coarse Reddish Brown pottery styles. Some of the more widely-used ceramics were *tecomates* (globular jars without collars) during the Early Formative and *cazuelas* (vertical wall bowls with handles) during the Late Classic (Santley 2004).

The salt makers at Sacapulas, Guatemala, utilized raised platforms inside wooden buildings to produce salt (Reina and Monaghan 1981). They poured soil saturated with salt from the *playa* (piece of land containing a salt spring) into a raised wooden box on top of a mound. Water was poured over the soil, which leached the brine, increasing the salinity content of the water. The resulting briny water was collected in a tray below the raised wooden box (Reina and Monaghan 1981). A water jar was filled with the brine-laden water and poured into several clay

containers situated over a fire. The water evaporated, leaving salt that was transferred into jars situated along the inside wall. Sometimes the salt makers placed the salt back into the bowls and turned the containers upside down over the fires, hardening them into salt cakes and making them ready to transport to other sites.

Salt Trade in Mesoamerica

Andrews (1983) surveyed salt production in Mesoamerica. He stated that salt trading networks began in the Formative period and included, when possible, trading via waterways. He argued not only did the elite gain power from water control, but also from the control of salt trade, especially in the development of the Maya lowlands. Andrews asserted that the salt pans of the northern Yucatán supplied the southern Maya lowlands with salt. By this time, complex civic centers had formed and the demand for salt was increasing.

Salt production workshops appeared on the coast of Belize and concentrated on a variety of uses for salt (MacKinnon and Kepecs 1989; McKillop 2002, 2004b; Valdez and Mock 1991).

The Isla Cerritos Archaeological Project investigated the control Chichen Itza had on the salt trade in the northern Yucatán during the Itzá period (AD 700-1200; Andrews et al. 1988; Andrews and Mock 2002). Andrews (1983) argued the southern Maya elite would have preferred the pure white salt from the salt beds of the northern Yucatán, thus participating in long-distance trade networks. Celestún is a salt work on the Yucatán coast that participated in long-distance trade networks (Dahlin and Ardren 2002). Obsidian from Mexico and Guatemala was recovered at Celestún. Wild Cane Cay is a major trading port near the Paynes Creek Salt Works in southern Belize that may have facilitated the salt trade (McKillop 2002). Figurine whistles from Lubaantun and obsidian from highland Guatemala have been recovered at Wild Cane Cay.

Recent archaeological work in the southern Maya lowlands refutes Andrews' original hypothesis, which stated the salt flats of the Northern Yucatán supplied the entire Maya area with salt through long-distance trade networks. Salt can be acquired indirectly by eating meat or burning palms (Andrews 1983; Dillon 1977; Gann 1918; Marcus 1984, 1991; McKillop 1994, 1996). Inland sites such as Salinas de los Nuevos Cerros in the Chixoy floodplain of Guatemala (Dillon 1977, 1981; Dillon et al. 1988; Woodfill et al. 2015), the salt springs at Sacapulas, Guatemala (Reina and Monaghan 1981), and Lake Cuitzeo Basin, Michoacán (Williams 1999, 2002, 2004, 2010), also produced salt for local consumption and trade.

Salt makers along the coast of Belize not only produced salt for local consumption and trade, but also may have preserved marine resources for inland transportation. MacKinnon and Kepecs (1989) hypothesized that salt workshops at Placencia Lagoon were seasonal and produced salt for local consumption during the Classic period, whereas the Maya elite consumed high-quality salt imported from the Yucatán. Evidence of salt production included briquetage – the pottery used to evaporate brine over fire to make salt, which include sockets and spacers. Although seafood may not have been a significant component of the inland diet, archaeological evidence indicates that marine resources were traded from coastal sites (Emery 1999; McKillop 1984, 1985; Wing 1975, 1977). Valdez and Mock (1991) suggested the Maya at New River Lagoon, a permanent settlement, used salt to preserve fish for inland trade.

Who governed the salt trade from these coastal sites to the inland communities? McKillop (2008:257; 2009b:58) proposed three models to describe the political economy of the Paynes Creek Salt Works in relation to the coastal-inland trade network of southern Belize: 1) the *tribute model*; 2) the *alliance model*; and 3) the *household production model*. The *tribute model* represents control of coastal centers and their resources by the inland dynastic Maya. In

this model, the elite would combine communities into one region, which would pay tribute to those elite to participate in the coastal-inland trade network. Conversely, the *alliance model* provides the coastal communities with more control over the trade of their resources by forming trade networks and alliances with inland dynastic centers, which were often solidified through feasts and rituals. In the *household production* model, the households would have been self-sufficient and produced a limited amount of materials, such as salt, for household industries (McKillop 2009b).

Wild Cane Cay might have controlled the distribution of salt, and other marine resources, from the coastal workshops to the inland communities (McKillop 2009b) based on its geographic location of ritualistic trade goods. Salt could have been traded for inland resources, such as obsidian recovered from excavations at Wild Cane Cay. Other inland items, such as figurine whistles from Lubaantun and serving vessels for salt rituals, have been recovered from underwater excavations at the Paynes Creek Salt Works (McKillop 2002, 2009b). Additionally, the discovery of the preserved K'ak' Naab' canoe paddle supports evidence of canoe transport at the Paynes Creek Salt Works (McKillop 2005a, 2007a, 2007b). The number of settlements along the coast of the Yucatán and Belize increased after the Classic Maya collapse. Once the inland market system disappeared, the Paynes Creek Salt Works collapsed (McKillop 2009b). Salt production occurred at the household level during the Postclassic at Wild Cane Cay, Frenchman's Cay, and other coastal communities (McKillop 2002).

Previous Research in Paynes Creek, Belize

The Paynes Creek Salt Works were discovered during regional survey and were initially comprised of only four sites: Killer Bee, Stingray Lagoon, Orlando's Jewfish, and David Westby (McKillop 2002). Subsequent survey and excavation in Paynes Creek National Park have

documented over 105 sites, highlighting the need for salt during the Classic period for the lowland Maya (McKillop 2002, 2004a, 2004b, 2005a, 2007a, 2007b, 2008, 2009a, 2009b, 2010; McKillop et al. 2010a, 2010b; Sills and McKillop 2010, 2013; Watson et al. 2013).

Paynes Creek National Park provides the only preserved wooden architecture in the Maya area due to the anaerobic, or oxygen-free, nature of the mangrove peat sea floor. Thatching for roofs and wooden posts for residential dwellings decayed at inland sites due to the humid nature of the rainforest. However, evidence of perishable pole-and-thatch structures (Wauchope 1938), such as the remains of post holes, has been found at the inland sites of Tikal (Haviland 2014; Haviland et al. 1985) and Cerros (Freidel 1979). The wooden architecture at the Paynes Creek Salt Works, comprised of palmetto palm posts (*Acoelorrhaphes wrightii*) and hardwood posts, was mapped using a total station survey instrument (McKillop 2002, 2004b, 2007a, 2009a; McKillop et al. 2010a, 2010b; Sills and McKillop 2010).

At least some of the underwater sites date to the Late Classic (McKillop 2005a). Most sites contain an abundance of briquetage. People at other prehistoric sites in Central America employed this technique in ancient times (Andrews and Mock 2002; Dillon 1981; MacKinnon and Kepecs 1989; McKillop 1995, 2002, 2004b, 2005a, 2005b, 2007a, 2007b, 2008, 2009a, 2009b, 2010; Santley 2004; Sills and McKillop 2010; Woodfill et al. 2015) while others continue to use this method of salt production today (Reina and Monaghan 1981; Williams 1999, 2004, 2010).

Dissertation Research Hypotheses

Was Eleanor Betty a production or household workshop? Ceramics and other material culture remains recovered from the 2013 excavations were analyzed to examine site chronology and function. Three hypotheses were developed to investigate the role of the Eleanor Betty site.

If the site was residential, then household materials such as storage containers, marine and terrestrial faunal remains, and possibly human remains would be present. Alternatively, if Eleanor Betty was a salt production workshop, then a large amount of production refuse (briquetage) would be expected in the excavations. Animal and human remains, as well as household cultural remains, would be minimal or absent. Lastly, if Eleanor Betty was a household workshop, then a combination of household and production materials would be present.

The function of the shell deposit was investigated in conjunction with the function of the site. Was the deposit natural or cultural? The recovered shells were microscopically analyzed for butcher marks (Kent 1988). Other analyses included measurements for predation (Kent 1988) and calculations for the minimum number of individuals (MNI) and number of individual specimens present (NISP; Claassen 1998; McKillop 2004b; McKillop and Winemiller 2004).

The site's original placement (on dry land or on platforms over the water) was investigated once the function of the site was determined. In order to assess sea-level rise at the site, sediment samples were subjected to loss-on ignition (LOI; the burning of sediment to obtain the percent of organic matter present) and microscopic analysis. If the marine sediment contained an abundance of red mangrove roots and the sediment was highly organic, then Eleanor Betty would have been constructed on dry land and inundated due to rising seas (McKee and Travis 2006; McKillop et al. 2010a, 2010b). Alternatively, if the sediment was low in organic matter and red mangrove roots were absent, then the sea floor likely formed on land, indicating the site was built on elevated structures over the water. The presence of floorboards also would support the latter hypothesis.

The function of Eleanor Betty (household workshop, residence, production workshop) is investigated in the first manuscript. Survey and excavation techniques conducted during the 2013 field season are discussed to highlight the inclusion of preserved wooden posts in relation to a submerged shell deposit. Ceramic analyses were conducted in 2014 in accordance with the type-variety classification for Maya ceramic analysis. The recovered ceramics were identical to those recovered from other sites in Paynes Creek (i.e., briquetage). Additionally, the shells associated with the excavated units were identified as *Crassostrea rhizophora*. The shells, as well as recovered marine sediment from the excavations, were exported under permit to the Archaeology Lab at Louisiana State University (LSU) for study.

The nature of the Eleanor Betty shell deposit (cultural versus natural) and maritime trade of shell as well as its use at inland and coastal sites are examined in the second manuscript. The minimum number of individuals (MNI) and the number of individual specimens present (NISP) were determined for the recovered shell. Human predation was assessed using height-length ratios for shells with complete margins included in the MNI count. Butcher marks were classified according to a modification of Kent's (1988) break pattern classification for oyster shells.

The site's original location and subsequent cause for abandonment is discussed in the third manuscript. Marine sediment samples were subjected to loss-on ignition and microscopic analysis to identify the type of organic matter present. Additionally, pH analyses were performed on the sediment samples to inform on the impact the calcium carbonate (CaCO₃) matrix of the shell had on the preservational properties of the marine sediment. Two samples of red mangrove roots were submitted for accelerated mass spectrometer (AMS) dating to determine the rate of sea-level rise.

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Chapter 2: Excavating the Underwater Shell Midden at an Ancient Maya Salt Work in Belize: The Eleanor Betty Site¹

Introduction

Excavations of a shell deposit at the Eleanor Betty site in 2013 were carried out to investigate if the shell was a natural or cultural feature and what the shell could tell about ancient Maya salt production. The underwater site of Eleanor Betty is part of the Classic period (AD 300-900) Paynes Creek Salt Works located in Punta Ycacos Lagoon, a shallow salt-water lagoon in Paynes Creek National Park, Belize (Figure 2.1). Salt flats on the north coast of the Yucatán Peninsula were once thought to have produced salt for the entire Maya area during the Classic period (Andrews 1983).



Figure 2.1. Map of Belize showing location of Paynes Creek National Park. Base map from ESRI® ArcGIS® ArcMap™ 10.3 ©1999-2014.

However, the discovery of salt production on the coast of Belize changed that view (MacKinnon and Kepecs 1989; McKillop 1995, 2002, 2004b; Valdez and Mock 1991).

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MacKinnon and Kepecs (1989) hypothesized that Placencia was involved in seasonal salt production for local consumption. They suggest high-quality salt was imported from the Yucatán for the Maya elite. New River Lagoon was viewed as a permanent Maya settlement where salt was used as a preservative for fish to be traded to inland sites (Valdez and Mock 1991).

At the Paynes Creek Salt Works, salt was produced inside wooden buildings preserved in a peat bog below the sea floor (McKillop 2005a). The acidic peat at the Paynes Creek Salt Works did not preserve bone. However, the shell deposit at the Eleanor Betty site was an ideal matrix for bone preservation due to the calcium carbonate (CaCO_3) in the shell, so there was a possibility of identifying human burials and/or food remains. Since burials and animal food remains are typical of Maya residences, the search for bone would help answer if the Paynes Creek salt works were also residential. If human bone was present within the wooden structure located at the site, then Eleanor Betty could have been a coastal residence, perhaps a residential workshop. The presence of bone at the site could be used as a model for excavating other salt works where bone was not preserved due to the acidic peat. The extent and nature of the shell deposit (natural or cultural) and the accompanying preserved wooden architecture, were investigated.

Heather McKillop and her team discovered the salt works during regional survey in Punta Yucacos lagoon (McKillop 1995, 2002). Underwater excavations of the salt-making sites began in 1991. The excavation of four sites (Killer Bee, Stingray Lagoon, Orlando's and David Westby) led to a comprehensive underwater survey of the lagoon. Survey and excavation in Paynes Creek National Park underscore the production of salt during the Classic period (McKillop 1995, 2002, 2004b, 2005a, 2007a; Sills and McKillop 2010). This production is mirrored by the increase in inland Maya population and concomitant demand for dietary salt (McKillop 2002). After the

Classic Maya collapse, settlement along the coastline increased. The Paynes Creek salt works collapsed due to the disappearance of the inland demand for salt with the abandonment of the inland cities (McKillop 2009b). Salt was made at the household level in the Postclassic period (A.D. 900 – A.D. 1550) at Wild Cane Cay and Frenchman's Cay (McKillop 2002).

A total of 105 sites has been documented in Paynes Creek National Park (McKillop 2002, 2004b, 2005a, 2007a, 2008, 2009a; Sills and McKillop 2010). The sites contain briquetage – pottery used for the evaporation of brine over fire to make salt. The technique is seen elsewhere at prehistoric sites in Central America (Andrews and Mock 2002; Dillon 1981; MacKinnon and Kepecs 1989; McKillop 1995, 2002, 2004b, 2005a, 2005b, 2007a, 2007b, 2008, 2009a, 2009b, 2010; Santley 2004; Sills and McKillop 2010) and is still employed today (Reina and Monaghan 1981; Williams 1999, 2004, 2009, 2010).

Unlike other ancient Maya sites where materials such as thatching for roofs and wooden posts for residential dwelling and other wooden structures decayed, the Paynes Creek Salt Works have wooden posts preserved by the anaerobic mangrove peat matrix (McKillop 2005a, 2009a, 2010; McKillop et al. 2010a, 2010b; Sills and McKillop 2010). Post locations were mapped and recorded in a geographic information system (McKillop 2002, 2004b, 2007a, 2009a; McKillop et al. 2010a, 2010b; Sills and McKillop 2010). Radiocarbon (^{14}C) dates obtained from wooden structures date to the Classic period (AD 300-900; McKillop 2005a). The finding of the preserved K'ak' Naab' paddle supports evidence of inland salt trade (McKillop 2005a, 2007a, 2007b).

Mangrove peat is an acidic environment and, therefore, does not preserve bone. However, the peat is ideal for the preservation of wood. The shell deposit contained within the structure contains CaCO_3 from the shells which would preserve bone, if present.

Research Questions

The shell deposit was unexpected, so we were interested to discover if it was a post-inundation deposit or cultural and if cultural, how did it relate to salt production? If the shell deposit was a natural deposit, then there would be paired valves along with an absence of butcher marks, burned shell, faunal remains, charcoal, hearths, ash, or other artifacts, such as ceramics (Marquardt 2010). Alternatively, if the shell deposit was the result of deposition by the ancient Maya, then some or all of the following items would be present: burned shell, charcoal, ash, butchering marks on the shells, a lack of paired valves, and artifacts (Marquardt 2010).

If cultural, was the shell deposit associated with a residence, production workshop, or household workshop? If the area was residential, then human and animal bone (within the shell deposit) would be expected as the Maya buried their dead beneath household floors. Other household materials such as storage containers also would be expected. If the site was used solely for the production of salt, then production refuse material would be found, but animal, human, and other household cultural remains would be absent. If the site was a household workshop, then both household materials and production refuse materials would be expected.

Artifact analysis at other Paynes Creek Salt Works indicates they were not residential areas, but workshops for salt production due to the abundance of briquetage (McKillop 2005c; Sills and McKillop 2010). The trade of salt produced from these coastal workshops to inland communities (along with other marine resources) during the Classic (A.D. 300 – 900) may have been controlled by Wild Cane Cay (McKillop 2005b, 2008, 2009b). Salt likely was traded for inland items such as ocarinas and serving vessels, ritualistic objects which have been recovered at the Paynes Creek Salt Works (McKillop 1995, 2002, 2009b).

Underwater Excavations

During the 2013 field season, systematic flotation survey was used to relocate and mark previously-mapped wooden posts at the Eleanor Betty site and to locate new posts. Each post was marked with a pin flag. The acidic mangrove peat below the sea floor preserved hardwood and palmetto palm posts (*Acoelorrhaphe wrightii*). Palmetto palm posts are small in diameter with a hard exterior. Hardwood posts are solid and large in diameter. Palmetto palm posts were marked with red flags whereas hardwoods were marked with yellow flags (Figure 2.2).



Figure 2.2. Photo showing flags marking post locations and excavation units on the sea floor. Photo by V. Feathers.

Previously-discovered posts were easier to locate as they had small PVC pipe markers that had been placed on their north and northeast sides. The PVCs were labeled with the post number. New wooden posts at the site were recorded and mapped (Figure 2.3). All posts had been vertically placed in the mangrove peat. A curved line of palmetto palms runs north to south along the western edge of the site forming a wall. The curved line of palmetto palm posts surrounding a wooden structure is found at other sites in the lagoon, such as Chac Sak Ha Nal (McKillop 2008; Sills and McKillop 2010; Sills and McKillop 2013).

Upon completion of the systematic survey, the team uncovered the shell deposit in Transect 4 from the 2011 excavations (Aucoin 2012). After the 2011 excavations, the transect had been lined with plastic sheeting and weighted down with sandbags. They were removed along with silt that had washed into the transect. The silt was screened off-site in the water.

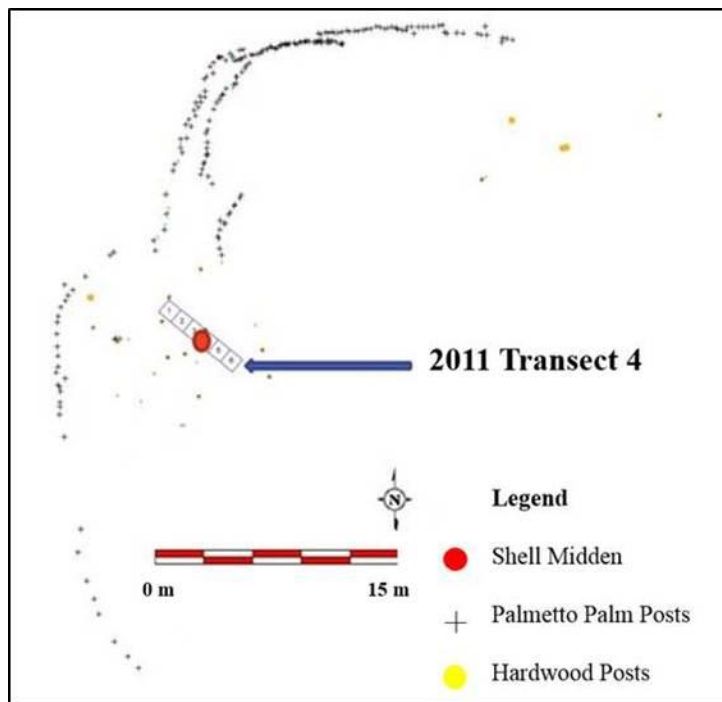


Figure 2.3. Map of Eleanor Betty. Map by V. Feathers annotated from base map by H. McKillop.

Four new transects were set out to horizontally expose the shell deposit (Figure 2.4). A total of 19 units was excavated (Figure 2.5). Each 1x1 m unit was marked with a yellow flag (labeled with the Transect and Unit numbers) and a quarter inch PVC pipe. Transects were placed north and south of the 2011 Transect 4, each seven meters in length. Excavations were placed to define the boundaries of the shell deposit and recover organic material, botanical remains, and microfossils, such as ostracods and foraminifera to inform of sea-level rise and the paleoenvironment.



Figure 2.4. Photo of triangulating with a tape measure to set out an excavation unit on the sea floor. Photo by R. Watson.

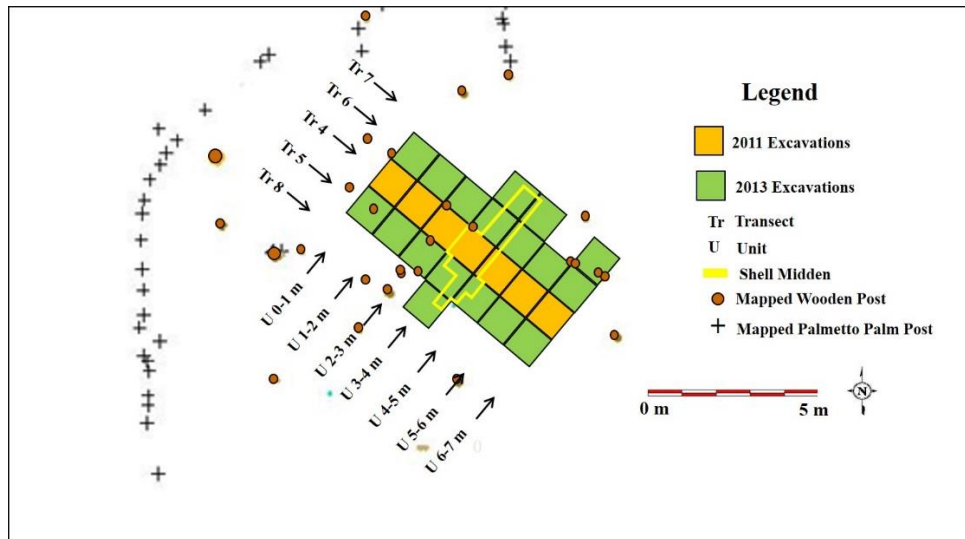


Figure 2.5. Map of underwater excavations at the Eleanor Betty site. Map by V. Feathers from base map by H. McKillop.

Each unit was excavated in 10 cm levels to 30 cm depth below the sea floor. The sea floor was 55 cm below the water surface during the 2013 excavations. Levels were measured using a plastic sewing tape. The first level, 0-10 cm depth, was the silt layer above the mangrove peat. The layer was comprised of sand, small shells, and briquetage. The second and third layers were composed of solid mangrove peat. Using a trowel, the peat was excavated, placed in the sandbag without loss of material or sediment, and secured with ties. A Ziploc bag with the

transect number, unit number, level, date, and excavator's name was placed in the sandbag along with the sediment. The bags were ferried off-site in the Marine Transportation Devices (MTDs) which were connected by a pulley system to a screening station.

The screener used a wooden screen box lined with 1/8th inch screen. The material was placed into the screen one bag at a time. The screener pushed the material through the screen and shook it in the water to remove the excess mangrove peat. Items were sorted into material classes (obsidian, chert, charcoal, shell, and pottery). Excavated ceramics were placed in the empty sandbag along with a new label. Smaller labeled bags were placed inside for other materials.

The horizontal extent of the shell deposit measured 5 m in length by 0.5 to 1 m in width whereas the vertical extent was 12 cm thick. The deposit was concentrated in Unit 3-4 m and 4-5 m of all transects and was excavated as a separate feature. After Transect 4 was exposed, the shell deposit was visible in the walls of unit 3-4 m. The north wall of unit 3-4 m was cleaned using a trowel. The profile was drawn and photographed. A transect placed beside Transect 4 to the north was labeled Transect 6. The shell deposit in Transect 6, Unit 3-4m, was excavated in 2 cm levels. The shell reached a maximum depth of 12 cm. The deposit contained more shell toward the surface of the mangrove peat and less shell as the depth increased. In the mangrove peat surrounding the shell deposit, there was an abundance of briquetage—the remains of pots used to evaporate brine over fires to make salt.

Sediment samples were collected in all levels throughout the shell deposit to evaluate the composition of the marine sediment, if it was marine or terrestrial in origin, and to assess sea-level rise. Sediment samples were taken in the southwest corner of each excavated unit. All samples were placed into whirl pack bags and labeled.

Methods

All recovered ceramics were sorted into type-varieties, drawn, photographed, weighed, and counted during the 2013 and 2014 field season to examine site chronology (following the type-variety system or Maya ceramic classification) and site function (attribute analysis). At the field station at Village Farm, selected rim sherds and other artifacts were scanned using a portable NextEngine 3D Laser scanner from the LSU Digital Imaging and Visualization in Archaeology (DIVA) Lab. The type-varieties include Punta Ycacos Unslipped (sherds from jars, basins, bowls), two types of water jars – Mangrove Unslipped (jars with incurved walls and outcurved necks, with round, square or grooved lips) and Warrie Red (jars and open bowls) as well as Moho Red pottery (open serving bowls; McKillop 2002).

Punta Ycacos Unslipped refers to all salt-making ceramics (briquetage) recovered from the ancient Paynes Creek National Park Salt Works. Types and varieties include: sherds from jars, basins, and bowls as well as whole and fragmentary vessel supports, including cylinders, spacers, sockets, and bases (McKillop 2002:54,55). Mangrove Unslipped jars were used to house and pour brine into Punta Ycacos vessels (McKillop 2002:77). Warrie Red jars were red-slipped with some of the shoulders of the jar having unit-stamped, impressed, or incised decorations. Other decorations included incised decoration on the exterior of some bowls (McKillop 2002:77). Although smaller in form than Mangrove Unslipped, Warrie Red also was used to store and pour brine into salt-making vessels. McKillop (2002:86) suggests Warrie Red jars may also have been used in salt rituals at Punta Ycacos Salt Works. Warrie Red was found mapped on the sea floor at the site but was not in found in the excavations, which were dominated by briquetage. Moho Red consists of red-slipped, yellow paste bowls or dishes with tripod bases

that are tempered with volcanic ash (McKillop 2002:86, 87). They were not part of the salt-making process. However, they likely were used as serving vessels in salt production rituals.

Shell and sediment samples were exported to the Archaeology Lab at LSU where wet weights were obtained for all recovered, exported material. Weights were obtained for all shells, charcoal, and botanicals by using a Taylor Glass LED digital scale in the field and Delta Range[®] Mettler PE 3600 in the Archaeology Lab at LSU. A plastic Tupperware container was used to hold items on the scale during this process. The material was then dried in a low-heat drying oven (64°C) and sorted into groups consisting of charcoal, shell, botanicals, and a miscellaneous group of rocks and coral. The materials were reweighed to obtain a dry weight. Fragmentary counts and weights were obtained for the macrobotanical remains of edible tree fruits, which were sorted into species: crabbo (*Byrsonima crassifolia*), coyol (*Acrocomia mexicana*), and cohune (*Orbignya cohune*).

Results

Two types of shell were discovered. The first type of shell was small and mixed with sand and silt and was found in several of the excavated units close to the surface layer. The second type of shell consisted of one species of mangrove oyster: *Crassostrea rhizophorae* (Figure 2.6).

Approximately 5,518 pieces of briquetage and 16,262 g of charcoal were recovered from the excavations. A total of 104 Mangrove Unslipped sherds, 266 Warrie Red sherds, and 47 Moho Red sherds were recovered (Figure 2.7) in addition to eight Paynes Creek sherds, 14 chert fragments, and 21 obsidian fragments (Table 2.1).



Figure 2.6. Photo of *Crassostrea rhizophorae*. Photo by V. Feathers.

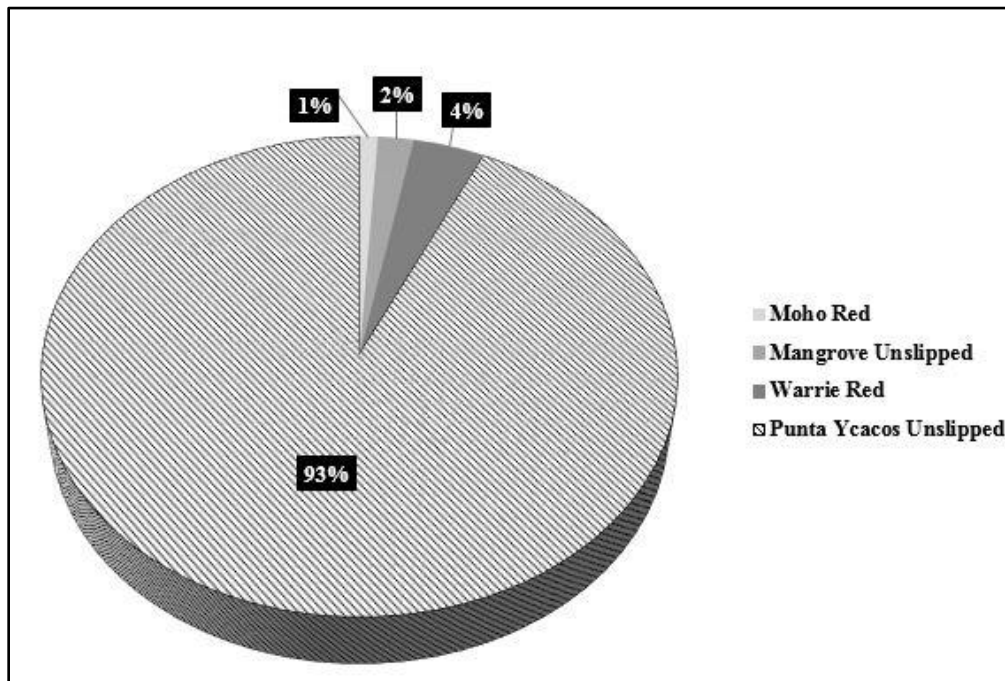


Figure 2.7. Pie chart showing the percent of all recovered ceramics from the 2013 Eleanor Betty excavations.

Clay and ash features were encountered in Transects 5 and 6. Transect 5, Unit 2-3 m, contained a clay features in level 10-20 cm. The clay was grey, soft, and malleable. Transect 5, Unit 5-6 m, 10-20 cm, contained an ash feature in the northeast corner of the unit. The ash had hardened into amorphous lumps. The outside was a white-grey color which rubbed off when

dried. A clay and ash feature was encountered in the same designation starting at 20 cm and extended to 25 cm. The feature was not excavated.

Table 2.1. Quantity, Use, and Origins of Artifacts recovered from the 2013 excavations.

Items	Quantity	Uses	Origin
Punta Ycacos Unslipped Rims	391	Salt-making	Paynes Creek
Punta Ycacos Unslipped Body Sherds	4,790	Salt-making	Paynes Creek
Punta Ycacos Sockets	43	Salt-making	Paynes Creek
Punta Ycacos Spacers	3	Salt-making	Paynes Creek
Punta Ycacos Cylinders	290	Salt-making	Paynes Creek
Punta Ycacos Bases	1	Salt-making	Paynes Creek
Mangrove Unslipped Rims	12	Salt-making	Inland?
Mangrove Unslipped Body Sherds	92	Salt-making	Inland?
Warrie Red Rims	1	Salt-making	Inland?
Warrie Red Body Sherds	265	Salt-making	Inland?
Moho Red Rims	1	Serving vessels	Inland?
Moho Red Body Sherds	46	Serving vessels	Inland?
Paynes Creek Rims	4	Water Jar	Unknown
Paynes Creek Body Sherds	4	Water Jar	Unknown
Chert flake and biface fragments	14	Unknown	Unknown
Obsidian flake and biface fragments	21	Unknown	Volcanic Highlands

Discussion

The excavated material, in particular the abundance of briquetage and the lack of household material, indicates that Eleanor Betty is not a household workshop, but rather a salt production workshop. The Mangrove and Warrie sherds were from jars use to store brine or loose salt. The paucity of Moho Red sherds indicates they were for serving vessels probably used in ceremonies related to opening the salt making season. No household items, such as pots used for food storage or figurine whistles, were recovered from the underwater excavations.

Approximately 376 macrobotanical remains were recovered during excavations, including 338 endocarp fragments for *A. mexicana*, the majority of which were found in Transect 7, 3-4 m (n=91; Figure 2.8). Fragments of endocarps for *O. cohune* and seeds for *B. crassifolia* also were present. The macrobotanicals could have been used as part of the ritualistic feast

during the opening ceremony. Alternatively, they could have been snacks or simply fallen onto the ground from nearby trees. The excavated units at Eleanor Betty yielded a large amount of charcoal (~16,262 g). Of this amount, 6,248.48 g were recovered from the shell deposit (Units 3-4 m and 4-5 m of all transects) with the largest concentration in Transect 6, 3-4 m.

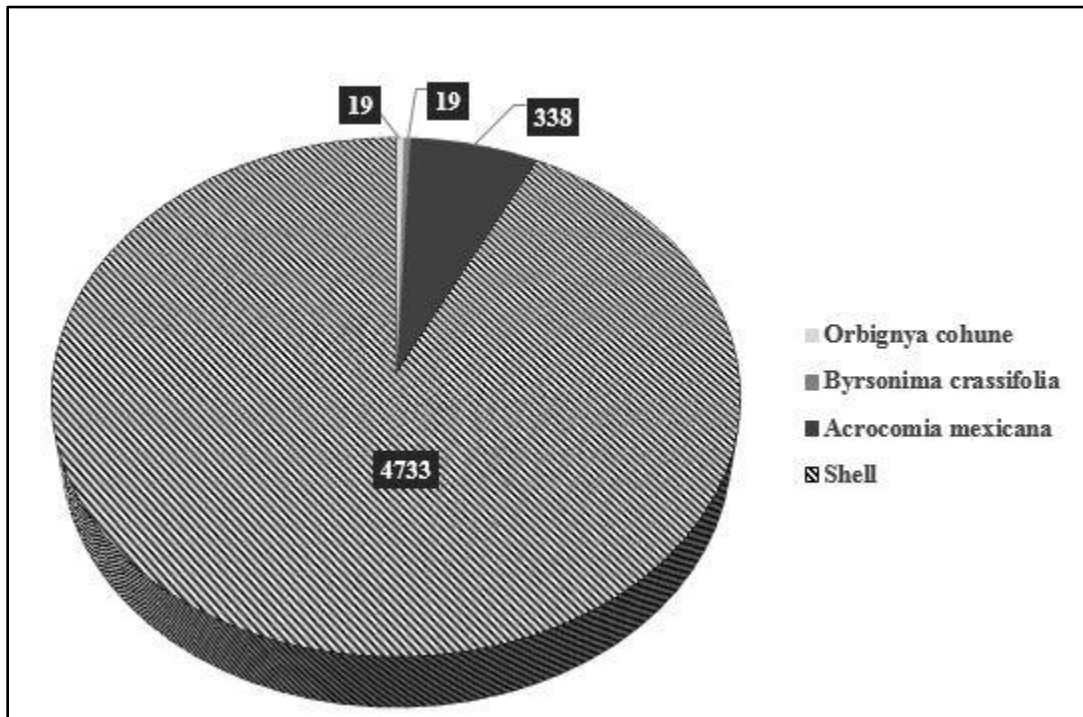


Figure 2.8. Pie chart showing the number of recovered shell and botanical fragments from the 2013 Eleanor Betty excavations.

The obsidian fragments consisted of proximal (n=7), medial (n=8), and distal (n=6) fragments recovered from Transects 5, 6, and 7. No complete obsidian blades were recovered. The blades could have been used as part of the opening ceremony. Additionally, the blades could have been utilitarian items used to process fish for consumption. The small amount of recovered chert flakes (primarily found in Transects 5 and 6) could indicate the reworking of stone tools that perhaps were used in the modification of post ends.

The palmetto palm posts on the western edge of the site form a curved line, suggesting the Maya were trying to hold back the rising seas. The location of the hardwood posts to the east

of the palmetto palm comprised a rectangular structure. This structure could have been the location of the salt production workshop.

The shell deposit measured 5 m in length by 0.5–to–1 m in width, depending on the location. The deposit was mainly in level 10-20 cm depth in Units 3-4 m and 4-5 m. The maximum thickness was 12 cm. The deposit extended both inside and outside the wooden architecture. Transect 7, 3-4 m and Unit 4-5 m of Transects 4, 5, 6, and 7 were outside the wooden architecture.

The shell deposit was determined to be a midden: Charcoal, clay, and briquetage were intermixed with the shell midden. Briquetage, charcoal, and clay were recovered in levels above and below the shell midden. None of the pottery was shell tempered. The briquetage has sand temper. The Maya at this site probably were eating oysters which were likely available on red mangrove roots as they are today.

Despite the favorable conditions for the preservation of bone due to the CaCO_3 from the shell, no human bone and only two unidentified animal bones were recovered. The lack of bones and household refuse supports our interpretation that the area was used for salt making. Briquetage was abundant in all units. Several units contained clay and ash features. The abundance of clay suggests the salt makers were making or repairing the salt making vessels on-site. The ash features could indicate possible firing episodes of either the pottery or are the remnants of hearths used to boil brine. Charcoal was present in all units.

Based on the weight of briquetage, water jars, Moho Red, utilitarian items, and ceramics likely were stored in the western portion of the building (Units 0-1 m and 1-2 m). The primary location for salt production was located in the middle of the wooden structure (Units 3-4 m and 4-5 m). Items which could no longer be used (broken pots/water jars and spent charcoal) were

disposed of at the eastern edges of the building (Units 4-5 m, 5-6 m, and 6-7 m). The evidence garnered from excavations indicates the area was a salt workshop.

Conclusions

Eleanor Betty was a Classic period ancient Maya salt production workshop which was once situated on the shore of a lagoon. Rising seas and subsidence activities have inundated this site and others in the area (McKillop 2002, 2004b, 2005a, 2005b, 2008, 2009a; McKillop et al. 2010a, 2010b). Excavations of a shell midden associated with a wooden building at the Eleanor Betty salt work indicate the area was used for salt production and not habitation. The presence of briquetage indicates salt production. The absence of household refuse supports the interpretation that Eleanor Betty was a production workshop as evidenced by the presence of briquetage and charcoal. The shells were not used as temper for ceramics, but likely were dietary.

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Chapter 3: Exploitation and Subsistence Patterns: An Assessment of the Shell Midden at an Ancient Maya Salt Work in Belize

Introduction

Analyses of recovered shells from the underwater site of Eleanor Betty were carried out to assess their role at this Classic period (AD 300-900) salt work. Although shell remains are not uncommon at coastal and inland Maya sites, only four other shell middens have been excavated, including Cancun (Andrews IV 1969; Andrews IV et al. 1975; Wing 1975, 1977), Moho Cay (McKillop 1984, 2004a), Frenchman's Cay (McKillop and Winemiller 2004), and Butterfly Wing (McKillop 1996, 2005b). Excavation and analyses of the Eleanor Betty shell deposit were performed with the following questions in mind: Was the inundated shell deposit at Eleanor Betty cultural or natural? Is there evidence of shell modification for ritualistic items? Are butcher marks present, indicating processing for consumption?

Importance of Marine Resources and Shell in the Maya Area

Marine Subsistence – Coastal and Inland

Lange (1971) hypothesized that the Classic period inland population of the northern Yucatán and Belize was larger than what could be supported by agriculture. He argued that the exploitation of marine resources and the preservation of marine fish for inland trade imply a substantial nutritional increase in the quality of the inland diet. Although Lange's (1971) work has found little support in terms of evidence of the substantial nutritional increase of the inland diet, his interpretation of coastal-inland resource use has prompted several important questions, which are currently being explored.

The coastal Maya traded marine resources, such as stingray spines, conch shells, fish, and salt to inland communities for ritualistic and subsistence purposes (Andrews 1983; Andrews and Mock 2002; Avery 1993; Haines et al. 2008; MacKinnon and Kepecs 1989; McKillop 1984,

1996, 2002, 2004a, 2005a, 2005b, 2007b, 2009b; McKillop and Winemiller 2004; Valdez and Mock 1991). The use of waterways as trade networks increased in the Late Classic (A.D. 600-900; Andrews 1983; Hammond 1982; McKillop 2005a, 2010b). Marine resources have been recovered from inland and coastal sites throughout Mesoamerica, providing supporting evidence, in part, for Lange's (1971) hypothesis that the ancient Maya incorporated marine resources into their diet.

Marine resources are common at coastal sites (Andrews IV 1969; Andrews IV et al. 1975; Carr 1986; Dahlin et al. 1998; Glassman and Garber 1999; Hamblin 1984; Lange 1971:623; Masson 2004; McKillop 1984, 1985; McKillop and Winemiller 2004; Miller 1977; Seidemann and McKillop 2007; Seymour 2004; Sosa et al. 2014; Valdez and Mock 1991, Voorhies 1978; White 2005; Williams et al. 2009; Wing 1975; Figure 3.1). The ancient Maya of Marco Gonzalez and San Pedro exploited marine fauna for subsistence purposes. Unlike San Pedro, the Maya at Marco Gonzalez incorporated more terrestrial-based resources into their diet, such as deer. Williams et al. (2009) suggests the resources could have been traded from Lamanai (Williams et al. 2009).

Excavations at New River Lagoon (NRL) revealed a large amount of fish remains (approximately 97.7% of the identified sample; Masson 2004: 112). Species included catfish (*Galichthyes felis*), jacks (*Carangidae*), bony fish (*Osteichthyes*), and barracuda (*Sphyræna barracuda*) among others (Masson 2004: 114). NRL exhibits evidence of a processing station for inland movement of catfish as the cranial elements (likely removed before transport) account for 64.9% of the recovered material, whereas the vertebrae only account for 10% (Masson 2004: 115).

NRL was a salt production site during the Terminal Classic. Mock (1997) and Valdez and Mock (1991) hypothesize that catfish were dried, salted, and then traded inland. Conversely, at the inland site of Mayapán, cranial and postcranial remains of catfish were recovered in equal quantities, suggesting the Maya at Mayapán obtained preserved catfish (and salt) through trade with Ah Kin Chel in exchange for deer and other inland game (Masson and Lope 2008; Tozzer 1941).

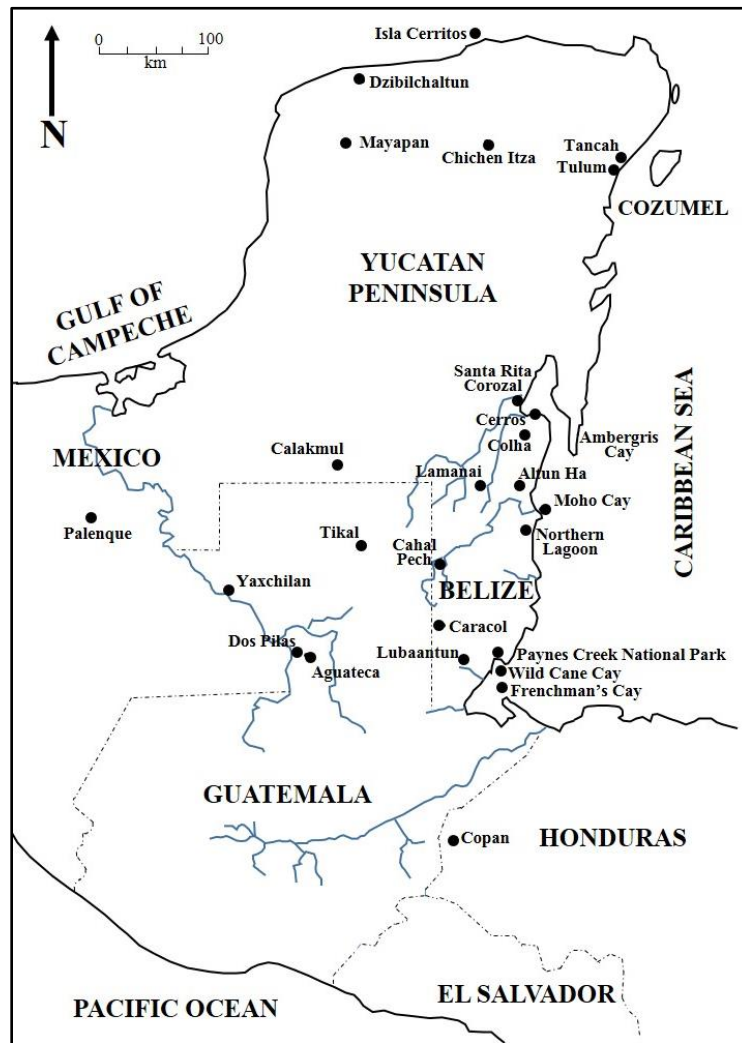


Figure 3.1. Map of Maya area with sites mentioned in the text. Adapted from McKillop 2004b:4.

The Cozumel Maya relied heavily on the sea for subsistence. Recovered faunal remains included *Serranidae* (groupers and seabasses), *Scaridae* (parrotfish), and *Carcharhinidae*

(requiem sharks), among others (Hamblin 1984). Excavations at Isla Cancun revealed that thousands of shells had been modified for subsistence purposes, including *Strombas gigas* (Queen Conch) and *Melongena corona* (Crown Conch; Andrews IV 1969: 57, 58).

Archaeologists recovered a large number of fishing weights and *Strombas gigas* shells from Tanchah, a coastal site along the western coast of the Yucatán just north of Belize, suggesting marine exploitation for export as well as local consumption (Miller 1977). Remains of *Dinocardium r. vanhyningi* (cockle shells) were recovered from excavations at Dzibilchaltun and were interpreted as use for subsistence purposes (Andrews IV 1969: 59).

“Working” Shell for Trade and Utilitarian Use

In addition to use as subsistence items, marine shells were made into items such as jewelry and scrapers for trade to coastal and inland sites. Microwear analysis of lithics coupled with the presence of an incised shell in Structure 4A, supported the interpretation that shell manufacturing took place at Pook Hill, Belize (Stemp et al. 2010). Similar analyses at the rapidly abandoned site of Aguateca, Guatemala, in conjunction with the presence of worked shell ornaments (including one depicting the face of a monkey, which may represent the patron deity of the scribes,) suggests the people of Aguateca were involved in the procurement of marine shell and the production of shell ornaments via chert flakes, bifacial thinning flakes, oval bifaces, bifacial points, and obsidian prismatic blades (Aoyama 2007, Tables 3 and 4; Emery 2008; Emery and Aoyama 2007; Inomata and Stiver 1998: 442; Inomata et al. 2002).

Leaders of the Chan community were involved in the production of *Strombus* shell beads and other shell ornaments (Robin et al. 2014). Aoyama (1995) suggests that marine shell ornaments may have been produced by members of the royal family or attached specialists at Copan. Evidence for the elite control of marine shell production and trade also was found at

Piedras Negras and Aguateca (Sharpe and Emery 2015). Both sites had a high amount of diversified marine mollusks when compared to the surrounding secondary centers of Punta de Chimino and El Kinel. Several thousand marine mollusks were recovered from the primary center of Aguateca, whereas only four were recovered from Punta de Chimino, a secondary center located downstream from Aguateca. Additionally, items such as stingray spines were found only in elite contexts. Elite caches also contained more marine mollusks than any other cache at Aguateca and Piedras Negras, suggesting the elite controlled the distribution of marine items to the secondary centers.

Evidence for non-dietary uses also can be found at coastal sites. Shells were carved into tinklers and discs for non-utilitarian purposes at the trading ports of Wild Cane Cay and Moho Cay (McKillop 2004a:269; 2005b, Figure 6.32). Gastropods from Moho Cay were used as scrapers, sinkers, whorls, gorgets, beads, hammers, and as cutting tools (McKillop 1984:30-32). Remains of the southern stingray (*Dasyatis americana*) recovered from excavations at Cozumel were used in ceremonial events, including bloodletting (Hamblin 1984: 31). Queen Conch remains, along with a large amount of worked and unworked shells from Ek Luum on Ambergris Caye, Belize, indicated that Ek Luum was a possible processing station where shells were prepared for inland trade (Shaw 1995). Few shells at Ek Luum exhibit breaks indicative of meat removal. The absence of breaks could indicate inland trade for consumption or trade of a non-manufactured shell for ritualistic purposes. Worked shells were recovered from other location on Ambergris Cay, including shells cups from Ek Luum, San Juan, and Chac Balam as well as tinklers, pendants, and beads (Garber 1995:126-133, 135).

Coastal-Inland Maritime Trade: Ritual and Status

The most common instances of coastal-inland trade occur in the archaeological record with the recovery of *Spondylus* shells and stingray spines. Stingray spines have been traded inland from coastal communities since the Middle Preclassic (1000-300 B.C.), including ritual caches at inland sites such as Aguateca (Emery and Aoyama 2007) and Tikal (Moholy-Nagy 1963; Shaw 2012). Elite household excavations at Tikal (Coe 1990; Maxwell 2000; Moholy-Nagy 1963, 1997; Price et al. 2008, Shaw 2012), Caracol (Teeter 2004), and Aguateca (Emery and Aoyama 2007; Inomata and Stiver 1998; Inomata et al. 2002) revealed both *Spondylus* shells and stingray spines. Over 30 marine species were recovered from Chichén Itzá. The abundance of shell remains suggests a reliance on local mollusca (Cobos 1989).

Excavations at Lubaantun uncovered the remains of a worked Queen Conch used to produce shell-disc blanks along with other marine shells and fauna (Hammond 1975:385; Wing 1975). Excavations at Altun Ha, Belize, revealed ritualistic caches with a *Spondylus* disc and tubular shell beads, a *Spondylus* notched pendant, and *Oliva* beads, as well as many other shell adornments (Pendergast 1979). Remains of pendants made from *Spondylus americanus* and tinklers made from *Oliva sayana* were recovered from Dzibilchaltun (Andrews IV 1969 54:55). *Spondylus* shells, stingray spines, and a sea star were recovered from the Structure 10L-26 tomb at Copan, where they functioned as a burial offering (Beaubien 2004).

Kidder et al. (1946: 145) reported that “shell formed part of the mortuary furniture in every tomb...” at Kaminaljuyu. Shell remains included *Spondylus*, *Oliva*, *Olivella*, and *Marginella* shells in the form of trumpets, tinklers, and pendants. Stingray spines also were recovered from the burials. *Spondylus* shells, a carved *Strombus* shell, and unidentified shell “teeth” from a jadeite mask were recovered from the burial of Yukom Yich’ak K’ak at Calakmul

(Carrasco et al. 1999). Other sites where shell has been recovered from inland burials included Pacbitun (Healy 1990), Caledonia (Healy et al. 1998), Bats'ub Cave (Prufer and Dunham 2009), Dos Pilas (Emery 2008), Buenavista del Cayo (Yaeger et al. 2015), Chan (Robin et al. 2014), and Lamanai (Pendergast 1981).

At the inland site of Caracol, 197 marine fish elements were recovered from excavations. Approximately 173 of the 197 elements were recovered from the Epicenter, whereas 24 were recovered from the site core (Teeter 2004:183), suggesting consumption by the elite, which is an interpretation supported by the stable isotope analyses (Chase and Chase 1999). Additionally, 50 tail-spine elements from stingrays were recovered from eight caches, 12 burials, and two structure floors, highlighting the role of marine resources as ritual elements. In some cases, the entire stingray was imported and utilized as evidenced by the recovery of spines, vertebrae, and cranial elements recovered from three caches and a child's burial (Teeter 2004:189).

Marine remains from Tikal caches consisted primarily of stingray spines used for bloodletting (Maxwell 2000). Remains of a crocodile and *Spondylus* shells were recovered from the tomb of Yax Nuun Ayiin I at Tikal (First Crocodile; Price et al. 2008). Additional marine remains recovered from Tikal include pufferfish (*Diodon*) spines and sawfish (*Pristis*) barbs.

Ancient Maya Shell Middens

Shells were important to the coastal and inland ancient Maya for food, tools, and ornaments. They have been recovered from shell middens and construction fill at coastal sites, in burials and caches at coastal and inland sites, and in household refuse deposits (Andrews IV 1969; Emery 1999; Hamblin 1984; McKillop 1984, 2005b; McKillop and Winemiller 2004; Pendergast 1992; White 2005; White et al. 2001). Few ancient Maya shell middens have been excavated (Andrews IV et al. 1975; McKillop 1984, 1996, 2005b:36, 37, 39, 141; McKillop and

Winemiller 2004). Mollusks were an integral part of the coastal Maya diet. Isla Cancun, a Preclassic Maya settlement in Quintana Roo, Yucatán, had a large midden containing a variety of marine remains, including 6,547 shells, which were categorized into 99 species (Andrews IV 1969; Andrews IV et al. 1975). Approximately 28.6% of the midden was comprised Queen Conch (*Strombus gigas*) remains in addition to remains of jack (*Carnax*), grouper (*Epinephelus*), and manatee (*Trichechus manayus*), suggesting a reliance on marine resources (Andrews IV et al. 1975:186-187).

Unlike the shells recovered from Isla Cancun, the shells recovered from Frenchman's Cay were analyzed to provide an in-depth look at the diet and landscape of the Maya who occupied the site (McKillop and Winemiller 2004). Three mounds are present on Frenchman's Cay – Great White Lucine, Crown Conch, and *Spondylus*. Excavations indicated Frenchman's Cay was a Late Classic to Early Postclassic site (A.D. 600-1000; McKillop 2005b). Fifty-eight genera of shell were recovered from Frenchman's Cay for a total of 2,785 shells with a weight of 13,528.46 g. Ninety-eight species, including *Isognomon alatus* and *Crassostrea rhizophorae* (mangrove oysters), and 1,315 minimum number of individuals (MNIs) were identified. Butchering for meat removal was indicated by the presence of a circular hole in the spire of conch shells, which would have been made by the ancient Maya. Almost all species recovered were edible and likely contributed to the coastal diet (McKillop and Winemiller 2004).

A large midden was discovered on the northern end of Moho Cay near Belize City (McKillop 1984). The midden contained predominately marine shells and manatee bones, but also pottery sherds, broken chert, obsidian, as well as the remains of deer, shark, and green turtle (McKillop 1984, 2004a). Small holes for meat removal were found near the muscle attachment point of the Queen Conch shells recovered from the site.

Similar shell modifications are present on shells recovered from Postclassic deposits in Fighting Conch mound at the trading port of Wild Cane Cay. Carved *Olivella*, shell disks, stingray spines, sea-urchin disks, and manatee rib carvings were recovered from the mound excavations. *Spondylus* shells and carved *Melongena* shell disks, as well as carved *Olivella* shells and stingray spines, were recovered from burial contexts at Fighting Conch (McKillop 1996:59, McKillop 2005b).

Additional evidence for marine exploitation was recovered from the coastal midden of Butterfly Wing – a Protoclassic (75 B.C – A.D. 400) site located by the mouth of the Deep River on the southern coast of Belize (McKillop 1996, 2002:11; McKillop et al. 2004:349). *Strombus pugilis* remains were the most abundant recovered shell and were probably used for subsistence purposes. However, the recovery of a *Strombus gigas* celt indicates the ancient Maya at Butterfly Wing were using the sea as a resource for utilitarian items (McKillop 1996:59).

In an attempt to categorize marine resource use and trade, Andrews IV (1969: 41) divided shell remains into two categories. The first concerns shells from coastal middens, which would have been used for local consumption and perhaps for meat extraction for inland trade, whereas the second focuses on shells at inland sites, which were not used for subsistence purposes, but rather for ritualistic events. He suggests that sites close to the coast, such as Dzibilchaltun, could have imported the shell for both ritualistic and subsistence purposes as the meat would have been a delicacy (Andrews IV 1969: 41). How does the shell midden at the Eleanor Betty site in Paynes Creek National Park, Belize, compare to previously excavated coastal shell middens?

The Eleanor Betty Shell Deposit

Eleanor Betty is part of the Paynes Creek Salt Works located along the southern coast of Belize (Figure 3.2). Previous analysis of the recovered ceramic material indicates that 93%

(n=6,140) of the recovered ceramics were briquetage – the pottery used to evaporate brine over fires to make salt. Archaeologists have recorded briquetage at other prehistoric sites in Mesoamerica (Andrews and Mock 2002; MacKinnon and Kepecs 1989; McKillop 1995, 2002, 2004b, 2005a, 2005b, 2007a, 2007b, 2008, 2009a, 2009b, 2010a; Santley 2004; Sills and McKillop 2010; Valdez and Mock 1991) as well as modern sites (Reina and Monaghan 1981; Williams 1999, 2004). The Eleanor Betty site also has wooden architecture, such as chiseled wooden posts found at other Paynes Creek sites (McKillop 2005a, 2009a, 2010a; McKillop et al. 2010a, 2010b; McKillop et al. 2014; McKillop and Sills 2016; Sills and McKillop 2010; Sills et al. 2016). The wooden posts have been preserved due to the anaerobic mangrove peat.



Figure 3.2. View of Eleanor Betty from the eastern edge of the site. Yellow flags represent transects. Red flags represent posts. Photo by the Underwater Maya Project.

Excavations of a shell deposit at the Eleanor Betty site where the sediment was expected to be alkaline and preserve bone, was an ideal place to see if human and/or animal bone was present. The shells have a calcium carbonate (CaCO_3), which allows the movement of bacteria. Although no human remains were recovered during excavations, the presence of faunal remains

and the absence of wooden architecture within the shell midden highlight the distinct preservational properties of these two environments.

During underwater excavations in the summer of 2011, a shell deposit was unexpectedly discovered in Transect 4 at the Eleanor Betty site (Aucoin 2012). The excavations were part of an ongoing project titled “Ancient Maya Wooden Architecture and the Salt Industry.”

Excavations of the Eleanor Betty shell deposit were undertaken in the summer of 2013 to map the extent of the shell deposit and to discover if the deposit was natural or cultural. The recovered artifacts were studied during the 2013 and 2014 field seasons. The presence of charcoal, ceramics, and production refuse above, within, and below the shell deposit indicates it was a shell deposit associated with the ancient Maya at the Eleanor Betty salt work.

Four transects were added north and south of the 2011 Transect 4 to horizontally expose the shell deposit. A total of 19 new units was excavated in 10 cm levels to a depth of 30 cm below the sea floor. The shell deposit was mapped and excavated separately from the rest of the unit. Transect 6 Unit 3-4 m was excavated in two-centimeter levels from 16 cm to 30 cm depth due to the concentration of shells (Figure 3.3). Two-centimeter levels were possible because most of the shell were broken and small. The deposit was very compact with little sediment intermixed with the shell. The wall of Transect 4 was cleaned to see the depth of the deposit (Figure 3.4). Shell, botanical remains, and charcoal were exported to the Archaeology Lab at Louisiana State University (LSU) for study.

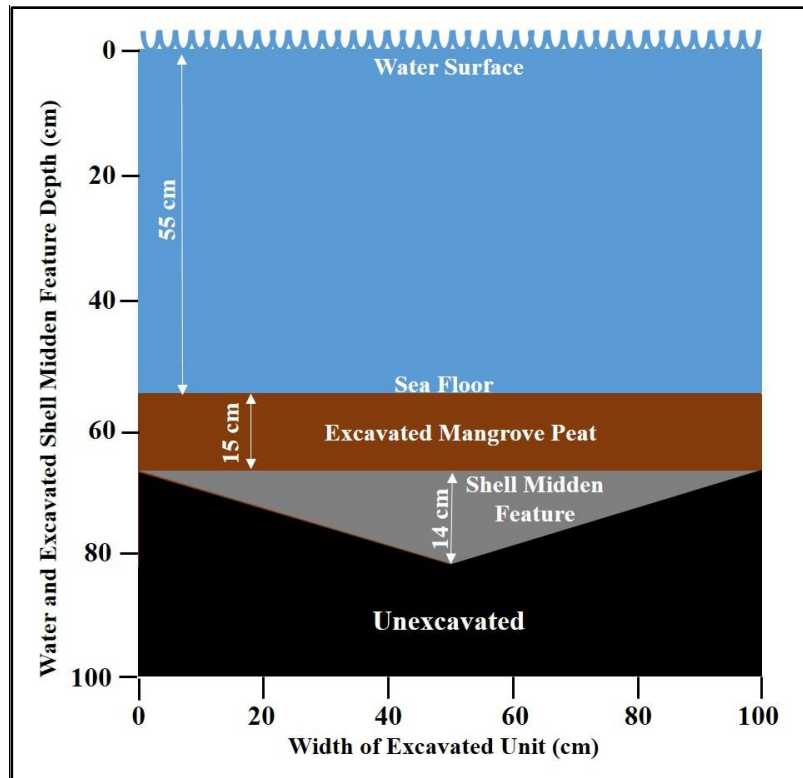


Figure 3.3. Schematic profile drawing of shell midden excavation by V. Feathers.

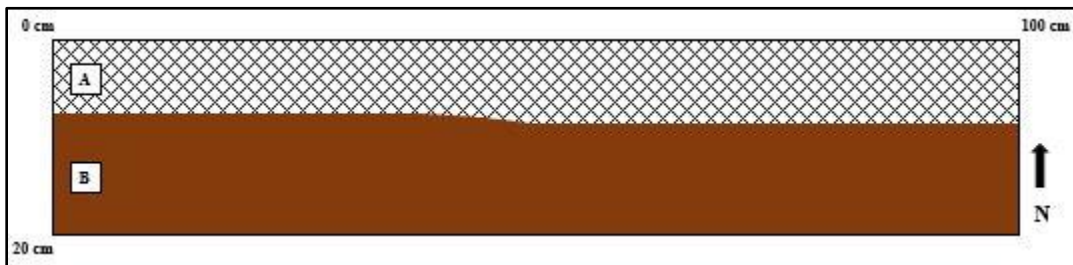


Figure 3.4. Schematic drawing by V. Feathers of north wall profile of Transect 4, Unit 3-4 m, at Eleanor Betty starting approximately 70 cm below the water's surface and 15 cm below the sea floor. A) Shell mixed with cultural material; B) Sterile mangrove peat.

Laboratory Methods

The minimum number of individuals (MNI) and the number of individual species present (NISP or fragments), weight, presence/absence of butcher marks, and height-length ratio (HLR) for human predation were determined for the recovered shell following methods used by other researchers (Andrews IV et al. 1975; Claassen 1998; Kent 1988; McKillop and Winemiller 2004). The MNI assessment was performed by identifying a trait unique to the shell, in this case

the umbone (the raised protuberance or beak located posteriorly to the hinge on a bivalve shell; Figure 3.5) and counting the number of umbones on one side of the shell. Although an effective method, MNI can provide unreliable data because not all of the shells collected may be of the same side. Another way to sort shells by counting is to use the NISP.



Figure 3.5. Photograph of *Crassostrea rhizophora* from the Eleanor Betty site. The red circle indicates the umbone. Photo by V. Feathers.

All shells were included in the counts for NISP. Weights for the shell were obtained using a Delta Range[®] Mettler PE 3600 in the Archaeology Lab at LSU. A plastic container was used to hold the shell on the scale during the weighing process. Weight can prove problematic depending on the environment. For example, a shell of one taxa found in less acidic soil has more calcium carbonate than that of the same taxa of shell from more acidic soil. Thus, the weight of the shells will be different.

Shells were counted and sorted by species in the lab at LSU, in the field, and at the field base camp in Belize. Fragmentary shells smaller than a dime were not included in the counts as they were not considered diagnostic. Complete right and left umbones were used to obtain an MNI count. The umbones were sorted by side.

Measurements of the shell height (maximum dorsal-ventral) and shell length (anterior-posterior) were converted into height-length ratios (HLR) to assess predation and identify if the shell deposit at Eleanor Betty was a multiple or one-time deposit (Gunter 1938; Kent 1988:28; Figure 3.6). Changes in shell size are helpful in defining stratigraphic layers. Archaeologists use

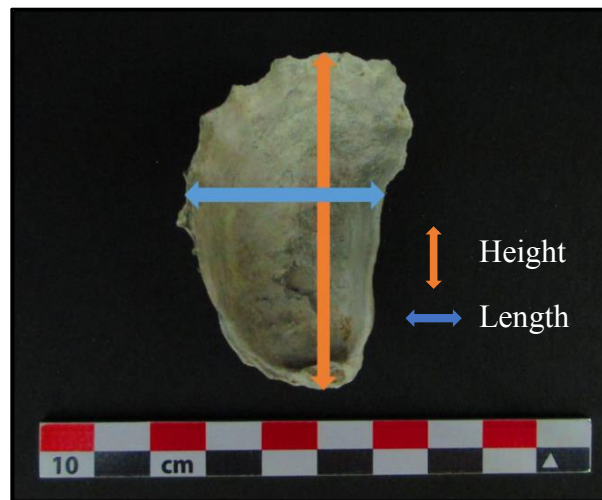


Figure 3.6. Measurements for Height-Length Ratio. Orange line represents height. Blue line represents length. Photo by V. Feathers.

shell size to determine the impact of human predation and meat yield. Shell size is also determined by age and can be substituted for age. The height-length ratios for both complete right and left valves were obtained by dividing the height by the length. Only shells with a complete umbo, ventral, anterior, and posterior margins were used. Measurements were obtained with a pair of Spi 31-414 sliding calipers.

Butcher marks were identified and classified into six categories: 1) L-shaped, 2) V-shaped, 3) horizontal break, 4) vertical break, 5) slanted break, and 6) notched break based on Kent's (1988) methods for opening oysters (Figure 3.7). There are several opening methods which result in the different break patterns. The first method involves heating, steaming, or boiling the oyster to easily open the valves and cook the meat. This method does not leave a butcher mark on the shell. The second method is stabbing. A blade-like object is forced between

the valves along the posterior margin in order to cut the abductor muscle. A U-shaped notch usually forms parallel to the muscle scar on the margin of the shell as a result. Marks of this nature are classified as “notched” (Category 6). The third method, hammering, involves striking the oyster. A hammerstone is used to lightly strike the shell valve above the abductor muscle. This impact stuns the oyster, allowing the harvester to open the valves and retrieve the meat. A small abrasion mark is usually located on the valve as a result of hammerstone use.

Finally, the cracking method involves breaking the ventral edge of the shell in order to remove the meat with a blade. A hammerstone is usually employed with this method. This method results in a straight break along the ventral margin. Categories 1-5 could be a result of the cracking method.

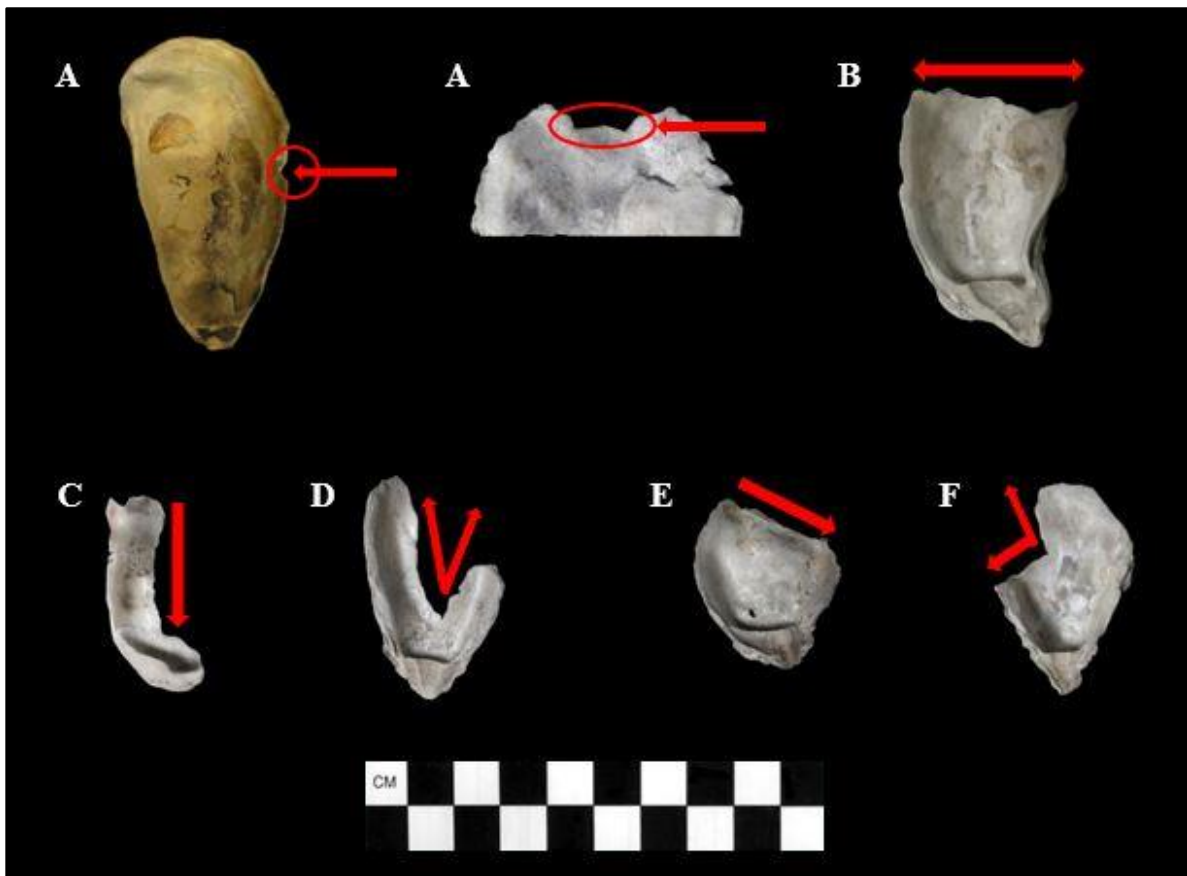


Figure 3.7. Photos of break patterns on Eleanor Betty *Crassostrea rhizophora* shells based on Kent (1988). A) Notch; B) Horizontal; C) Vertical; D) V-Shape; E) Slanted; and F) L-shape.

Results

Approximately 4,733 shell fragments weighing 2,304.24 g were recovered from the excavated units. Eighty-three percent (n=3,933) of the recovered shell were associated with the shell midden. The most abundant species was *Crassostrea rhizophora* (n=3,979; Figure 3.8), red mangrove oysters, which form beds along the roots of red mangroves in intertidal, brackish waters. Transect 6, Unit 3-4 m contained the most oysters (n=3,204).

Assessment of the right and left umbones of *C. rhizophora* resulted in an MNI of 198 shells (198 left, 64 right). A total of 57 left valves and 43 right valves were measurable (complete; Table 3.1). Seventy of the 100 complete valves had complete dorsal-ventral and anterior-posterior margins and were used for HLR measurements. The average for the left and right valves was 1.89 cm and 1.87 cm, respectively. The maximum HLR was 2.84 cm for the left and 2.92 cm for the right. The minimum was 1.22 cm for the left and 1.35 cm for the right. The range was 1.62 cm for the left and 1.57 cm for the right. The standard deviation was 0.34 cm for the left and 0.33 cm for the right. Twenty-four of the 100 shells could be measured for length and not height. Six could be measured for height but not length.

Butcher marks were present for 57 of the 198 shells assessed for MNI. The most abundant break was a notch (n=17; Table 3.2). No hammerstone abrasions were observed. However, the outside layer of the shell was fragile and flaking. The fragile nature of the outside shell layer could have obscured the hammerstone scar. The notch marks could have resulted from the use of a tool, such as a piece of chert, inserted parallel to the abductor muscle in order to open the shells and collect the meat. The cracking method appears to be the most employed method for opening shells based on the vertical, horizontal, V-shaped, and L-shaped breaks. If these breaks are considered as one class, then this combination would result in the most abundant break pattern (n=38).

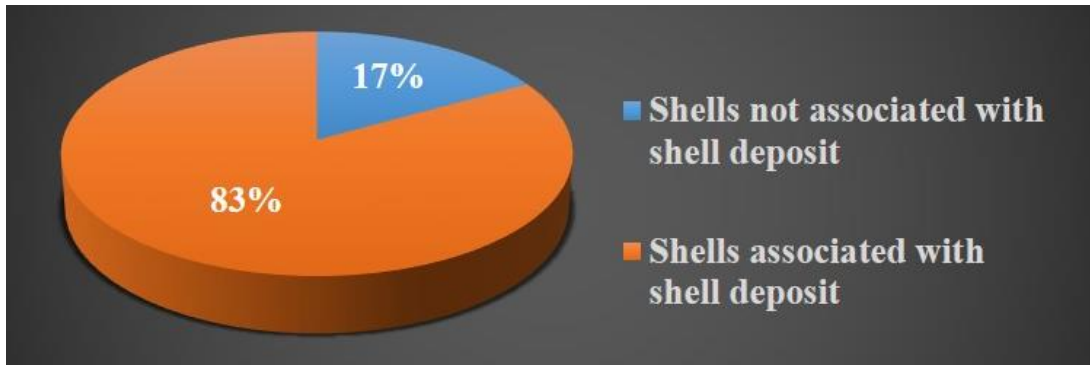


Figure 3.8. Pie chart showing *C. rhizophorae* shells from the shell midden and outside the midden from the 2013 transect excavations at Eleanor Betty.

Table 3.1. Height-Length Ratio (HLR) measurements for all excavated transects and units.

	Height (cm)	Length (cm)	Left	Right	HLR – Left (cm)	HLR – Right (cm)
Total Number	-	-	57	43	-	-
Minimum	2.66	1.19	-	-	1.22	1.35
Maximum	7.7	3.78	-	-	2.84	2.92
Average	4.69	2.47	-	-	1.89	1.87

Table 3.2. Classification of *C. rhizophora* break patterns from the Eleanor Betty Shell Midden.

Break Pattern	Number Present	Processing Method
L-shaped	14	Cracking
V-shaped	6	Cracking
Horizontal Line	8	Cracking
Vertical Line	10	Cracking
Notch	17	Stabbing
Slanted	2	Cracking

Discussion

No human remains and only two unidentified animal bones were recovered during the underwater excavations of the shell midden. However, the absence of skeletal material is not

surprising if Eleanor Betty was a salt production workshop and not a residence or household workshop. The lack of human and faunal remains underscores the interpretation that Eleanor Better was a workshop.

The shell midden was determined to be a cultural midden for several reasons. An abundance of briquetage (3,721 g) and charcoal (6,248.48 g) was found intermixed with the deposit. There is no evidence the shells were used as jewelry, music, tools, or musical instruments as seen at other Maya sites (Chase 1981; Chase and Chase 1989; Hammond 1975:385; McKillop 1984, 1996:59, 2004a: 269; 2005b: Figure 6.32). Approximately 55% of the recovered shell was located within the shell midden feature (Transect 6, Unit 3-4 m).

Approximately 40 g of Warrie Red jars and Mangrove Unslipped jars were associated with the shell midden feature. The water jars likely would have stored brine. A minimal amount of Moho Red sherds (14 g) was recovered. Moho Red ceramics were serving vessels used during rituals. The associated briquetage is composed of sand temper and not shell, so shell clearly was not used as temper.

The feature could have been part of an opening ritual prior to the opening salt production season. Ocarinas and serving vessels were recovered at other Paynes Creek Salt Works, indicating the occurrence of ritualistic activities (McKillop 2002; Watson et al. 2013). Rituals are performed prior to salt production season at inland sites such as San Mateo Ixtatán and Sacapulas (Andrews 1983; Reina and Monaghan 1981). The discovery of temple platforms, colonial or modern shrines, and large wooden crosses attest to the sacred nature of Emal, Yucatán, perhaps the largest salt production site in prehispanic Mesoamerica (Andrews 1983:11; Kepecs 2003:128; Roys 1957:108). A central ballcourt in addition to burnt offerings of cacao was discovered near the epicenter of Salinas de los Nueve Cerros (Woodfill et al. 2015). The site of

Chunchucmil had several quadrangles which acted as ceremonial and administrative centers (Magnoni et al. 2008). The shell feature and associated ceramics lay 16 to 30 cm depth below the seafloor. No ceramics, shell, charcoal, or botanicals were encountered past 30 cm, suggesting this deposit was the initial layer of the site.

Once the ritual was complete, the salt makers at Eleanor Betty could have built their hearth on top of the initial offering. Due to the shallow nature of the site (55 cm below the water table at its deepest depth on the western edge of the excavated units), the hearth (located in Units 2-3 m and 3-4 m of all transects) did not survive due to the slow inundation process. Land subsidence and rising seas have inundated this site and others in Paynes Creek, Belize (McKillop 2002, 2004b, 2005a, 2005b, 2008, 2009a; McKillop et al. 2010a, 2010b). The changing tides would have spread the shell north-to-south and east-to-west along the transects, thus creating a shallow, elongated shell midden rather than a heaped deposit within one unit.

Based on the height-length ratio averages for the left and right valves, the oysters for Eleanor Betty are bed oysters (Kent 1988). The average salinity for *C. rhizophora* habitats is 7.2 to 28 practical salinity units (PSU). However, growth can occur in areas with 0 PSU to 40 PSU (Galstoff 1964; Nascimento 1991). The underwater environment of Punta Ycacos Lagoon is ideal for the development and harvesting of mangrove oysters. The Eleanor Betty site is in an intertidal, brackish area surrounded by red mangroves that have *C. rhizophora* oysters growing on the prop roots in the water.

Shell height and length were measured to determine if there was evidence of overharvesting. If the measurements showed a large difference in the average height-length ratio, then this difference would suggest the salt makers were regularly harvesting, and possibly overharvested, the oysters. The shells would not have matured into adulthood, resulting in a

difference of shell height and length throughout the midden. Alternatively, if the average HLR measurements do not differ, then human predation by the salt makers likely did not occur. The HLR measurements showed no major differences as the averages were 1.87 cm and 1.89 cm for the right and left, respectively, indicating a lack of predation by humans. However, several shells were porous in appearance, suggesting predation by animals such as sponges, mud conchs, oyster borers, or barnacles (Galstoff 1964; Kent 1988; Figure 3.9).

Although the shell midden was relatively small compared to other coastal middens, several of the shells exhibited butcher marks. The presence of butcher marks on the oyster shells indicates that they were used for subsistence. A hammerstone likely was used to open the shells. The pressure of the hammerstone would have broken the ventral edge of the shell and “stunned” the oyster (Kent 1988). The salt makers would have removed the meat for consumption at this point. Although the presence of butcher marks presents a hard line of evidence of modification for subsistence, the use of heat to open the oysters should not be dismissed.

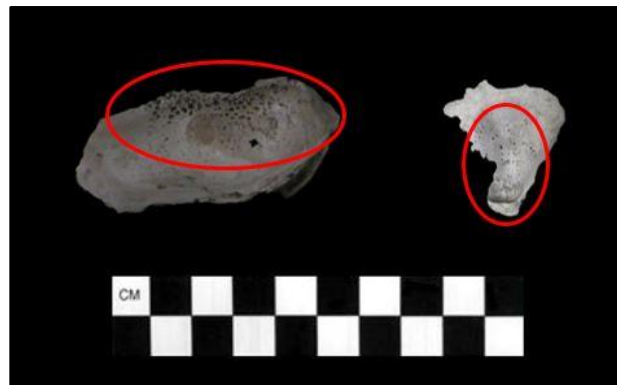


Figure 3.9. Porosity of *Crassostrea rhizophora* shell due to predation by sponges, mud conchs, oyster bores, and/or barnacles from the Eleanor Betty 2013 excavations.

Conclusion

Eleanor Betty was a salt production workshop located along the coast of southern Belize during the Classic period. The Eleanor Betty shell midden consisted of a single species, *C. rhizophora* (MNI=199). The recurrence of a single species further underscores that the shell

midden was a single-use event. Conversely, at the nearby trading port of Wild Cane Cay, there were more than 45 species of shell (McKillop 2005b). At Frenchman's Cay, there were 98 species (McKillop and Winemiller 2004). Butterfly Wing was dominated by several species, including *C. rhizophora*, *Isognomon alatus*, and *Spondylus pugilis* (McKillop 2002). The Cancun shell midden also had a variety of shells (Andrews IV 1969).

Single-species reliance on nearby available shell at Eleanor Betty suggests the shell midden was a single meal or feast perhaps eaten as part of an opening ceremony prior to the salt production season. The presence of a few Belize Red sherds – the remains of painted serving bowls tempered with volcanic ash – also indicates a small feasting event took place (McKillop 2002:95). Continuous sea-level rise and fall, in conjunction with the changing motion of the tides, spread this deposit across the site over time, obscuring the midden's original depth and location.

Available data for the Cancun, Butterfly Wing, Frenchman's Cay, and Wild Cane Cay middens indicate a heavy reliance on marine resources, supporting, in part, Lange's (1971) hypothesis that marine fauna were an essential part of the Maya diet. Although true for the coastal Maya, more evidence exists for the support of marine fauna as status indicators (elite versus non-elite and male versus female) when incorporated into the inland Maya diet than as a stable dietary resource. However, in the majority of instances, items such as shell were imported for ritualistic purposes and not subsistence.

The presence of butcher marks on 57 of the recovered shells from the Eleanor Betty shell midden indicate they were used as part of a meal, once again supporting, in part, Lange's (1971) original hypothesis that the coastal Maya had a heavy reliance on marine fauna. This evidence, coupled with studies of marine mollusk reliance at Frenchman's Cay (McKillop and Winemiller

2004) and Isla Cancun (Andrews IV 1969), as well as the importation of catfish to inland sites such as Mayapán from Ah Kin Chel (Masson and Lope 2008; Tozzer 1941) and other inland sites from New River Lagoon (Masson 2004; Mock 1997; Valdez and Mock 1991) provides additional support. The two recovered faunal remains from the Eleanor Betty shell midden provide additional support. At one time, there could have been more fish remains within the shell midden feature. However, with land subsidence, the continuous fluctuation in sea levels, and the dispersal of the shell midden over time, the remains could have been lost. The surrounding marine sediment is acidic in nature. As such, the marine sediment would not preserve the faunal remains once they became intermixed with the sediment.

Unlike shells recovered from sites such as Aguateca, Piedras Negras, Wild Cane Cay, and Moho Cay, the shells at Eleanor Betty do not provide additional evidence for shell modification for musical instruments or utilitarian items. The absence of human burials at the site precludes testing for nitrogen isotopes, which would have informed on the diet of the coastal salt makers. The absence of burials with shells placed in the interments also would seem to exclude the possibility of ritual activities happening at Eleanor Betty. However, the placement of the midden (initial layer of the excavations), along with the presence of a minimal amount of Belize Red, Warrie Red, and Mangrove Unslipped sherds and an obsidian blade fragment suggests that the midden was part of a feasting ritual prior to the salt production season.

Eleanor Betty is only the fifth coastal shell midden to be analyzed. It is the first coastal midden to be examined for evidence of subsistence using Kent's (1988) methods for analyzing the modification of oyster shells for meat consumption. The methods used here can be employed to analyze the recovered shells from other coastal and inland sites.

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Chapter 4: Assessment of Late Holocene Sea-Level Rise in Belize: The Inundated Ancient Maya Salt Production Site of Eleanor Betty

Introduction

One of the primary goals of the 2013 field excavations was to determine if the original location of Eleanor Betty was built on cleared mangrove stands and subsequently was submerged by sea-level rise or if the buildings were on platforms over the water. In order to assess the original placement of the site, sediment samples were taken from every excavated unit and every two-centimeters throughout the shell midden feature. The sediment samples were exported to the Archaeology Lab at Louisiana State University (LSU) for further analyses, including loss-on ignition (LOI; the burning of sediment to determine the percent of organic matter) and microscopic sorting to identify the presence of organic content, such as *Rhizophora mangle* (fine red mangrove roots), which could infer on sea-level rise.

McKillop et al. (2010a, 2010b) utilized microscopic analyses and LOI to determine the rate of sea-level rise. They found that rates had increased as much as 0.87 cm per year during the Classic period (A.D. 300-900) along the southern coast of Belize. Although underwater sites are not uncommon, they are rarely explored in the Maya area (Andrews and Corletta 1995). Some notable examples of early underwater archaeology in the Maya area include the Cenote of Sacrifice at Chichen Itza (Coggins 1992; Thompson 1992), Cenote Xlakah at Dzibilchaltun (Andrews and Andrews 1980; de Borhegyi 1961), and Lake Peten Itza in Guatemala (de Borhegyi 1963).

Research Questions

Analyses of marine sediment samples from the site were carried out to determine the terrestrial versus marine origin of the sediment. The sediment was searched for the presence of red mangrove peat, which forms under conditions of sea-level rise (McKee and Faulkner 2000;

McKee et al. 2007; McKillop et al. 2010a, 2010b). Living red mangroves rise vertically in response to sea-level fluctuation until the rate of sea-level rise out-paces the growth rate of the mangroves. Over time, the mangrove roots trap leaves and organic matter forming detritus and peat, which creates an anaerobic environment low in organic matter.

If the sediment is comprised of mangrove peat, then the site may have been built on cleared mangrove stands and inundated due to the rising sea (McKillop et al. 2010a, 2010b). Conversely, if the sediment is not mangrove peat, then the site may have been built on elevated structures over the water. If the structures were elevated above the water, then there would be floorboards. Alternatively, if the building was constructed directly on the ground, then floorboards would be absent.

Eleanor Betty is located in a shallow salt-water lagoon system in Paynes Creek National Park, Belize. Excavations during the 2013 field season and analyses of recovered archaeological material suggest that Eleanor Betty was part of the Paynes Creek Salt Works. The Paynes Creek Salt Works have the only known ancient Maya wooden architecture, which is associated with briquetage – the pottery used to evaporate brine over fires to make salt (McKillop 2005a). Previous research at other sites in the lagoon indicates they were workshops for salt production and not residential areas (McKillop 2002, 2004a, 2005a, 2005b, 2006, 2007a, 2007b, 2008, 2009a, 2009b; McKillop et al. 2010a, 2010b; Sills and McKillop 2010).

Eleanor Betty has preserved wooden architecture (comprised of hardwood and palmetto palm posts) due to the acidic, anaerobic sediment below the seafloor. The acidic sediment has not preserved human or animal bones, including microfossils that can inform on environmental changes. A curved line of palmetto palms runs north to south along the western edge of the site, which could have acted as a retaining wall to keep the rising sea at bay (McKillop 2014 personal

communication). If Eleanor Betty had been built directly on the surrounding mangrove stands, then the peat would contain a high amount of organic matter and small roots (*Rhizophora mangle*) belonging to red mangroves: trees which keep pace with sea-level rise. Alternatively, if the peat was low in organic matter and lacked red mangrove roots, then the site could have been on platforms over the water.

Background

Sea-level Rise in the Maya Area

The southern Belize barrier reef lagoon has a Holocene sediment history, which has generated as much as 11 m of mangrove peat located on the Pleistocene limestone bedrock (Macintyre et al. 1995; McKee et al. 2007; McKillop 2002:138-146; McKillop et al. 2010a, 2010b). The sediment record can be compared with other sediment records obtained from Lake Chichancanab (Hodell et al. 1995; Hodell et al. 2001; Hodell et al. 2005). Other proxy records include sediment cores from Lake Punta Laguna (Curtis et al. 1996), and Tzabnah cave, Tecoh, (Medina-Elizalde et al. 2010) which identified a warming trend in the Maya area. Mangrove peat sediment records obtained along the coast of Belize north of Paynes Creek from Tobacco Range (Cameron and Palmer 1995; Macintyre et al. 1995), Twin Cays (Macintyre et al. 2004; McKee et al. 2007), and Pelican Cay (Macintyre et al. 2000) document fluctuations in sea-level from 9,000-3,000 years ago (Figure 4.1). Additional evidence of sea-level rise can be found in northern Belize at Marco Gonzalez on Ambergris Caye, where the barrier lagoon is much shallower than in southern Belize, so there is no similar record of mangrove peat (Dunn and Mazullo 1993; Graham and Pendergast 1989).

Sea-level rose swiftly worldwide during the Holocene Climatic Optimum (9,000-5,000 years ago) and slowed approximately 4,000 years ago. The decline in the rate of sea-level rise

around 4,000 years ago allowed red mangroves to develop in shallow water and keep pace with the now-gradual sea-level rise. Relative sea-level rise (subsidence, erosion, compaction of sediment) along the cays of the Belize Barrier Reef has been minimally observed and has contributed to the settlement and overall compact nature of mangrove peat (McKee et al. 2007).



Figure 4.1. Map of Belize showing location of Paynes Creek National Park and surrounding cays. Map by V. Feathers (from ESRI® ArcGIS® ArcMap™ 10.3 ©1999-2014).

McKee et al. (2007) hypothesizes that relative sea-level rise has contributed to the settlement and compact nature of the red mangrove peat in the area, particularly at Twin Cays. Subsidence due

to tectonic activity has not been documented during the Holocene, (Dillon and Vedder 1973; Mann et al. 2007; Toscano and Macintyre 2003).

Evidence of Sea-level Rise in Paynes Creek

Radiocarbon analysis of the sediment core collected by McKillop et al. (2010a, 2010b) revealed a 4,000-year record of actual sea-level rise near the K'ak'Naab' Site, with occupation beginning in the Early Classic (AD 300-600) and continuing into the Late Classic (AD 600-900). Mangrove peat accumulation from K'ak' Naab' was compared to the western Atlantic sea-level curve (Toscano and Macintyre 2003) to calculate the rate of actual sea-level rise. Radiocarbon dates from the K'ak' Naab' sediment core provided a rate of actual sea-level rise of 0.010 cm per annum from 4140 BP to 1580 BP, with an increase in the rate of sea-level rise during the 660-year occupational period of the site (0.087 cm per annum; McKillop et al. 2010a, 2010b).

Sea-level rise is documented at many sites in southern coastal Belize. Excavations at Wild Cane Cay revealed buried stratigraphy 150 cm below the current water table (McKillop 1994, 1995, 2005b, 2009b). The coral foundations of two mounds at Frenchman's Cay are located 80 cm below the water table (McKillop 2005b; McKillop et al. 2004). The Classic deposits at Pelican Cay (near Wild Cane Cay) were submerged by sea-level rise after the site's abandonment, as indicated by 40 cm of mangrove peat above the site (McKillop 2002: 156-159). Other sites submerged by sea-level rise include: Pork and Doughboy Point (McKillop 2002: 160-161); Stingray Lagoon, David Westby, and Orlando's Jewfish (McKillop 1995, 2002: 29).

Methods

Sediment samples were taken vertically in two-centimeter levels to the maximum depth of the shell midden (30 cm) to assess sea-level rise. Additional sediment samples were taken at the southwest corner of each excavated unit. The samples were sealed in sterile whirl pack bags,

labeled, and sent, under permit, to LSU. The marine sediment was studied to see whether it was mangrove peat. If the recovered sediment was mangrove peat, the sea-floor sediment was created under conditions of actual sea-level rise. Two separate techniques were used: 1) loss-on ignition to determine the percent of organic matter in each sample, and 2) microscopic sorting of sediment to identify the presence of organic matter, such as *R. mangle*.

The presence and abundance of red mangrove roots (*R. mangle*) were of interest, since they are a known marker of sea-level rise. Red mangroves grow vertically to keep their leaves above the water as sea-level rises. Particular attention was given to the recovery of small red mangrove roots that do not have much vertical movement in the sediment and so are useful for radiocarbon (^{14}C) dating sea-level rise (McKee and Faulkner 2000). Additionally, the pH values for all sediment samples were determined to assess the differences in preservational properties between the mangrove peat and shell midden. If the sediment was acidic throughout the excavated units, including the shell midden, then no human or faunal remains would be preserved. Acidic values were expected for all units without shell. However, an alkaline value would suggest an environment capable of preserving human and faunal remains. Alkaline values were expected for units with shell.

Loss-on Ignition (LOI)

A sediment sample was taken from the southwest corner of 25 excavated units during the 2013 field season at the Eleanor Betty site. An additional seven samples were taken at two-centimeter intervals throughout the shell midden feature (Transect 6, 3-4 m). The marine sediment samples were exported under permit to LSU and refrigerated to prevent the growth of mold. A portion of all recovered sediment was subjected to loss-on ignition to determine the amount of organic matter present (Figure 4.2). Loss-on ignition was performed on sediment

samples from a sediment column recovered from the south wall of Transect 4, 3-4 m, after the 2011 excavations. The column sample began at the seafloor and extended to a depth of 14 cm below the seafloor. Samples were taken in two-centimeter intervals, with seven samples in total.

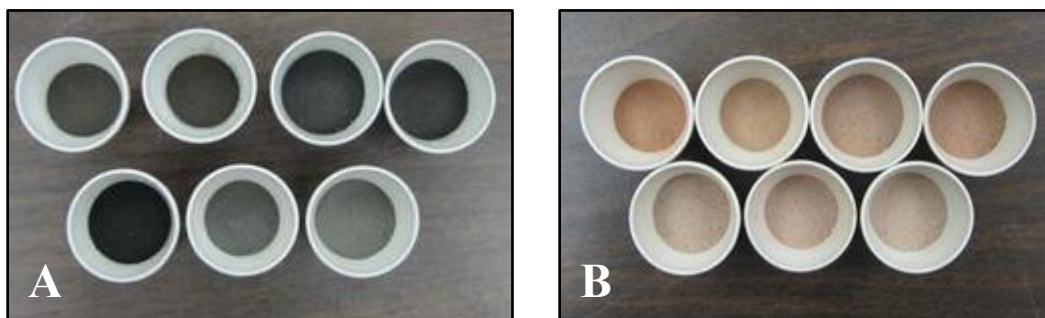


Figure 4.2. A: Photo of samples in crucibles prior to heating in the muffle furnace; B: Photo of samples in crucible after removal from muffle furnace. Photos by V. Feathers and R. Watson

A quarter-sized sample of sediment was removed from each container and placed in an aluminum foil tray labeled with the corresponding transect, unit, and level numbers. Seven samples were prepared at a time, which was the maximum number to fit the size of the drying oven and muffle furnace. The Underwater Maya Project set up equipment for LOI in the H.J. Walker Geomorphology Lab following protocol established by project mangrove ecologist Dr. Karen McKee (McKee and Travis 2006). The seven wet samples were placed in a Lab-Line® L-C drying oven at 60°C for 24 hours in order to dry prior to grinding. Temperature was measured with an external/internal thermometer. The position of the samples in the drying oven were photographed and recorded.

Seven porcelain crucibles (15 mL) and lids were sterilized in a diluted 1% hydrochloric acid bath. The crucibles and lids were dried in a Captair™chem Filtration System for 24 hours prior to use. A desiccator was prepared to store the samples throughout the LOI procedure, which allowed the crucibles to cool without gaining moisture. The samples were removed from the drying oven. Numbers, one-to-seven, were painted on the side and bottom of each crucible in

blue acrylic paint. The painted number correlated with each sample: 1 (0-2 cm), 2 (2-4 cm), and so on. The crucibles were weighed with an OHAUS Explorer Pro electronic scale.

All measurements were recorded in grams and calibrated to three decimal places in accordance with the OHAUS scale settings. McKee and Travis (2006) determined the analytical precision for LOI and provided the following formula:

$$\% \text{OM} = [(W_{105} - W_{400}) / W_{105}] \times 100^2$$

The formula was modified by the Underwater Maya Project due to the highly organic nature of the marine sediment. The formula was entered into a Microsoft® Excel® spreadsheet.

A ceramic mortar and pestle and small plastic spatula were washed and dried. The dried samples were ground into fine sediment and placed into the corresponding crucible. The crucible and sample weight were obtained through the use of the triple beam balance. The samples were then placed into the Thermolyne™ Type 1400 Furnace (muffle furnace; Figure 4.3), which was heated to 105°C. The temperature was monitored while the samples were burning. After four hours, the crucibles were removed from the muffle furnace and placed in the desiccator to cool for 10 minutes. The cooled samples were weighed, covered with a ceramic lid, and placed back into the muffle furnace. The muffle furnace was heated to 500°C. After 10 hours, the temperature was decreased to 105°C at which time the lids from the crucibles were removed and the crucibles were placed into the desiccator. The samples were weighed, placed into whirl pack bags and labeled with the site name, transect number, unit, level, date, loss-on ignition label, and researcher name, and stored in the Archaeology Lab.

² W₁₀₅ equals the weight of soil at 105°C. W₄₀₀ equals the weight of soil at 400°C.



Figure 4.3. Photo of Valerie Feathers placing sediment samples into the muffle furnace. Photo by R. Watson.

Microscopic Identification of Organic Matter (Plants)

A separate portion of the recovered sediment from each unit, including levels 0-14 cm of the excavated shell midden (Transect 6, 3-4 m), were microscopically sorted and analyzed for the presence or absence of plant material, specifically *R. mangle* (Figure 4.4). A dime-sized portion from each recovered sediment sample was rinsed in a 250 μ m sieve, placed in separate Petrie dishes, diluted with distilled water, and sorted under a microscope.

A Bausch & Lomb Stereo Zoom[®] 4 Zoom Range 0.7x – 3.0x coupled with a Bausch and Lomb Transformer[®] illuminator was used for sorting and identification. The illuminator provided an additional light source for the identification of *R. mangle*. A white paper disc was placed on the transparent glass sheet on the bottom of the microscope. The white disc allowed for better identification of the red mangrove roots. Needle-nosed dissection tweezers were used to extract *R. mangle* samples, which were placed into a sterile glass 10 mL dram labeled with the

corresponding transect, unit, and level numbers. The recovered material was separated into four classes: organic (wood, charcoal), inorganic (coral), coarse and fine mangrove roots.

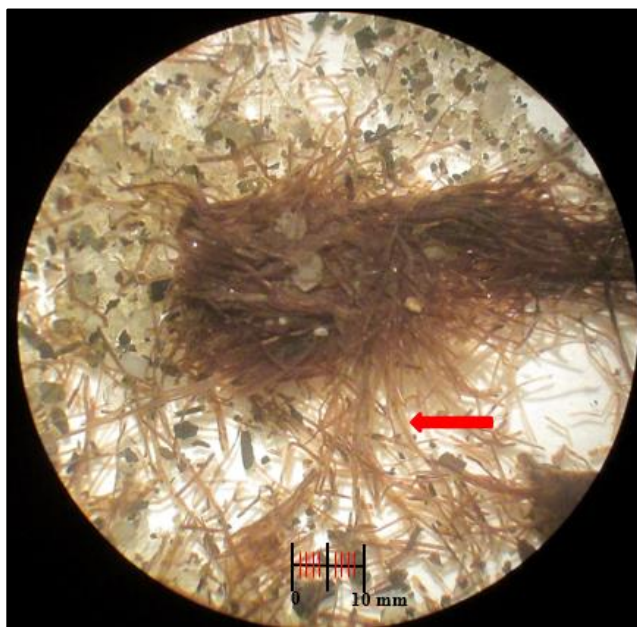


Figure 4.4. Diluted sediment sample. Red arrow indicates *R. mangle* roots. Photo by V. Feathers.

Radiocarbon Dating

Two separate samples of *R. mangle* were recovered from the top layer of the shell midden feature (0-2 cm) and the bottom layer of the shell midden feature (10-12 cm). Both were placed into 10 mL dram vials, sealed, and sent to Beta Analytic for accelerated mass spectrometer (AMS) dating. The dates will aid in the determination of the rate of sea-level rise for the site.

pH Analysis

A total of 44 samples underwent pH analyses to determine the acidity or alkalinity of the sediment. Each sample was set out for 24 hours to achieve room temperature. A solution of diluted 1% hydrochloric acid was used to clean the 50 mL glass beakers the magnetic spinners. The magnetic spinners created a “slurry” (or mixture) of the marine sediment. Each beaker was labeled by site, unit, and level. A portion of the sediment was extracted and placed into a clean Petrie dish. Each sample was weighed using a calibrated Mettler PE 3600 Delta Range® scale.

Sample weights ranged from 8.02 g to 8.25 g. All samples were placed into 50 mL glass beakers along with one magnetic spinner and filled with 40 mL of distilled water.

The pH analyses were performed in the Geochemistry Lab at LSU. A Thermolyne Nuova Stir Plate, pH probe, and temperature probe were used to measure the pH values. The pH probe was calibrated with a number four and number seven buffer solution at the start of each day. Both probes were placed into a “resting” beaker after calibration and between each use. The temperature probe was damaged prior to the start of analyses. Although both probes were employed for the first 16 samples, the use of the temperature probe was discontinued due to severity of the damage. The absence of the temperature probe did not affect the pH results.

Each sample was assessed individually. Once placed on the Thermolyne Nuova Stir Plate, the magnetic spinner was activated. The sample spun for one minute, creating a slurry. The temperature and pH probes were removed from the resting beaker, rinsed with deionized water, and dried with kimwipes. At the end of one minute, the temperature and pH probes were placed into the spinning slurry for two minutes. Both the pH and temperature values were displayed using a Sargent-Welch pH 8200 pH reader. The readings were photographed and recorded in a notebook. At the end of two minutes, the stir plate was stopped. The probes were removed from the sample, rinsed in deionized water to avoid cross-contamination, dried with kimwipes, and placed back into the resting beaker. This series of actions was performed for each sample.

Results

Loss-on Ignition

The percentage of organic matter in the sediment varies across the excavation, with percentages ranging from 8% to 40% (Figure 4.5). The results from the shell midden mirrored those of the excavated units (12% to 40%). The percentage of organic matter in the

column samples ranged from 26% to 35% (Figure 4.6). A higher percentage of organic matter exists to the west of the shell midden (Figure 4.7).

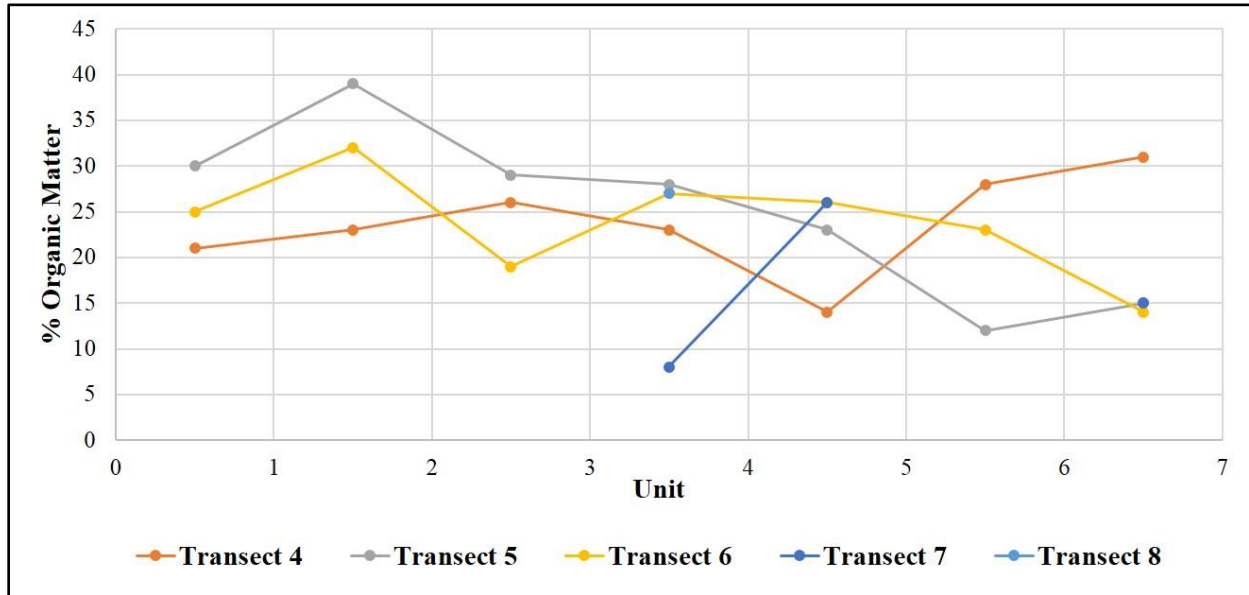


Figure 4.5. Graph showing results of loss-on ignition for all transects at Eleanor Betty.

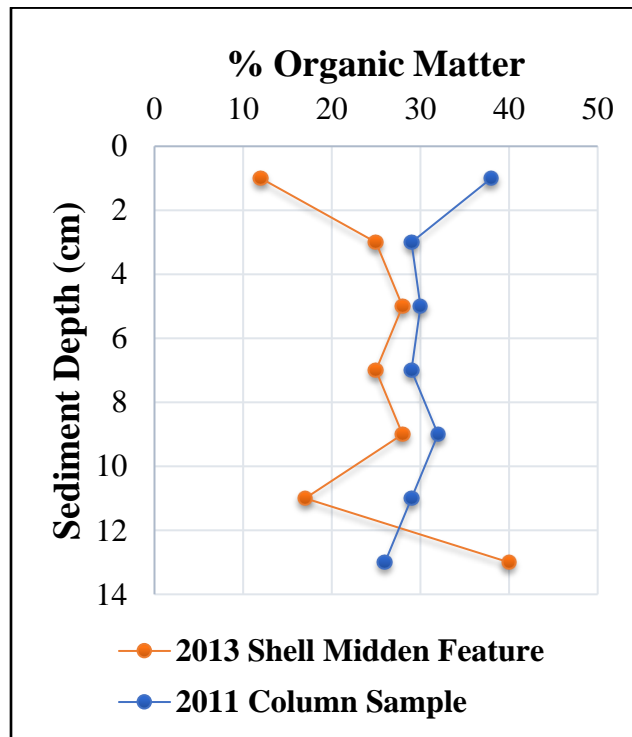


Figure 4.6. Graph showing results of loss-on ignition by depth for the 2011 column sample and the 2013 shell midden feature. 0 cm depth represents 0-2 cm depth, 2 cm depth represents 2-4 cm depth, etc.

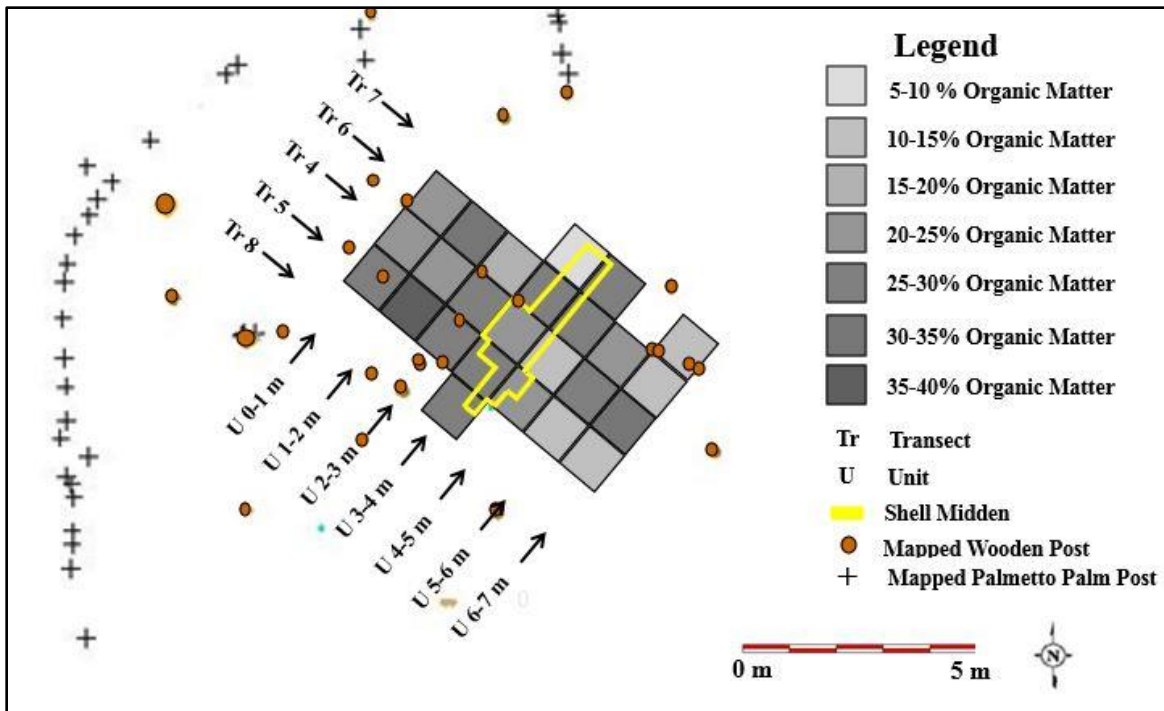


Figure 4.7. Map showing percentage of organic matter across all excavated transects. Map by V. Feathers annotated from base map by H. McKillop.

Sorting Organic Component

The recovered samples from the southwest corners of all excavated units contained fine roots, coarse roots, and salt crystals. Charcoal and briquetage bits were present in some samples but were absent in others. A minimal amount of shell and wood was recovered (Table 4.1). Samples from the layers of the shell midden feature (Transect 6, Unit 3-4 m, Levels 0-14 cm) contained a high amount of fine roots from *R. mangle*.

Fine roots extracted from the top layer were more structurally sound than those recovered from the basal layer. Charcoal was present in all layers (Table 4.2). The basal layer (10-12 cm) contained an abundance of coarse roots. The two *R. mangle* samples from Transect 6, Unit 3-4 m, 0-2 cm and 10-12 cm sent for AMS dating produced two Postclassic dates (Table 4.3).

Table 4.1. Microscopically sorted organic and inorganic remains from sediment samples (“X” indicates present).

Transect	Unit (m)	Charcoal	Shell	Briquetage	Wood	Fine Roots	Coarse Roots
7	3-4	X				X	X
	4-5	X				X	X
	6-7	X				X	X
6	0-1				X	X	X
	1-2					X	X
	2-3	X		X		X	X
	3-4	X				X	X
	4-5	X				X	X
	5-6			X	X	X	X
	6-7					X	X
4	0-1					X	X
	1-2	X				X	X
	2-3					X	X
	3-4	X		X		X	X
	4-5	X		X		X	X
	5-6	X		X		X	X
	6-7	X		X		X	X
5	0-1	X				X	X
	0-1	X				X	X
	1-2					X	X
	2-3			X		X	X
	3-4	X				X	X
	4-5	X				X	X
	5-6	X	X		X	X	X
	6-7	X		X		X	X
8	3-4	X		X	X	X	X

Table 4.2. Material recovered from microscopically sorted sediment samples from shell midden excavations (“X” indicates present).

Transect	Unit (m)	Level (cm depth)	Charcoal	Shell	Briquetage	Fine Roots	Coarse Roots
6	3-4	0-2	X	X	X	X	X
	3-4	2-4	X	X	X	X	X
	3-4	4-6	X		X	X	X
	3-4	6-8	X	X	X	X	X
	3-4	8-10	X	X		X	X
	3-4	10-12	X			X	X
	3-4	12-14	X	X	X	X	X

Table 4.3. AMS dates for the Eleanor Betty shell midden feature (Transect 6, Unit 3-4 m).

Depth (cm)	Sample ID	Measured Age (BP)	¹³ C/ ¹² C	Conventional Age (BP)	¹⁴ C age (years BP ± 2σ calibration)	Calibrated BP (95% Probability)
0-2	3218015S0-2	550 ± 30	-25.8 ‰	540 ± 30	AD 1320-1350 and AD 1390-1435	630-600 and 560-515
10-12	3218015S10-12	710 ± 30	-25.3 ‰	710 ± 30	AD 1265-1295 and AD 1370-1380	685-655 and 580-570

pH values

The results of the pH values indicate a mix of alkaline (≥ 7) and acidic (≤ 7) sediment depending on the content of the unit (i.e., more shell versus more mangrove peat; Table 4.4). The results indicate an increase in alkalinity with the shell midden feature (average pH = 6.31), supporting the hypothesis that the calcium carbonate in the shell influences the pH value of the mangrove peat. However, not all units with shell exhibited the same result. Only the unit with the largest amount of shell (Transect 6, 3-4 m, 0-2 cm to 12-14 cm; n = 2982) altered the pH value³.

Table 4.4. Combined results of loss-on ignition (LOI), number of individual specimens present (NISP), pH, and recorded features.

Transect	Unit (m)	Depth (cm)	LOI (%)	NISP	pH	Feature
4	0-1	NA	21	NA	3.56	NA
	1-2	NA	23	NA	3.49	NA
	2-3	NA	26	NA	3.82	NA
	3-4	NA	23	NA	3.69	NA
	4-5	NA	14	NA	5.97	NA
	5-6	NA	28	NA	4.72	NA
	6-7	20	31	18	4.06	None
5	0-1	30	30	51	3.42	None

³ The elemental composition of separate sediment samples were analyzed using a handheld portable x-ray fluorescence (PXRF) machine. The results were compared to the LOI, NISP, and pH results. The resulting graphs and elemental identifications did not match the NISP counts. For example, Transect 5, 4-5 has an NISP of 334 and Transect 5, 6-7 m has an NISP of 33. However, the calcium peak for Transect 5, 6-7 m is larger than that of Transect 5, 4-5 m. This error resulted from a piece of shell in the sample being placed directly on the PXRF window when the sample was assayed.

(Table 4.4 continued)

Transect	Unit (m)	Depth (cm)	LOI (%)	NISP	pH	Feature
	1-2	30	39	36	3.22	None
	2-3	30	29	30	3.37	Clay
	3-4	20	28	81	3.44	None
	4-5	20	23	334	5.42	None
	5-6	30	12	18	3.88	Clay/Ash
	6-7	20	15	33	6.27	Clay
6	0-1	30	25	116	3.27	None
	1-2	20	32	43	3.57	Clay
	2-3	20	19	13	3.32	Clay
	3-4	15	27	320	3.4	None
	4-5	20	26	106	4.66	Fire pit?
	5-6	20	23	34	4.04	Fire pit?
	6-7	20	14	22	3.79	None
7	3-4	20	8	387	3.86	None
	4-5	20	26	73	3.7	Fire pit?
	6-7	20	15	27	3.73	None
8	3-4		27	9	3.38	None
6	3-4	0-2	12	607	6.19	Midden
		2-4	25	519	5.74	Midden
		4-6	28	663	6.43	Midden
		6-8	25	454	6.69	Midden
		8-10	28	217	6.18	Midden
		10-12	17	191	6.46	Midden
	3-4	Facecut	40	331	6.51	Midden

Discussion

Three hypotheses exist to explain the present underwater location of the Eleanor Betty Site: 1) the workshop was built on the dry, cleared mangrove stands and succumbed to sea-level rise and degradation due to climate; 2) the site was built on stilts over the water, which were placed into an inundated red mangrove stand; and 3) the site was built on stilts over the water, which were placed into an inundated piece of land and not a red mangrove stand. If the building was constructed on the dry mangrove stands and inundated due to sea-level rise, then evidence of red mangrove peat (*R. mangle*, a proxy for sea-level rise) and preserved wooden posts would be present. If the workshop was built on stilts over the water placed into a sunken piece of red

mangrove stand, the mangrove peat and preserved wooden posts would be present. Alternatively, if the workshop was built on stilts over the water, and the stilts were placed in a sunken piece of land that was not a red mangrove stand, then there would be an absence of red mangrove peat and preserved wooden posts.

The presence of preserved wooden posts and red mangrove peat indicates the Eleanor Betty site was built on a cleared red mangrove stand, thus nullifying the third hypothesis. Multiple problems exist with the second hypothesis. Although mangrove peat is present, indicating sea-level rise, the challenge of driving wooden posts into an inundated red mangrove stand would be challenging during ancient times and highly unlikely since dry land would have been nearby. Even if the mangrove stand had turned to peat, the stability of the workshop would be severely compromised as the peat is very soft, allowing heavy objects to sink straight through its matrix. The placement of the workshop on stilts over the water would add the difficulty of traveling to and from the site. Transportation of workers and materials would be possible via canoe only depending on the height of the workshop above the water.

The most likely scenario is the first hypothesis. The Eleanor Betty site was built on the dry, cleared red mangrove stands near the water. The workshop likely was constructed in a traditional pole-and-thatch construction that was, and still is, common throughout Mesoamerica (Wauchope 1938; West 1976). The floor of the workshop would have been bare earth. No wall structures were encountered during the excavations, suggesting the building was an open-air structure with wooden posts comprising only the corners and perhaps vertical support beams for the thatch roof. Once the building was abandoned, the thatch and upper portions of the wooden posts would have degraded due to the tropical climate. Sea-level rise and the red mangrove peat matrix preserved the lower portions of the wooden posts, along with the cultural material.

The presence of *R. mangle* along with a high percent of organic matter in the recovered marine sediment samples, in conjunction with those reported by McKillop et al. (2010a, 2010b), indicate a mangrove swamp once dominated the landscape in Paynes Creek. The recovery of red mangrove peat indicates actual sea-level rise, which supports the findings by McKillop et al. (2010 a, 2010b) along the southern coast of Belize.

The AMS dates indicate that peat deposition for the shell midden feature occurred between AD 1265 and AD 1435. Approximately 15 cm of peat accumulated over a period of less than 200 years (Figure 4.8). Subsequently, the rate of sea-level rise increased, drowning the red mangroves and halting the production of mangrove peat.

The ^{14}C date provides new information on sea-level rise in southern Belize. The dates of the fine red mangrove roots indicate continued sea-level rise in the Postclassic as late as AD 1435. The rate of sea-level rise at this site, 7.5 cm per 100 years, compares with western Atlantic sea-level curve (Toscano and Macintyre 2003). In the southern Belize barrier lagoon, Postclassic stone and coral architecture was inundated at Wild Cane Cay (McKillop 2005b: 62, 64-66, 68-72, 74-75) and at Frenchman's Cay (McKillop 2005b: 173, 177-178, 180-181, 183, 187-188; McKillop et al. 2004).

The results from loss-on ignition and sediment sorting indicate the Eleanor Betty site was once on dry land. However, the abundance of red mangrove and the absence of black mangroves (*Avicennia germinans*) and white mangroves (*Laguncularia racemosa*) in the analyzed sediment samples calls into question exactly how much of the area was dry land. Red mangroves form in brackish areas (Cameron and Palmer 1995). Black mangroves form in brackish estuaries and live in coastal areas above the high tides. White mangroves live farther inland than black mangroves

and above the tide line. Although red mangroves can produce land, this land forms over hundreds of years and must exist within the tidal zones for red mangrove growth.

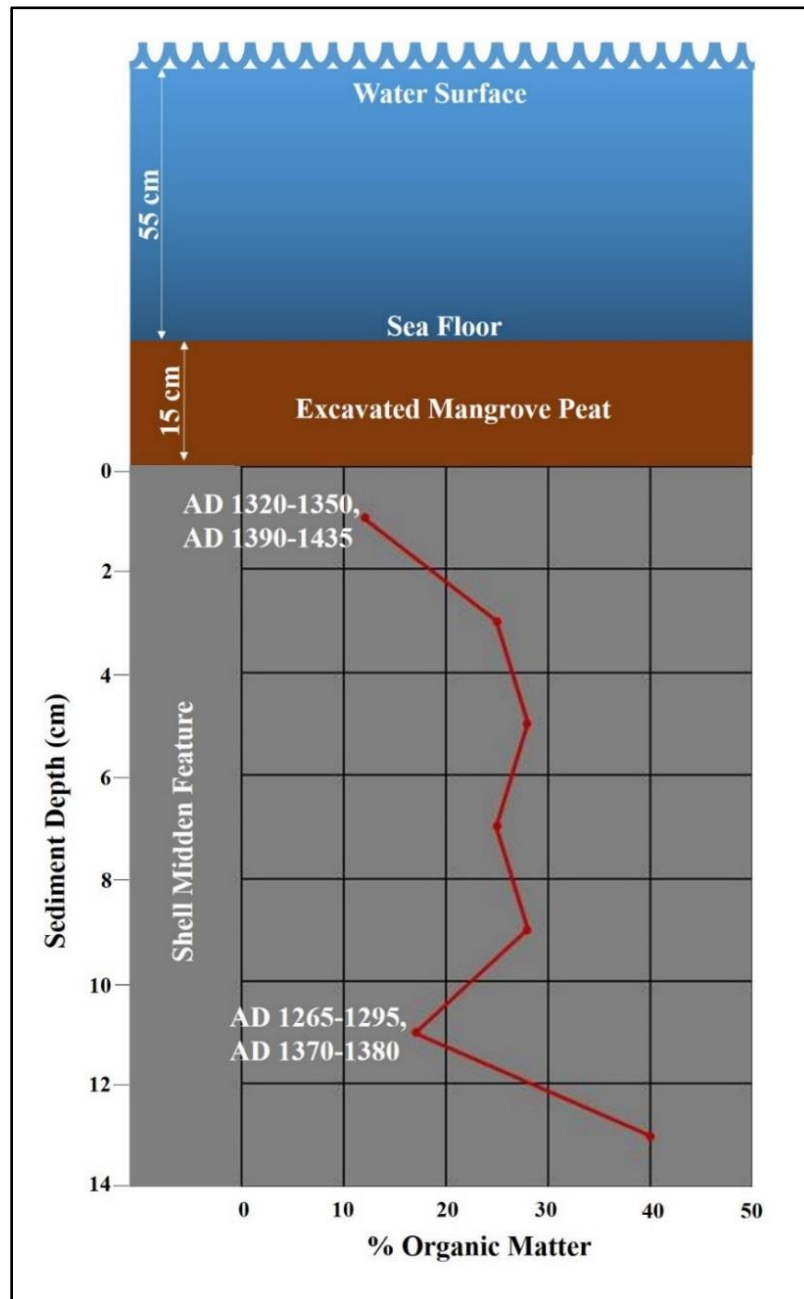


Figure 4.8. Schematic drawing showing profile of underwater shell midden with loss-on ignition results and AMS dates from levels 0-2 cm and 10-12 cm depth. 0 cm depth represents 0-2 cm depth, 2 cm depth represents 2-4 cm depth, etc. Drawing by V. Feathers.

The analyzed sediment samples contained an abundance of red mangrove roots. Black and white mangrove roots were absent from the samples. The absence does not preclude the

aforementioned interpretation. In fact, the presence of the preserved underwater wooden architecture indicates otherwise.

The preserved hardwood posts form the outline of an inundated structure. The structure lacks a floor, so was not a raised platform over the water. Additionally, archaeological excavations revealed stratigraphic cultural layers beginning 55 cm below the water table and extending another 30 cm below the seafloor. The layers were comprised of compact mangrove peat mixed with briquetage, fineware pottery, obsidian, and chert artifacts. The archaeological evidence indicates Eleanor Betty was once located on dry land.

The pH analyses revealed new information about the sediment chemistry between the mangrove peat and the shell midden. The average pH for samples obtained outside of the shell midden feature was 3.96, whereas the average pH for the shell midden feature was 6.31. The less acidic, more alkaline value for the mangrove located within the shell midden feature indicates the calcium carbonate of the shell has some effect on the acidity of the mangrove peat. One possible explanation for the more alkaline values is the leaching of calcium from the shells into the mangrove peat. The midden preserved two unidentified faunal remains, supporting the hypothesis that the shell midden would contain remains. The altering of the sediment chemistry could have contributed to this preservational aspect.

Conclusion

The results of various analyses, including loss-on ignition and microscopic identification of organic matter, in conjunction with the absence of wooden or stone floors, supports the interpretation that Eleanor Betty was built on dry land. The sea continued to rise once the site was abandoned. After time, the archaeological deposits were inundated 55 cm below the water's surface and incorporated into the red mangrove peat. The inundation of Eleanor Betty coincides

with the inundation of other sites in the area, including K'ak' Naab' (McKillop et al. 2010a, 2010b) and the inundation of other archaeological sites along the coast of southern Belize (McKillop 1994, 1995, 2002: 29, 156-159, 160-161, 2005b, 2009b; McKillop et al. 2004). The AMS dates from the red mangrove samples indicate the sea continued to rise during the Postclassic period. McKillop et al. (2010a, 2010b) compared the radiocarbon dates from the K'ak' Naab' site to Toscano and Macintyre's (2003) sea-level curve. They documented a rate of sea-level rise of 0.01 cm per annum from 4140 BP to 1580 BP. When the same comparison was performed for the Eleanor Betty site, the results indicated a rate of sea-level rise of 7.5 cm/100 years from 515 BP to 685 BP (AD 1265 to AD 1435).

The AMS dates do not match the ceramic type-variety for the site, which indicates a Classic period occupation. Salt production at Eleanor Betty likely did not continue into the Postclassic period (A.D. 1000-1452) due to the shallow nature of the deposit (~30 cm below the sea floor) and an unchanging ceramic type-variety. Two possible explanations for this conflict are: 1) As the mangrove roots rose vertically to keep pace with sea-level rise, the accumulated peat mixed with the archaeological deposits, causing them to rise with the peat, and 2) The mangrove peat grew around the archaeological deposit during the Postclassic period, encasing the archaeological material in the peat matrix. The first hypothesis seems unlikely as the excavations revealed little-to-no mangrove peat mixed within the artifact and shell midden layers. An abundance of mangrove peat surrounded the artifacts and shell midden and sterile mangrove peat, or peat free of cultural material, was found below the 30 cm layer. This evidence shows support for the second hypothesis. Remnants of the shell midden and artifacts were visible once the silt was removed prior to excavating the first layer (0-10 cm). If the accumulated peat had raised the archaeological material, then there would be a disparity between the placement of

ceramics (heavier) and the shell, botanicals, and charcoal (lighter). The lighter elements could have been raised higher than the heavier ones. Additionally, the lack of archaeological material below 30 cm is indicative of the site's original depositional location. Radiocarbon dates are needed to refine the timeline of occupation for the Eleanor Betty site.

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Chapter 5: Conclusion

Significance

The underwater ancient Maya site of Eleanor Betty, one of the Paynes Creek Salt Works in southern Belize, was excavated in 2013 to answer questions concerning salt production and subsistence activities, including the following: 1) Was the site a residence, household workshop, or production workshop; 2) What was the nature of the submerged shell midden; 3) Was the site once on platforms over the water or constructed on dry land; 4) What was the extent of the submerged shell midden; and 5) What was the purpose of the shell midden? Analyses on the material recovered from the 2013 excavations were performed in the field, at the Village Farm base station, the Archaeology Lab at Louisiana State University (LSU), the H.J. Walker Geomorphology Lab at LSU, and the Geochemistry Lab at LSU. The results not only supported previous evidence conducted on sea-level rise in Paynes Creek National Park and, by proxy, along the coast of Belize, but also contributed new data to the western Atlantic sea-level curve and new information on the effect that a calcium carbonate matrix has on the surrounding mangrove peat. The results are summarized below.

Manuscript 1

Fieldwork

Wooden posts from the 2011 field season were relocated during systematic survey and marked with red flags. All posts were vertically situated in the marine sediment. Four new transects (Transects 5, 6, 7, and 8) were added to the north and south of Transect 4 (originally set out in 2011). Nineteen units were excavated. Transect 5 and Transect 6 had seven 1x1 m units while Transect 7 and Transect 8 contained three and one 1x1 m units, respectively. Unit (U) 6-7 m was added to Transect 4. All units were marked with yellow flags. The submerged wooden

architecture extended approximately four meters north-to-south (Transect 8 to Transect 6) and approximately seven meters east-to-west, with hardwood posts being the most common form.

The shell deposit expanded north-to-south in U 3-4 m and U 4-5 m across all transects. The midden measured 5 m in length by 0.5-to-1 m in width. Transect 6, U 3-4 m, contained the bulk of the shell and was excavated as a separate feature in two-centimeter levels beginning at 16 cm reaching a maximum depth of 30 cm. A profile was excavated in 10 cm levels along the south wall of Transect 6, U 3-4 m. Clay and ash deposits were found in Transect 6, U 1-2 m and U 2-3 m, and Transect 5, U 5-6 m and U 6-7 m. A possible fire pit was found in Transect 6, U 4-5 m and U 5-6 m that extended into Transect 7, U 4-5 m. The cultural and shell deposits, were within the wooden structure. Excavations of the Eleanor Betty site revealed cultural layers extending 30 cm below the sea floor (approximately 84 cm below the water's surface).

Utilitarian Items

Few utilitarian items were found during survey and excavations. Recovered items resulted in 21 obsidian fragments and 14 pieces of chert. No complete utilitarian tools were recovered.

Charcoal and Macrobotanicals

Approximately 16,262 g of charcoal were recovered from the excavations at Eleanor Betty. Of this amount, 62% (n=6,248.48 g) was associated with the shell deposit (U 3-4 m and 4-5 m of all transects). However, the majority of the recovered charcoal was directly associated with the shell midden feature in Transect 6, U 3-4 m (~10,013.52 g or 62%). Macrobotanical remains (n=376) were recovered, including 338 full or partial coyols (*Acrocomia Mexicana*). The remaining 38 macrobotanical fragments consisted of crabbo (*Byrsonima crassifolia*) and cohune (*Orbignya cohune*).

Results of Ceramic Analyses

Ceramic analyses conducted in the field and at the Village Farm basecamp indicate that the Eleanor Betty site was a salt production workshop, not a resident or residential workshop. The large amount of briquetage recovered from the excavations (n=5,526) supports this interpretation. Mangrove Unslipped and Warrie Red jars used for water transport and storage, accounted for 4% of the recovered ceramics. Less than 1% of the recovered ceramics resulted in a ceramic class other than briquetage – Moho Red. The Moho Red ceramics could have comprised a serving vessel used during a ritual ceremony for the opening of the salt production workshop.

Manuscript 2

Shell Analyses

Analysis of the shells resulted in a number of individual specimens present (NISP) of 4,733 shell fragments weighing 2,304.24 g. Eighty-four percent of the recovered shell were *Crassostrea rhizophora* (red mangrove oysters; n=3,979). The remaining 16% consisted of environmental indicators such as false mussels (*Mytilopsis domingensis*), which likely entered the site through storm surges or tidal changes. Cultural material, such as ceramic sherds and charcoal, were intermixed in all levels of the shell deposit, suggesting the deposit was a cultural, not natural, midden placed by the ancient Maya. The minimum number of individual (MNI) analysis of the umbo resulted in 198 *C. rhizophora*. Measurements of the shell height (maximum dorsal-ventral) and/or shell length (maximum anterior-posterior) were obtained from 57 left valves and 43 right valves (n=100). Of those, 27 had complete margins and were used to evaluate the height-length ratio (HLR). The average HLR was 1.89 cm and 1.87 cm for the left and right valves, respectively.

Assessment of the HLR suggested the midden accumulation was a one-time event as the average HLR for the left valve was 1.89 cm and 1.87 cm for the right valve. Ninety-seven of the 198 *C. rhizophora* exhibited butcher marks, indicative of modification for meat removal. Seventeen shells exhibited a notch break, which could have occurred when a piece of chert was inserted into the shell margin in an attempt to pry the shell open and retrieve the meat. Further analysis revealed a variety of break patterns, including vertical, horizontal, V-shape, and L-shape breaks, indicating the cracking method was the most commonly employed method for meat removal. There was no evidence that shell was used as temper for ceramics, construction fill (i.e., floor leveling), modification for inland trade, ritualistic purposes, or jewelry.

Manuscript 3

Loss-on Ignition and Sediment Sorting Results

Sediment analyses, including loss-on ignition and sediment sorting, were performed to determine whether Eleanor Betty was built directly on the red mangroves or on platforms over the water. A total of 39 sediment samples were subjected to loss-on ignition to determine the percent of organic matter present. Thirty-two separate sediment samples were microscopically sorted to identify the present or absence of plant material.

Loss-on ignition analysis resulted in a high percent of organic matter across all excavated units, including the shell midden and 2011 column sample (8% to 40%). All sorted sediment samples contained an abundance of *Rhizophora mangle* (red mangrove roots), which keep pace with gradual sea-level fluctuations. Together, the scientific evidence supports the theory that, like other submerged salt works in the area, Eleanor Betty was constructed on the mangroves and submerged by sea-level rise.

pH Analyses

pH values were determined for all sediment samples. Although the majority of the sediment exhibited acidic values (average = 3.96), the values for the sediment recovered from the shell midden feature exhibited more alkaline pH values (average = 6.31). The large amount of shell (and CaCO_3) in the shell midden feature (n=2,982) altered the chemical composition of the mangrove peat.

Summary

Eleanor Betty was part of the Paynes Creek Salt Works during the Classic period (AD 300-900) in southern Belize (McKillop 2002, 2004a). The abundance of briquetage and subsequent absence of household refuse, such as figurine whistles or pots used for storage, indicates that Eleanor Betty was a salt production workshop. Based on the presence of briquetage, the inundated wooden structure, a possible leaching canoe (McKillop 2015; McKillop et al. 2014), and brine enrichment mounds found at Witz Naab' and Killer Bee in the Punta Ycacos Lagoon (Watson et al. 2013), the salt makers most likely employed the same method of salt making as the present-day salt makers of Sacapulas, Guatemala (Reina and Monaghan 1981). A submerged, curvilinear structure made from palmetto palm posts runs south-to-north along the western edge of the site, suggesting placement of a retaining wall to protect the site from the rising sea. The site was assigned to the Classic period based on the recovered ceramics. The shallow nature of the cultural deposits (30 cm below the sea floor), could suggest that this site was used during one salt production season and then abandoned.

The Eleanor Betty shell midden was the first shell midden in this area to be excavated due to its shallow nature. The original location of the shell midden was probably in Unit 3-4 of Transect 6 as the depth of the midden was at its greatest in this location. Wave action likely

spread the shell throughout the site over time. Analysis of the shell indicated it was used for subsistence purposes and not as jewelry, fishing weights, ceramic temper, or construction fill as seen in other areas (Cobos 1989; Emery and Aoyama 2007; Hammond 1975; McKillop 1984, 2004a, 2005b; Moholy-Nagy 1963; Pendergast 1979; Shaw 2012; Teeter 2004; Wing 1975).

Unlike other shell middens found at Wild Cane Cay (McKillop 2005b), Frenchman's Cay (McKillop and Winemiller 2004), Butterfly Wing (McKillop 2002), and Cancun (Andrews IV 1969) where several species of shell were recovered, the Eleanor Betty shell midden was comprised primarily of one species: *Crassostrea rhizophora* (red mangrove oysters). The salt makers likely harvested the oysters from the surrounding red mangroves. The shell meat was probably ingested as part of a ritual ceremony for the opening of the salt workshop at the beginning of the salt production season. The presence of a minimal amount of Moho Red pottery sherds and fragmented obsidian blades supports the interpretation that a salt ritual could have occurred prior to the beginning of the salt production season (McKillop 2002:86, 87; Watson et al. 2013).

New AMS dates contributed to the understanding of the rate of sea-level rise in Paynes Creek National Park, and, by proxy, southern Belize. The results indicated the seas rose approximately 7.5 cm per century from AD 1265 to AD 1435. These data match the data reported by Toscano and Macintyre (2003) and McKillop et al. (2010a, 2010b) when plotted against the western Atlantic sea-level curve.

Sea-level rise during the Late and Terminal Classic (AD 600-900) could be one cause for the abandonment of the site. The physical presence of a retaining wall along the western edge of the site, along with the high percent of organic matter and abundance of fine red mangrove roots in the recovered sediment samples, supports the hypothesis that the site was built directly on the

red mangroves and the succumbed to sea-level rise. This evidence also supports the idea that sea-level rise inundated other sites in the area (McKillop 2002, 2004b, 2005a, 2005b, 2008, 2009a; McKillop et al. 2010a, 2010b).

Given the unstable nature of the Late and Terminal Classic period (A.D. 600-900); Chase and Chase 1996, 1998; Demarest 1996; Foias and Bishop 1997; Fox et al. 1996; Haviland 1997; Marcus 1993; McKillop 2002, 2004b; Urban et al. 2002), the more likely cause of abandonment was cultural and not environmental. The Paynes Creek Salt Works were utilized during the Classic period (McKillop 2004b, 2005a, 2005c, 2006, 2008, 2009b, 2012). The coastal salt makers may have traded salt inland through the use of canoes (McKillop 2005a, 2007a, 2007b) to city centers such as Lubaantun and Nim Li Punit. The Paynes Creek Salt Works were part of the domestic economy (as previously discussed in Chapter 1) and participated in the alliance model with the inland centers (McKillop 2009b, 2015; McKillop and Sills 2016). The salt works, including Eleanor Betty, were subsequently abandoned when the need for salt in the Southern Maya lowlands decreased due to the unstable infrastructure and eventual collapse of the ruling system at the inland centers. The collapse negatively affected trade lines throughout the political landscape. The salt works were abandoned shortly after the collapse of major inland trade centers. Salt continued to be made at the household level for local consumption along the southern coast of Belize (McKillop 2009b).

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Appendix: Consent Letter



INSTITUTE OF ARCHAEOLOGY

Preserving the Past for the Future

Please Quote

Ref No: IA/ R/10/03/17

Dr. Heather Mckillop,
Professor
Department of Geography and Anthropology
227 Howe-Russel Geoscience Bldg.
Louisiana State University
Baton Rouge. LA 70803-4105

October 31st, 2017

Dear Dr. Mckillop,

This letter is being written to grant permission for Valerie Feathers to use the article listed below within her dissertation for the Department of Geography and Anthropology, Louisiana State University.

“Feathers, Valerie, Heather Mckillop, E. Cory Sills and Rachel Watson”

2017 Excavating the Underwater Shell Deposit at an Ancient Maya Salt Work in Belize: The Eleanor Betty Site. *Research Reports in Belizean Archaeology* 14:289-297.

If there are any concerns, kindly contact the Institute of Archaeology, NICH at ianichbelize.com or phone number 501-822-2106.

Regards!

Dr. John Morris
Director, Institute of Archaeology
Culvert Road
Belmopan, Belize



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national institute of culture and history

VITA

Valerie Feathers enrolled at East Tennessee State University (ETSU) in August of 2004 where she originally pursued a Bachelor of Arts degree in Foreign Languages (French concentration) and a minor in Anthropology. However, after attending several Archaeology courses, she enrolled in a field school. She was afforded several research opportunities, including analyzing human skeletal remains. She graduated from ETSU in 2008 with a double major in Anthropology and Foreign Languages (French concentration).

She enrolled in the graduate program at Louisiana State University (LSU) in 2009 to pursue a Master of Arts degree in Anthropology. Her thesis research concentrated on creating a postmortem interval template for recently mummified remains. While at LSU, Valerie was awarded a scholarship through the Cox Communications Academic Center for Student-Athletes (CCACSA) where she mentored and tutored student-athletes in all academic subjects. During this time, she also was awarded a scholarship through the Forensic Anthropology Computer Enhancement Services (FACES) Lab. She shifted from CCACSA to FACES where she began working with a team analyzing human skeletal remains and building profiles for unidentified individuals. She completed her thesis in May of 2011 and graduated with a Master of Arts in Anthropology from LSU.

In August of 2012, Valerie was awarded the Dean's Research Scholarship for four years and returned to LSU to pursue a Doctor of Philosophy degree in Geography and Anthropology with a Concentration in Anthropology. She became part of the Underwater Maya Project team in the spring of 2013 and has continued working on the project throughout her graduate career. Additionally, Valerie has managed both the Archaeology Lab and the Digital Imaging and Visualization in Archaeology (DIVA) Lab at LSU. She has maintained and repaired two

different types of 3D printers, written manuals on techniques for scanning different types of materials and for using different types of post-processing software, instructed undergraduate and graduate students in the use of the NextEngine (a 3D desktop laser scanner), and printed and processed 3D replicas for exhibits both at LSU and in Belize. She has taught three courses for the Department of Geography and Anthropology: World Archaeology, Introduction to Archaeology, and Human Geography: Americas and Europe.

Valerie received multiple awards during her graduate career, including the Maya Assistantship, Graduate Dean's Summer 2016 Research Stipend, Three Minute Thesis Award at LSU, the William G. Haag Graduate Student Conference Paper Award, South Central Conference on Mesoamerica Travel Award, LSU SeaGrant Coastal Communication Clips Award, and Sigma-Xi Grant-in-Aid of Research Award from the National Sigma Xi Chapter. She has presented papers on her research at the Society for American Archaeology (SAA), the Belize Archaeology Symposium (BAS), the South Central Conference on Mesoamerica, the Louisiana Archaeological Society (LAS), the Graduate Studies Fair at LSU, the Geography and Anthropology Undergraduate Society at LSU (GAUS), Traveler's Tales at LSU, the Anthropology Club at East Tennessee State University, and organized a session at the SAA. Valerie will continue working with the DIVA Lab as an Affiliated Scientist.