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An Investigation into the Survival of Submerged Prehistoric Cultural Resources in Florida Bay, Everglades National Park

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UNIVERSITY OF MIAMI

AN INVESTIGATION INTO THE SURVIVAL OF SUBMERGED PREHISTORIC CULTURAL RESOURCES IN FLORIDA BAY, EVERGLADES NATIONAL PARK

By

Leah Grace Colombo

A THESIS

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AN INVESTIGATION INTO THE SURVIVAL OF SUBMERGED PREHISTORIC
CULTURAL RESOURCES IN FLORIDA BAY, EVERGLADES NATIONAL PARK

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Submerged prehistoric archaeological material exists on the continental shelf in Florida. Florida Bay is a shallow marine body of water located between the Florida Peninsula and the Florida Keys. Previously, no attempts have been made to locate such material in Florida Bay, Everglades National Park. This National Park Service funded study was initiated to develop a method to quantify submerged prehistoric cultural resources that may be harmed by world sea level rise and regional anthropogenic changes. No technology now exists to remotely sense prehistoric archaeological material, thus this investigation involved first the development of a predictive model. This included an analysis of sea level change since the Pleistocene, island migration, and identification of karst features and freshwater peat within Florida Bay. The methodology included use of ArcGIS, geophysical remote sensing, and subsurface sampling. The study revealed that (1) the basins within Florida Bay were likely freshwater during the Archaic (9950-2450 BP) and (2) present day mudbanks and islands were exposed dry land. Submerged prehistoric archaeological material was not identified in Florida Bay but it is hypothesized such material exists preserved beneath the mudbanks and mangrove islands.
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CHAPTER 1

Introduction

The curiosity of understanding North America’s first inhabitants has hooked many archaeologists. Recently, within the last 40 years or so, focus has turned to investigating submerged prehistoric sites due to an increase in the exploitation of offshore resources. The continental shelf of the Gulf of Mexico, which has been central to the United States oil and gas industry, is believed to entomb evidence of prehistoric anthropogenic use of the paleocoastline. During the Last Glacial Maximum, sea level was roughly 125 meters below current sea level (Fairbanks 1989) and created an opportunity for early North Americans to inhabit the exposed land. These sites are significant because they offer important information regarding context and age of prehistoric North Americans (Faught and Flemming 2008). Cultural resource managers and government agencies, such as the Bureau of Ocean Energy Management (formerly the Minerals Management Service), have stepped in to locate potential prehistoric sites (Tidewater Atlantic Research Inc. 2004) in accordance with the National Historic Preservation Act of 1966. Historic, prehistoric, and all other cultural resources are required to be protected by federal agencies as mandated by Section 106 of the Act (NPS 2014). This law and several others have been responsible for protecting archaeological sites in the United States. Some other relevant laws include: Antiquities Act of 1906, Historic Sites Act of 1935, Archaeological and Historical Preservation Act of 1974, Archaeological Resources Protection Act of 1979, and Native American Graves Repatriation Act of 1990 (NPS 2014). These are the foundation for cultural resource management (CRM).
Even with such laws in place, the protection of prehistoric archaeological sites is still challenging due to the difficulty in locating them (Faught and Flemming 2008: 37). There is no technology available today that can directly locate a prehistoric archaeological site. Archaeologists and cultural resource managers with a passion for prehistoric sites have sought to develop methodology to unfailingly locate this evidence. In Florida specifically, much research has been conducted on the western coast by many noted archaeologists: Clausen (1979), Dunbar et al (1992), Faught and Latvis (2000), Faught (2004), Adovasio and Hemmings (2009) are just some of the studies that have taken place to date. In some of these studies a unique approach has been taken to try and successfully locate submerged prehistoric sites via predictive models. Since evidence of these sites consist mostly of bone, wood, shells, and plant material, traditional survey methods do not apply. However, remote sensing technology such as side-scan sonar, sub-bottom profilers, and single and multi-beam echosounders have been successfully used to identify the submerged paleolandsapes that may have been opportune places for settlement (Faught and Flemming 2008). This coupled with extensive background research form the foundation of a successful predictive model. Even with thorough study, investigation of an area can prove to be unsuccessful; therefore it is important that a predictive model not go untested before it is employed. In the case of CRM, predictive models are used to develop avoidance areas that industry is not permitted to disturb. Therefore, if a predictive model goes untested it is possible for a project to disturb and destroy archaeological material.
Everglades National Park, hereafter EVER, is located at the southern tip of the Florida Peninsula. It was established in 1947 on the foundation of the National Park Service Organic Act of 1916. The Organic Act of 1916 established the National Park Service as a federal organization with the responsibility to “…conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations” (NPS 2014). In May of 1934, conservationists petitioned to Congress to have the Florida Everglades protected and were successful. Today EVER is bordered by two other National Parks, Big Cypress National Park to the northwest and discontinuously with Biscayne National Park to the east (Figure 1).

For this study, the components for a predictive model were evaluated to advise Everglades National Park where submerged prehistoric archaeological sites may be located in Florida Bay. Florida Bay, as it will be described in detail later, is a shallow water estuary that makes up the southernmost extent of EVER. Terrestrial prehistoric archaeological sites have been identified in northern parts of EVER previous to this study (Goggin 1950; Schwadron 2006). Therefore it is entirely possible for prehistoric archaeological material to exist in the region of Florida Bay either in submerged or terrestrial deposits. This is supported by several other reasons that include, but are not limited to: (1) the portion of present-day Florida Bay within EVER was, in the prehistoric past, above sea level, allowing cultures to utilize and perhaps colonize the region; (2) an abundance of natural plant and animal resources located near coastal environments allowed people to gather much of what was needed for subsistence activities; (3) the
region’s limestone karst topography fostered fresh water resources needed by both animals and humans. This thesis will detail the investigation into submerged prehistoric archaeological sites in Florida Bay and the components necessary to develop a successful predictive model for the region. It is with great hope this research will assist cultural resource managers at EVER in complying with Section 106 of the National Historic Preservation Act of 1906.

Figure 1. South Florida’s three national parks.
CHAPTER 2

Geological Background

Florida Bay is a shallow water estuary nestled between the mainland Florida Everglades and the Pleistocene barrier island chain known as the Florida Keys. To the south-west, Florida Bay abuts the Gulf of Mexico (Figure 2). The Bay is triangular in shape with its shallowest regions in the northeast, while it deepens as the bay widens southwest towards the open Gulf of Mexico. Depths range from less than one foot to as deep as ten feet to the southwest. The Bay’s bathymetry shows a “pitted” appearance due to the presence of mud banks, islands, and basins. The relatively deeper basins are locally referred to as “lakes” (Enos and Perkins 1979). Its shallow nature combined with the restriction of tidal flushing permits salinity in the Bay to be high as compared to the adjacent Gulf of Mexico. Salinity decreases towards the southwest where there is increased exchange between the two bodies of water (Wanless and Tagett 1989: 455-456). In addition, salinity can be highly variable as it is affected by freshwater outflow from the Shark River and Taylor Sloughs, precipitation, and evaporation (Swart and Price 2002).
Figure 2. Florida Bay and adjacent bodies of water.

A relatively thin layer of sediment blankets the Pleistocene limestone bedrock in Florida Bay. The bedrock slopes from east to west, which contributes to the bathymetry of the Bay. Enos and Perkins (1979) demonstrate that sediments are thickest in the western part of Florida Bay immediately behind the Florida Keys and continue to thin towards the northeast. In most of the Bay’s deeper basins (“lakes”) there is only a dusting of sediment over the bedrock that consists of mostly shell fragments. Fine-grained sediment is easily transported due to wave action and consequently does not have a strong presence in the Bay. Submerged Aquatic Vegetation (SAV) is distributed inconsistently throughout Florida Bay and SAV coverage often coincides with thicker sediment accumulation. SAV is a combination of seagrass or macroalgae that forms
coverage greater than 10% of a substrate (Florida Fish and Wildlife Conservation Commission 2012: 332). This chapter will discuss how Florida Bay evolved into a dynamic estuarine environment.

**Geological History**

The Florida Peninsula is part of the geomorphological feature known as the Florida Plateau, which formed roughly 180 million years ago during the Jurassic Period of the Mesozoic Era. Prior to the Jurassic Period, what is now the Florida Plateau was dry land mostly made of volcanic igneous rocks (rhyolitic) that formed during the Ordovician Period (445-490 MYA); these rocks today form the basement of the Florida Plateau (Stanley 2009: 302). Millions of years following the formation of the basement rock, the Mesozoic marks an era in Earth’s history with much tectonic activity. During the early Triassic the Florida Plateau was still dry and attached to Africa as part of the super continent known as Pangaea. However, as the Triassic progressed rifting began between North America, Africa, and South America breaking up the super continent. It is during this time and the following Jurassic that the early Atlantic Ocean began to open. As rifting continued, eustatic sea level rise during the Cretaceous Period (145-66.5 MYA) flooded and ultimately submerged the Florida Peninsula (Figure 3). The young Atlantic Ocean and shallow platform fostered the formation of mineral deposits composed of calcite and aragonite. Therefore, marine fauna did not consume all of the available carbonate minerals so excess remaining could be deposited onto the sea floor. The higher elevations of lithified carbonate rocks are what are currently exposed today (the Florida Peninsula), while the submarine remainder is the Florida shelf. Thus, most of the Florida
Peninsula is made up of sedimentary rocks representing shallow marine carbonate environments (Missimer 1984). The thickness of carbonate bedrock is on average 20,000 feet and underlain only by the Ordovician igneous basement. According to Missimer (1984), there seems to be some debate to the ages of the sediments that make up the bedrock in South Florida, but generally there are two main limestone formations to be considered for the period of time focused on for this paper, and both of these formations are of Pleistocene (1.8 MYA – 10,000 YA) in age.

Figure 3. North America during the Cretaceous, 115 MYA (Colorado Plateau Geosystems 2014).
Limestone is a sedimentary rock comprised of calcareous minerals such as calcite and aragonite. Some limestone may contain fossil reef structures and others may contain material representing reprecipitation of calcareous material (Hefferan and O’Brien 2010: 403). The type of calcareous material is what dominates the designation of different formations. The composition of the calcareous material may be calcite or aragonite, or in many instances a combination. A rock is only considered limestone if it contains more than 50% of calcite/aragonite (Hefferan and O’Brien 2010: 410). The Miami Limestone and the Key Largo Limestone are the two major carbonate bedrock formations in South Florida (Scott et al 2001).

The Miami Limestone occurs from Palm Beach south to Monroe County. It is found beneath the Florida Everglades and in portions of the Florida Keys. This is the limestone formation that underlies unconsolidated carbonate sediments in Florida Bay. The Miami Limestone is composed of ooids, which are calcium carbonate spherules (in the form of calcite/aragonite) that form in warm shallow marine environments (Hoffmeister 1974: 107). They are the result of layers of calcium carbonate being precipitated and accumulated onto a small grain of a small piece of shell or carbonate sand (Prothero and Schwab 2004: 214). In order for this to occur, the water must be supersaturated with calcium carbonate, which is why the sediment deposit typical of warm shallow marine environments worldwide. Because this depositional environment was so prominent in South Florida during the late Quaternary, the accumulation of ooids dominated the sediment and overtime cemented to form the Miami Limestone. This formation is estimated to be around 120,000 years old (Hoffmeister 1974: 23). The Key
Largo Limestone is the dominant bedrock within Monroe County. This limestone is comprised of fossilized shells, reef fragments, all in a calcarenitic matrix. Figure 4 illustrates the terrestrial extent of these formations.

To the north of Florida Bay, in the Florida Everglades, the rock type is slightly different. Due to the close proximity to Florida Bay, it may be expected to observe oolitic limestone; however, the rocks found within the Everglades area dominated by bryozoans (Hoffmeister 1974: 35). Bryozoans are marine invertebrates that secrete a calcareous shell and tend to form fixed colonies (Hoffmeister 1974: 35). A modern analog of bryozoan colony formation can be observed today in Florida Bay and the adjacent Florida Keys.

It should be evident by this point that there is a correlation between the rock type found in Florida Bay and the current depositional environment found there. Shallow marine environments with extensive carbonate deposits represent low siliciclastic (sediment traditionally rich in quartz and feldspars) sediment supply (Prothero and Schwab 2004: 213). As a result, the only sediment available for deposition is marine carbonate, typically in the form of fine carbonate mud. This is a typical environment for the Florida Peninsula. In addition, limestone formation requires agitation of the sediment to promote mixing (Prothero and Schwab 2004: 218). For limestone formation to have occurred in Florida Bay, wave action would have been needed in order to cause oxidation of the carbon dioxide. This is known to be true in a modern day model.
Modern reefs tend to have the most growth near regions where waves break at the reef fringe (Prothero and Schwab 2004: 218).

Limestone is a porous rock that can dissolve with exposure to freshwater. As a result, it has played a key role in Florida’s extensive karst topography, which also encloses one of the largest and shallowest aquifers on the North American continent that extends into Alabama, Georgia, and South Carolina (Hine 2009). Florida exhibits an extensive cave and cavern system that transports freshwater in a general north-south direction along the Florida Peninsula (Hine 2009). This system is charged by both rainfall and runoff. In addition, this type of environment contributes to the formation of spring fed sink holes (Hine 2009). The dissolution of limestone is also responsible for the pitted topography throughout South Florida. Since the formation of karst features is typically a subaerial process, it would make sense that this topography would have formed prior to the onset of sea level rise during the Pleistocene.

Sea level change played an important role in the formation of Florida Bay. One of the first attempts to understand sea level change in south Florida during the Holocene began in 1964 after David W. Scholl published a sea level curve (Robbin 1984). In the decades following, limited sea level research in Florida was published. Figure 5 shows a eustatic sea level curve that averages data from several curves developed. This post-glacial representation illustrates that present sea level conditions were reached between 3,500 and 5,000 years B.P.
Figure 4. Key Largo and Miami Limestone geologic formations in South Florida (Redrawn from Scott, M. et al 2001).
In addition, the curve illustrates there was a low seal level stand around 14,000 years BP (the end of the Last Glacial Maximum) and the rate of sea level rise drastically decreased around 8,000 years BP.

Roughly 20,000 years ago during the Late Wisconsinan, the global average sea level was 125 meters below present sea level. At 14,000 years B.P. sea level curves suggest world sea level was approximately 80 meters below current position. Robbin (1984) suggests rate of sea level rise changed pace over its postglacial continuous rise; it apparently began slowly, sped up, and then slowed to where it remains presently. This is evident when examining Figure 5.
By mid-Holocene (roughly 6,000 B.P.), Florida Bay was flooded and charged by freshwater from upslope sources, primarily Lake Okeechobee (Griffin, 2002: 42). Then Florida Bay resembled the present day Everglades as is confirmed by deposits of freshwater marls and peats beneath islands in Florida Bay (Davies 1980: 244). These same deposits have been identified in the present day Everglades dating to the same time period (Wanless et al. 1994). As sea level rose (between 5,000 and 3,000 years B.P.), Florida Bay transitioned from a freshwater dominated estuary to the marine environment recognized today (Wanless and Tagett 1989). This transition is marked by layers of freshwater and marine deposits beneath Florida Bay islands and mudbanks (Wanless and Tagett 1989). The regions of higher elevation “served as nuclei”, which allowed for the formation of the current islands and mudbanks which are found scattered throughout the Bay (Wanless & Tagett 1989).

Rising world sea level and the increase of freshwater flow southward from Lake Okeechobee aided in the formation of a unique geomorphological feature prominent in the Florida Everglades. Tree islands are tear-drop shaped, natural vegetated topographic features found throughout the present Everglades National Park, as studied by Schwadron (2006), Willard (2004), Bernhardt (2011), and many others (Figure 6). Tree islands are oriented sub-parallel to the direction of water flow in linear drainage channels, or sloughs. The head of the tree island forms upstream, while the tail points downstream. For instance, in the Shark River Slough tree islands are oriented in a generally north–south direction; however, in the Taylor Slough they are oriented more northeast-
southwest. Although, in both sloughs, the orientation of the tree islands change as water flow direction changes.

This orientation is evident on high-resolution topographic maps and because of their elevation tree islands can exhibit salt tolerant vegetation that can include mangroves, saw grass, and hardwoods. Recently, an interesting hard carbonate layer has been discovered underlying many tree islands. While excavating tree island sites, Schwadron (2006) encountered a “calcrete” layer overlying a deeper freshwater peat layer; artifacts were found in situ within the peat layer. This “calcrete” layer was further
examined by Graf et al (2008) who state (1) the calcrete layers form at the upstream heads of fixed tree islands located in the Shark River Slough and (2) throughout the layer shell, bone fragments, plant remains, and charcoal are found. They further state that “calcrete” is characteristic of arid locations, and therefore suggested that Florida’s alternating wet/dry climate may represent optimal conditions for the formation of such an authigenic deposit under most tree islands. It also appears the calcrete layer provides long-term stability (i.e. resistance to erosion) for the tree islands (Graf et al 2008). The calcrete deposits exist at varying depths (ca. 25 - 50 cm) from one tree island to the next throughout Everglades National Park. At two locations described by Graf et al. (2008) the calcrete layer is 50 to 70 cm thick.

Figure 7. Florida Bay bathymetry (Bathymetric data acquired from EVER).
The bathymetry exhibited today in Florida Bay reflects the evolution of its history. A larger scale of the microkarst topography formed while the Bay was freshwater is evident through the observation of the basins and pitted features within those basins (Figure 7). The regions of higher elevation represent the mudbanks that formed over higher carbonate features. Many of the islands visible in Florida Bay were created via deposition of sediments upon established mudbanks.

**Holocene Environmental History**

The sequence of change exhibited in Florida Bay from a geological standpoint parallels the changes observed environmentally. Roughly 5,000 years B.P. the Bay’s paleolandscape would have resembled the present day Florida Everglades. The flora found in this region would have consisted of saw grass, pine and cypress trees at higher elevations, palmetto, and other freshwater tolerant groups.

Much of this is reconstruction is supported by the analysis of peat deposits that make up the basal sediments in Florida Bay. According to Davies (1980), the oldest known peat dates to 5,500 years B.P. and is located towards the southwest of Florida Bay. This corresponds with the time when Florida Bay was flooded by mid-Holocene sea level rise. Davies described thirteen different peat types in Florida Bay, which reflect the vast differences in flora composition. As sea level continued to rise, Florida Bay evolved into an estuarine environment and the present day Everglades were born. This began about 5,000 years B.P. as the earliest basal peats in the present day Everglades date
to 5,000-4,500 years B.P. (Gleason & Stone 1994: 150). Peats form as a result of deposits of plant related organic material being preserved in a matrix of sediment. The transformation of Florida Bay into an estuarine environment is marked by the deposition of marine carbonate sediments over the top of the basal peats. Those sediments contain the remains of fauna associated with marine environments and provide a good indicator of this transition.

Florida has an extensive fossil record of fauna that existed during the last sea level low stand. These fossils represent animals that lived during the Miocene, Pliocene, and Pleistocene. During the Miocene, these animals include extinct species of “horses, rhinoceroses, bears, peccaries (pig-like mammals), proboscideans (elephant-like mammals), sloths, squirrels, camels, bear-dogs, and tapirs” (Hine 2013: 166). In the Pliocene and Pleistocene species including “saber-tooth cats, mastodons, mammoths, armadillos, porcupines, rodents, and many hoofed mammals” existed (Hine 2013: 166). Interestingly, some of the faunal remains have been found in situ with prehistoric archaeological sites in Florida, such as Little Salt Spring (Northport, FL) and Cutler Ridge (Miami, FL). Both of these sites will be discussed later in Chapter 4.

Interestingly, many of the animals mentioned above became extinct just following a dramatic climate shift. This climatic event is known as the Younger Dryas, which was a rapid global cooling event that began about 12,900 years B.P. (Stanley 2009: 501, 503). The most notable feature of this extinction was the large mammals that disappeared. The elephant-like mammals, five species of horses, the only North American camel, bison,
giant sloths, the dire wolf and others that once inhabited Florida were no longer present (Stanley 2009: 507). Though many large mammalian species disappeared with the onset of the Younger Dryas, others became extinct just following the event. These species are thought to have died off due to either a lack of food or from the migration of humans into North America (Stanley 2009: 507). Both hypotheses are the subject of current debate amongst paleontologists.
CHAPTER 3
Archaeological Background

Figure 5 shown in the previous chapter indicates that Florida Bay, along with most of the Florida Plateau, would have been dry land during the Last Glacial Maximum (LGM). While still very controversial, the current archaeological consensus regarding when humans first entered the North American continent postulates that humans migrated from NE Asia (almost certainly) or Western Europe (possibly; see Stanford & Bradley 2012) by land or by sea into North America, eventually expanding southeast to occupy paleocoastal regions of the Florida Peninsula. During this time (Early Paleoindian, see below), the entire West Florida shelf including Florida Bay would have been well above sea level, offering rich areas for exploitation by the new colonists. Many studies have been conducted to predict where such earliest settlements might be located, however, it has been impossible to offer irrefutable evidence as many of these areas are presently submerged under several meters of water. The only alternatives involve either general predictive models based on sea level rise curves or accidental discoveries (as for example at Ray Hole Spring in the Big Bend regional; Aunskiewicz and Dunbar 1993).

Aunskiewicz and several other researchers (notably – Faught and Flemming 2008; Dunbar et al. 1992; Bailey and Flemming 2008; Adovasio and Hemmings 2009) have attempted to identify inundated prehistoric settlement sites on the west Florida Shelf. Dr. Michael Faught, while a professor at Florida State University, has conducted the most extensive investigations into inundated prehistoric sites in Florida. The foundation of all these investigations was a proper understanding of the Late Pleistocene coastal
paleogeography in Florida. All studies support the conclusion that Florida has been inhabited for about 14,000 years, identifying five major cultural periods in Florida (Table 1).

Table 1. Chronology of cultural periods in the Florida Everglades in calendar years BP (Adopted from Schwadron 2010 and NPS.com).

<table>
<thead>
<tr>
<th>Period</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleoindian</td>
<td>11950-9950</td>
</tr>
<tr>
<td>Archaic</td>
<td>9950-2450</td>
</tr>
<tr>
<td>Early</td>
<td>9950-6950</td>
</tr>
<tr>
<td>Middle</td>
<td>6950-3950</td>
</tr>
<tr>
<td>Late</td>
<td>3950-2450</td>
</tr>
<tr>
<td>Glades</td>
<td>2450-450</td>
</tr>
<tr>
<td>Glades I</td>
<td>2450-1200</td>
</tr>
<tr>
<td>Glades II</td>
<td>1200-750</td>
</tr>
<tr>
<td>Glades III</td>
<td>750-450</td>
</tr>
<tr>
<td>Historical Contact</td>
<td>450-200</td>
</tr>
<tr>
<td>Historic</td>
<td>200-20</td>
</tr>
</tbody>
</table>

Paleoindian

As the earliest inhabitants of North America, Paleoindians are the earliest known inhabitants of Florida. In addition to the previous question of where they originated, the question of when these people arrived in North America is the subject of ongoing academic debate (Milanich 1994). It is generally believed that the initial entry occurred toward the end of the Last Glacial Maximum around 14,000-13,000 years ago. Undoubtedly, humans were occupying North America by at least 13,000 years ago as this
is supported by the identification of human feces in the Paisley Cave Complex of southern Oregon (Jenkins et al. 2012).

Only limited Paleoindian evidence, in the form of numerous isolated artifact finds (many from springs and river beds), as well as some sites, have thus far been located in Florida; it is believed that some may exist submerged on the West Florida continental shelf. Considering sea level was about 40 meters below present during Paleoindian time, the available land area for natural resource exploitation was more abundant than at present. In hunting and gathering food and raw materials, Paleoindians would have foraged along as well as inland of the paleocoastline where food and fresh water were plentiful. Paleoindian social groups were nomadic hunter-gatherers, travelling seasonally to optimize food resource acquisition. Perennial settlements did not exist during this time, and finding seasonal, temporary Paleoindian sites is difficult. In many instances, sites consist of hearth deposits, points, and food refuse. Items suggesting permanent settlement have yet to be uncovered.

As Florida has extensive karst terrains, many sites have been found near and within rivers and spring-fed sinkholes where potable drinking water was available (Milanich, 1994). In addition, some studies have correlated Paleoindian artifacts with the distribution of chert, a siliceous rock used for making projectile points, in limestone outcrops (Dunbar & Waller 1983). Webb et al. (1984) identified a partial *Bison antiquus* skull with a fragmented chert projectile point protruding from the bone. The skull had been recovered from the Wacissa River in Jefferson County, Florida.
Archaic

Following the Paleoindian is the Archaic Period, which is divided into Early (9950-6950 BP), Middle (6950-3950 BP), and Late (3950-2450 BP) (Milanich 1994). One Archaic Period site with excellent preservation of organic remains is Little Salt Spring, located in North Port, Florida near the Gulf of Mexico. This site has produced wonderfully preserved, unique artifacts and ecofacts dating to the Paleoindian and Archaic periods (Clausen et al. 1979, Gifford and Koski 2011, Bonomo et al. 2014, Kistle et al. 2014). The nearby Warm Mineral Springs prehistoric underwater site (8So19) has similar characteristics (Clausen et al. 1975).

The Florida Archaic marks a distinct social evolution from the preceding Paleoindian as it shows clear remains of sedentary, semi-permanent habitation. The Early Archaic served as a transitional period from the Paleoindian (Schwadron 2010) and some of the cultural changes seen in the archaeological record were possibly due to climatic changes as Florida became more wet (Milanich 1994: 62). Archaic groups tended to settle nearer to coastlines and rivers to obtain necessary food and water resources.

The archaeological record illustrates the transition from Paleoindian to Archaic is marked by the absence of Paleoindian projectile points and the introduction of stemmed tools (Milanich 1994: 63). This transition not only coincides with the onset of wetter climate, but also with the extinction of many Pleistocene animals that were mentioned in Chapter 2 (Stanley 2009: 503). Since overlap between these two cultures is to be
expected during a period of transition, the characteristics determining sites is based mostly on site locations (Milanich 1992: 63). As climate became wetter, the water table rose and settlements that would have been idea to the Paleoindian are flooded. As a result, Early Archaic sites were higher and drier locations. The Middle Archaic is even more distinct from the Paleoindian in that it exhibits extensive settlements and characteristic mortuary patterns that are more often preserved, such as those at Little Salt Spring (Wentz and Gifford 2007). The Bay West site in Collier County is another where burials took place in a wetland environment (Beriault et al. 1981).

Another distinct characteristic of the Middle and Late Archaic is the appearance of specialized marine shell processing sites (Russo and Heide 2001). This is interpreted as reflecting an increased reliance on marine resources such as mollusks (Carr and Beriault 1984). Evidence of such specialized marine food processing sites has been observed in Florida, Georgia, and South Carolina. Immediately northwest of Florida Bay, the Ten Thousand Islands exhibit an abundance of shell processing sites that include various refuse such as pottery and flint which indicate an early transition to a more permanent settlement pattern (Schwadron 2010: 15). In the Everglades, Archaic period sites have been identified on tree islands, which, as described above, are tear-drop shaped erosional geomorphological features that develop over areas of higher underlying bedrock (Graf et al. 2008).
Glades

The Glades culture sequence follows the Archaic Period; it is marked by the appearance of pottery, as well as regionally defined cultures largely defined by that technology. The Glades Period in the Florida Peninsula extended until ca. AD 1500, with the introduction of European cultures throughout the Western Hemisphere. There has been much debate as to how the Glades Period should be divided; Table 1 illustrates just one interpretation (Schwadron 2010: 16). Generally, three distinct periods exist: Glades I, Glades II, and Glades III. Sites of this period are fairly common in South Florida and parallel periods in other areas of North America.

The Glades Period has been well studied and offers more indicators, such as distinctive pottery and settlement patterns (Milanich 1994) than Paleoindian and Archaic sites reveal. Three major cultural groups existed in South Florida during the Glades Period: the Tequesta, the Calusa, and the Mayaimi (Figure 8). These groups were very marine oriented (Milanich 1992: 277) and as a result artifacts associated with these groups comprise of worked shell, bone, and wood as well as primitive ceramic pottery. Site types also include middens, shell working sites, and refuse mounds located near present day shorelines. These large-scale features are observable in Florida, Georgia, and the Carolinas and have been studied extensively in recent decades (Russo and Heide 2001). The Tequesta and Calusa not only represent prehistoric Glades sequences, but also extent into the period of historical contact with the first Europeans.
Historic Cultures

As mentioned above, three distinct cultures existed at the time of the first European contact in South Florida. These cultures (Figure 8) consisted of the Calusa, to the west; the Tequesta, to the east; and the Mayaimi to the north near Lake Okeechobee (Goggin and Sturdevant 1964). Everglades National Park was largely dominated by the Calusa (NPS.com 2014). These cultures overlap with the Glades III sequence, which shows evidence of the first European contact. As Schwadron (2010: 18) appropriately noted, it would be “inaccurate to assume that proto-historic tribes necessarily equate with prehistoric cultures, especially in view of how dynamic cultural groups and boundaries may have been over time”.

First European contact was made by Ponce de Leon in 1513 with the Ais, an aggressive group to the north (Griffin 2002: 161). His ventures lead him south where he encountered the Tequesta, and then on to the west where he made contact with the Calusa. Interactions between Europeans and the Calusa were hostile following initial contact (Griffin 2002: 161). Much of what is known today about the early ethnography of South Florida comes from Hernando de Escalante Fontaneda, a Spaniard who was shipwrecked and lived with the Calusa for seventeen years (Griffin 2002: 162). Despite his experience with the Calusa, future European encounters led to bloodshed. The Spanish continued to try and occupy South Florida up until the early 18th century. At that point, the aboriginal cultures that once existed now represented a very small percentage of the population in South Florida (Swanton 1922: 344). This is largely attributed to the introduction of disease by Europeans. The existing cultures became a mixture of Spanish
and aboriginal, making for the distinction as Spanish Indians. This became more
dramatic upon the return of the Spanish to South Florida in the latter half of the 18th
century. It was these remnant cultures that formed the foundation for the more modern
historic cultures that later occupied South Florida.

Two historic cultures exist in south Florida: the Seminole and Miccosukee
(NPS.com 2014). These cultures occupy the time period from the 18th century to the
present day. The Miccosukee are the tribe that inhabited the Everglades, mostly near Big
Cypress. The Seminoles occupied the territories to the North, though the group migrated
southward following the Second Seminole War (1835-42) (Griffin 2002: 186).
Interestingly, the present day Everglades is less inhabited now than during the time of the
Calusa. In fact, the current state of the Everglades, due to protection by the National Park
Service, represents something that would have been typical during prehistoric occupation.
Figure 8. South Florida cultural boundaries at first European contact (Goggin and Sturdevant 1964).
CHAPTER 4
Review of Previous Relevant Research

Much research has been directed to the identification of inundated prehistoric cultural resources around the Florida Peninsula. Studies have been undertaken along the West Florida shelf and the rest of the northeastern Gulf of Mexico by numerous researchers. Faught and Flemming 2008; Dunbar et al. 1992; Bailey and Flemming 2008; Adovasio and Hemmings 2009 are some of the researchers who have invested time and resources into refining previously outlined strategies for locating inundated prehistoric archaeological sites. The reality is that these sites are needles in a hack stack, as they say. Thus it is not surprising that no attempts to locate submerged prehistoric archaeological sites in Florida Bay prior to this study had been made.

In 1977 Coastal Environments, Inc. published a report titled “Cultural Resources Evaluation of the Northern Gulf of Mexico Continental Shelf.” It was one of the earliest reports to address possible inundated prehistoric sites in the region and it explicitly identified Late Quaternary sea level rise as the basic parameter controlling what type of cultural resources might exist. It concluded that, based on sea level curves, the west Florida shelf would have been flooded by 3,500 B.P., leaving an interval of roughly 7,000 years between when humans first entered North America to their arrival on the Florida Peninsula. As humans need water and food to survive, one of the first parameters to identify in association with prehistoric settlement patterns is the distribution of past freshwater sources. The 1977 CEI study looked at geological features, sedimentation sequences, and Holocene relict landforms. Analysis of these data sets were the
foundation of the methodology for locating submerged archaeological sites on the basis of analogous settlement patterns associated with upland early sites. Overall, the study concluded that to successfully discover submerged cultural resources, one must undertake the survey using a wealth of background information and then rely either on diving or remote sensing. Once an area of interest has been identified, the next step is to identify cultural signatures associated with the relict geomorphology. This 1977 report was one of the first to define a predictive model designed to explore for submerged prehistoric cultural resources in the Gulf of Mexico.

In 2002, Michael Faught presented a paper at the Twenty Second Annual Gulf of Mexico Information Transfer Meetings titled “Geophysical Remote Sensing and Underwater Cultural Resource Management of Submerged Prehistoric Sites in Apalachee Bay: A Deep-Water Example, Site Predictive models, and Site Discoveries.” This paper reviews the different methodology available when looking for submerged prehistoric archaeological sites. These methodologies involve use of bathymetric maps from navigational charts, sub-bottom profiler remote sensing, side-scan sonar, followed by diver verification. In addition to having sound methodology, much local knowledge must be attained for proper evaluation of sea level and paleolandscapes. Even with this predictive model, sites selected for sampling are still chosen at random (Faught 2002: 127) and it is not until an artifact is discovered that more intensive testing is carried out. Faught reported a 67% discovery rate for the areas selected using this approach (Faught 2002: 126). Faught concludes by saying “We have found that use of remote sensing
(sub-bottom profiler and side scan sonar devices) and coring operations are helpful to find paleotopographic features, sediment packages and sites” (Faught 2002: 127).

In 2009, Adovasio and Hemmings published a paper that was presented at the 74th Society of American Archaeology annual meeting titled “Inner Continental Shelf Archaeology in the Northeast Gulf of Mexico”. The paper shared the results of field work that was conducted in the Florida Middle Grounds region of the Gulf of Mexico. Interestingly, one of the main conclusions drawn was that in using remote sensing techniques to locate areas that possibly possess preserved archaeological material requires multiple technologies. For example, in their study side-scan sonar provided acoustic images of the sea floor, which in some regions had extensive sand waves. However, only the sub-bottom profile was able to reveal that beneath these sand waves were sink holes and extensive karst features. In addition, Adovasio and Hemmings (2009) point out that in Florida the most concentrated Paleoindian artifact assemblages are located near an extensive chert outcrop. Thus, identification of chert, a resource for creating points, near a paleo river channel is more likely to yield archaeological material in many instances. As for considering predictive models, this research supports the use of many aspects of evaluation that include background research, remote sensing, and ground-truthing.

A predictive model for locating archaeological material in Florida Bay has not been conducted prior to this current study. Therefore most of the relevant previous research specific to Florida Bay was conducted to support biological and geological
studies. One paper, in particular, provided the framework for the approach of this study. Davies (1980) published a dissertation in botany that investigated peat formation in Florida Bay. The study identified 12 different types of peat in the investigation area and established potential ages for environmental changes within Florida Bay. This paper is described in greater detail in Chapter 5.

This study was followed up by a paper in 1989 by Davies and Cohen, which used peat samples from sediment cores to reconstruct different depositional environments throughout the Bay. The peats identified could be broken into three categories: freshwater, brackish, and marine with the freshwater types being found at the bottom of the cores. This in association with other studies has confirmed the pattern of sea level transgression throughout the Bay. The most important conclusion from this paper stated that, “all of the freshwater peat types encountered in Florida Bay represent types that are forming today or have formed in the past in the Everglades of mainland Florida (Cohen and Spackman, 1977). Thus, it appears that when sea level was lower, Florida Bay was an extension of the freshwater Everglades.” This conclusion is what provided much of the motivation for investigating Florida Bay for archaeological material as presently there are numerous archaeological deposits recorded in Everglades National Park (Figure 10).

One study, especially noteworthy, focused on the Cutler Ridge Fossil Site (8Da2001) in Miami-Dade, Florida (Carr 1986). This location is unique in that an abundance of fossils representing extinct species are present in situ with human remains (Carr 1986). The assemblage of bones was initially discovered in 1979 by David and
Wonda Simmons. The couple discovered the fossils in a solution hole (Figure 9), which is a depression formed as a result of dissolution of limestone via exposure to water and weak acid from decaying plant material (NPS.gov 2014). Some of the species identified within the solution hole included, but are not limited to, extinct species of “horse, bison, camel, sloth, peccary, jaguar, Florida lion, and a significant number of dire wolves” (Carr 1986: 232). In addition, there were a number of fossil bones belonging to smaller species of mammalian and reptilian fauna. Charcoal samples found at the site dated to 9,670 +/- 120 years B.P. (Carr 1987: 63). This date is significant because this makes the Cutler Ridge site the oldest human occupational location in South Florida. Another unique aspect of Cutler Ridge is the organization of human remains which suggest it was “probable that most of the human bones represent intentional burials” (Carr 1987: 63). This is not the only prehistoric archaeological site in southern Florida to produce evidence of intentional burials within a freshwater environment.

Little Salt Spring, located in North Port, Florida, is a sink hole that reaches depths of about 256 feet (Clausen and Emiliani 1979). The water levels in Little Salt Spring have changed in reflection of variations in sea level that have affected the water table. When people first migrated to Florida, Little Salt Spring was filled with water up to a ledge at 27.0 meters below the top of the cavern (Clausen and Emiliani 1979). It is on this ledge that fossils of extinct giant tortoise are found,
"with an artificially pointed stake driven through the heart and with pieces of charcoal all around it. It was evidently killed and cooked in place. This happened 12,030 years ago, according to radiocarbon dating" (Clausen and Emiliani 1979: 261).

Further research of the spring revealed there had been several occupational periods. One period shows Little Salt Spring being used as a mortuary during the

Figure 9. West end of Cutler Ridge Fossil Site looking into the solution hole (Gifford, J.A. 1986).
Archaic (Wentz and Gifford 2007). Mitochondrial DNA from preserved brain matter recovered from a burial dated to 6,860 +/- 110 radiocarbon years B.P. (Wentz and Gifford 2007: 331). In addition, some of the faunal remains recovered from the site were dated to about 9,500 radiocarbon years B.P. This site is significant in that prehistoric human remains were found near a freshwater source. Little Salt Spring is only one example as other sites in Florida have been identified with similar assemblages. In addition, this site is important because data illustrating the changes in Florida’s water table that have been recorded.

The earliest archaeological investigations of prehistoric sites in the Everglades began in the 1930’s (Masson 1988). These investigations were carried out by both Broward and Dade counties. This work was followed by research conducted by John Goggin (1950) who conducted stratigraphic tests in the Everglades which lead to the identification of prehistoric archaeological sites on tree islands associated with the Glades Period. Figure 10 illustrates the distribution of previously identified archaeological sites in Everglades National Park. As the figure demonstrates there are two trends in the data. The first shows a curving distribution of sites from the northeast to the southwest. These sites are within the Shark River Slough represent where archaeological material has been identified on and beneath tree islands. The second trend is from the north to the south along the western edge of the Park. This is the Ten Thousand Islands and many archaeological sites consisting of prehistoric shell middens have been identified. Few sites have been identified within Florida Bay, though some are seen along the coastal margin of Florida Bay and the Everglades.
Figure 10. Archaeological sites previously identified in Everglades National Park with park boundaries (Data acquired from EVER).
CHAPTER 5
Research Approach and Methodology

Approach

The project investigation area was determined based on a paper written by Davies (1980) which assembled a wide range of biological and geological data illustrating the spread of peat formation in Florida Bay (Davies, 1980). The A to A’ transect evaluated for Davies’ research was used to generate the investigation area for this project as it almost bisects Florida Bay (Figure 11). As one of the main factors determining the location of inundated prehistoric sites is the location of fresh water sources, previously identified freshwater peat deposits create a baseline when trying to model where prehistoric sites may exist in Florida Bay.

Background research has identified three parameters that must be considered when attempting to identify high-probability areas for inundated prehistoric archaeological sites in Florida Bay:

1) Interpretation of the regional karst topography. The Pleistocene age Miami Limestone, which is the bedrock foundation of Florida Bay, has unique and irregular basin and ridge features that formed from freshwater dissolution and refilling, thus creating depressions in the limestone (Prothero and Schwab 2004). This interpretation builds on the “Oasis Hypothesis”, which itself is based on the supposition that large animals living in sub-arid late glacial Florida climates depended on local water holes as a
perennial source of drinking water and thus defined a probable locus of Paleoindian activity (Milanich 1994: 40). If this “Oasis Hypothesis” is true, then artifacts should be found near many past freshwater sources and those that have remained active for the last 10,000 years. In addition, Milanich (1994: 40) points out that many freshwater sources in Florida correlate with karst features. Combining this idea with Dodd and Seimers’ 1971 paper, if we assume that there are isolated artifacts, if not sites, located near at least some karst features submerged in Florida Bay, and then they can be used as an important paleoenvironment proxy.

2) Prehistoric coastal cultures depended on plant and animal resources; this is reflected in paleoethnobotanical information collected at some late Holocene South Florida archaeological sites (Milanich, 1994: 310). Such plants include mastic, cocoplum, cabbage palm, saw palmetto, sea grape, hog plum, acorns, and red mangrove sprouts (Milanich, 1994: 310). All of these plants and fruits can be found in pinelands and palm hammocks, which tend to be located at relatively high elevations near wetlands. The paleoethnobotanical record, both macro- and micro, would aid in relating human activity to any of the other potential indicators discussed. Food would have been present on tree islands, near water holes, and near shell mound sites; it could leave a record in core and excavation sediment samples.

The identification of peat, organic sediment comprised of partially decayed plant remains, complements paleoethnobotanical data and often represents the matrix in which those remains are found. Peat is indicative of past wetland environments and, depending
on the type of plant material remains identified; it can be determined whether the environment was marine, brackish, or freshwater in nature (Kremer and Spackman 1981). Davies and Cohen (1989) identified twelve different depositional environments in modern Florida Bay based on the diagnostic micro- and macromorphologies of their peats: three of these represent marine environments; two represent transitional environments; seven represent freshwater environments. Their data document the nature and timing of Holocene sea level transgression in south Florida; the freshwater peat types identified in their cores are the same as peats currently forming in the Everglades. Therefore, they argued that Florida Bay, at one point, was an extension of the Everglades (Davies and Cohen 1989). Enos and Perkins (1979) also examined peat layers in Florida Bay while conducting research on island stratigraphy. They identified freshwater peat between two and four meters below sea level in regional sediment sequences; it was deposited on basal Pleistocene limestone bedrock (Enos and Perkins 1979). Unfortunately neither Davies & Cohen nor Enos & Perkins obtained radiocarbon dates for their samples, as this would have allowed the construction a timeline of the transgression sequence. In turn such information could have been used to place constraints on when prehistoric cultures could have inhabited the region of Florida Bay. Gleason and Stone (1994) identified the oldest known peat layer at the time of publication to be 5,500 ± YBP in the Everglades. However, dates in Florida Bay are expected to be several thousand years older, if Florida Bay was exposed and potentially inhabited during the early Holocene.
In addition to indicating prehistoric freshwater sources, peat may also indirectly indicate prehistoric settlement. As described previously, the “Oasis Hypothesis” theorizes that prehistoric cultures settled near freshwater sources (Milanich 1994: 40). It is highly probable that archaeological remains have been deposited within the layers of peat; the preservation of any artifacts in such layers would likely be quite good as layers of peat can form an anoxic environment that inhibits the decomposition of organic material.

There is a major problem with this idea. Peat is a “soft” organic layer that can easily be eroded. Davies and Cohen (1989) noted that “…much of the original peat would have been eroded away during the marine transgression, [thus] the amount and continuity of peat originally present in this peat-forming area is conjectural”. Having an incomplete record of the transgressive sequence could be problematic when determining spatial distribution of prehistoric cultures.

3) Identification of large-scale archaeological features: primarily artificial marine shell deposits, or shell middens. Shell rings and middens were constructed by Florida prehistoric cultures for reasons about which archaeologists are not entirely in agreement; they might have been used for games, fish traps, ceremonies, and encampments (Russo and Heide 2001). Shell ring features are described as “…circular and semi-circular deposits of shell, faunal bone, artifacts, and soil” (Russo and Heide 2001). They also vary in the complexity of their construction. Schwadron (2010) describes extensive artificial shell works in the area of the Ten Thousand Islands and indicates that the
construction of shell middens/rings is deliberate, whether they were simply food refuse deposits or functional artificial structures such as ceremonial platforms. Schwadron, however, only studied sites above sea level, which raises the question of how well such features may have been preserved post-transgression. Although they are relatively solid, shell constructions sites are subject to many artificial and natural processes such as coastal development and erosion due to storms and associated storm surges. Hurricanes, tropical storms, and tropical depressions move across the Caribbean, Gulf of Mexico, and Atlantic Ocean several times a year. However it is unlikely that most shallowly submerged shell work sites will have been destroyed, but rather they may have been buried by storm deposition or by the continuous Holocene marine transgression. Russo and Heide (2001) described the Oxeye shell ring site in Florida dating to about 4600 B.P. that is half-buried in a salt marsh, thus supporting the idea that shell ring sites might not always be destroyed. In addition, previously identified evidence of Florida Bay mudbanks being used by the Calusa for fishing and hunting camps (Tabeau 1968) supports the possibility of prehistoric archaeological material being found in Florida Bay.

The identification of all three of these parameters, possibly even just two, will increase the probability of locating prehistoric submarine archaeological remains in Florida Bay. Of course, there is a possibility that the initial methodologies prove inconclusive. However, these results cannot be dismissed. Failure to find cultural remains at locations exhibiting the three parameters defined above will force a reassessment of the methodology and initial conclusions can be drawn about possible adverse effects sea level transgression may have caused.
The investigation area for this study was based on a 1980 dissertation at Pennsylvania State University by Thomas Daniel Davies on “Peat Formation in Florida Bay and its Significance in Interpreting the Recent Vegetational and Geological History of Florida Bay” (Figure 11). Davies came to several conclusions, four of which apply to this research:

1. Basal peat deposits occur beneath the mangrove islands and mudflats in Florida Bay, but are absent in the open basins;

2. 5,500 radiocarbon years B.P. approximately marks when peat formation may have begun in Florida Bay. The oldest deposits are found towards the south
and southwestern extents of the Bay where the limestone bedrock is deepest below sea level;

3. Charcoal is consistently abundant in freshwater and marsh peat types;

4. A transgressive sequence is clearly evident in the Florida Bay Holocene sediment record.

Assuming Davies' conclusions define the marine and freshwater boundaries, working from this dataset towards the submerged portions of Florida Bay offers a good baseline for this study. The oldest peat deposits identified in Florida Bay falls into the realm of the Archaic. This is not to say sediments dating to the Paleoindian periods are not present as well; it is entirely possible and probable given the time period that Florida Bay was dry. Working from the Davies (1980) paper creates a realistic starting point to begin to investigate a strategy for developing a predictive model to identify potential locations of prehistoric archaeological sites within Florida Bay, Everglades National Park.

Extensive data mining and gathering a previous research was integral for forming the foundation of this study. However, additional data collection was necessary to develop a comprehensive understanding of Florida Bay. Two field investigations were developed: geophysical and subsurface sampling survey. Due to the nature of the study being conducted in Everglades National Park, a U.S. Department of Interior Scientific Research and Collecting Permit was obtained (Permit # EVER-2014-SCI-0045). The permitting process involved not only the permit application, but also a presentation to the
National Park Service Wilderness Committee. About 85 percent of Everglades National Park is designated as wilderness (National Park Service 2009). The sea floor in Florida Bay is considered submerged wilderness, which is to remain “untrammeled by man” and leave no evidence of visiting (National Park Service 2009). Under the conditions of the Permit, subsurface sampling using a vibracore was allowed within the permitted study area. The permit process was completed after illustrating that minimal impact to the submerged wilderness would occur.

Island Migration

Late nineteenth through twentieth-century maps of Florida Bay were compared to present-day nautical charts to identify any recent migration of the mud flats and mangrove islands. In order to compare documents, historical navigational charts were downloaded from the NOAA Office of Coast Survey, the Historical Map & Chart Collection. The charts were saved as a JPEG and imported to ArcMap 10.1. A satellite basemap based on 2014 aerial imagery was used for comparison. Using the georeferencing tool in ArcMap, the historical maps were rubber sheeted (sometimes called edgematched) to the satellite basemap. Rubber sheeting, as defined by ESRI™, is:

“a procedure for adjusting the coordinates of all data points in a dataset to allow a more accurate match between known locations and a few data points within the dataset. Rubber sheeting preserves the interconnectivity between points and objects through stretching, shrinking, or reorienting their interconnecting lines”.
Once the historical chart was aligned properly, the image was rectified. The root mean square (RMS) error was recorded. This number illustrates the difference in locations that are known versus those that have been interpolated. In other words, the higher the RMS error, the more warped the image has become due to georeferencing. This process was repeated for each of the downloaded historical maps. The maps were georeferenced to the World Geodetic System (WGS) 1984 coordinates. The movement of mangrove islands and mudflats were evaluated by overlaying the maps using different colors for shorelines of different time periods. Any areas that did not align were documented as possible areas that have migrated.

**Geophysical Remote Sensing**

![Figure 12. R/V Cetacea loaded with gear for sub-bottom profile survey (Colombo 2014).](image)
The R/V *Cetacea*, provided by the Rosenstiel School of Marine & Atmospheric Science, is an 18.5’ center console steering Hydra-Sports with a 5.5’ beam, 2.0’ draft and a 150 hp Yamaha 4-stroke outboard engine (Figure 12). The vessel is equipped with a GARMIN GPSMAP 541s marine chartplotter/depth sounder, dual battery system, VHF radio, antenna, compass, hydraulic steering, dual battery system, 85 gallon fuel tank, Racor fuel/water separator and bilge pump.

A geophysical survey to collect seismic reflection profiles of the investigation area took place between June 2 and June 10, 2014. The planned tracklines were developed using Hypack 2013 navigation software. Planned lines ran northeast to southwest at 52.7° and were set at 90 meter line spacing. Tie lines were included for each area proportional to the length of the survey area. Positioning along tracklines was maintained using a Trimble SPS461 and visually tracked in Hypack.

An EdgeTech 3100 SB-424 full spectrum sub-bottom profiler (CHIRP) owned and operated by Eckerd College, St. Petersburg, Florida was used to collect the seismic reflection profiles (Figure 13). The CHIRP is a versatile wideband Frequency Modulated (FM) sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross sectional images of the seabed (up to a depth of 300m). The EdgeTech 3100 SB-424 transmits an FM pulse that is linearly swept over a full spectrum frequency range.
The tapered waveform spectrum results in images that have virtually constant resolution with depth. This sub-bottom profiler was selected for this study due to its range of frequencies and its weight (only 100 lbs). The weight and size, in particular, were ideal given that available space on the R/V *Cetacea* was limited. Data were collected within the defined investigation area along the planned tracklines. Throughout the geophysical survey, the CHIRP acoustic pulse was modified in real time in order to obtain the best possible resolution of geologic features and the sequence stratigraphy (i.e.
vertical sequence and lateral distribution of sediment bodies comprised by different grain sizes and sediment composition). The EdgeTech Discover 4.1 data acquisition system was used to collect and store the geophysical survey data in a digital format. All seismic reflection data were processed using the SonarWeb.MAP software package developed by Chesapeake Technologies, Inc.

**Subsurface Sampling by Vibracoring**

The vibracore survey took place July 6 - 10, 2014. The planned vibracore locations were chosen based on the data collected during the seismic reflection profile survey in June 2014. Areas where a strong subsurface contact existed were identified and chosen for vibracore locations. The planned locations were developed using Edgetech Discover software in conjunction with ArcGIS 10.1. A minimum of two cores were planned for each area. The GARMIN GPSMAP 541s marine GPS on the R/V *Cetacea* was used to navigate to the core locations.

A PowerLand PDZB35 6 ½ HP gasoline-powered concrete vibrator with a 20’ hose was used to collect the vibracores by attaching a stainless steel exhaust clamp to the vibrating head, which was then attached to the core tubes (aluminum irrigation pipe). The irrigation pipe was deployed in two ways: the first included a brass core catcher in the bottom of the tube and the second eliminated the brass core catcher. The decision to use either a core catcher or not was determined in the field based on an evaluation of the surficial sediment present. The use of no core catcher with sediments of high silt or clay content can increase the percentage of recovery. The assembled vibracore with the
A vibrating head was deployed off the side of the R/V *Cetacea*. Two researchers worked in the water to position the vibracore in place and initially guide it into the sediment (Figure 14).

Once the desired penetration was achieved, a core cap was placed over the top of the vibracore to generate suction. The vibracore was then slowly removed from the sediment and another core cap was placed on the bottom to prevent sediment loss from the bottom of the core. Once the vibracore was on the boat, the core was cut to the length of sediment recovered. The core was then labeled and stored for transit. Information pertaining to each core was recorded in the field log book.

The collected vibracores are temporarily being stored at RSMAS in a refrigerated core locker that is maintained at 40°F. Cores were split using a DeWalt DWE575 corded circular saw. The cut cores were photographed using a Geotek MSCL-S core logger (Figure 15). Cores were visually logged and described following the Unified Soils Classification System (USCS) classification guidelines. One-half of a core was used for sampling, while the remaining half of the core was stored as an archive. Samples were selected and removed from the core and stored in sterile Whirl-Pak sampling bags. After completion of photographing, logging, and sampling of the cores both the cores and the samples were stored in the refrigerated core locker.
Figure 14. Two researchers (Josie Hadfield and Chelsea Kuhs) supporting the portable vibracore in Florida Bay (Colombo 2014).
Select sediment samples from the vibracores were radiocarbon dated based on relevance to the objectives of the project. These samples were sent to Beta Analytic in Miami, FL for analysis using Accelerator Mass Spectrometry (AMS) radiocarbon dating. The AMS dating technique converts sample material to graphite and uses, as the name implies, a mass spectrometer to isolate negatively charged carbon atoms, and then to further isolate different isotopes of carbon (Radiocarbon.com). Simplified, these charged ions are separated using both electric and magnetic fields while in an accelerator. In the accelerator, the ions are bombarded with gas molecules that isolate the individual carbon isotopes that enter a terminal detector. From there, the $^{12}$C, $^{13}$C and $^{14}$C isotopes are
separated based on mass and momentum. The number of $^{14}\text{C}$ isotopes is measured in a detector. The ratio of $^{12}\text{C}$ and $^{13}\text{C}$ is also measured to assure the efficiency of the method and the detector being used (Radiocarbon.com). The radiocarbon age is then calculated from the $^{14}\text{C}$ isotopic data obtained. This method was chosen because it permits use of small sample size and is conducted quickly. Samples were processed and results were reported in less than one week.
CHAPTER 6

Results

This section presents results of this study, the first produced in support of underwater archaeological research in Florida Bay. However, previous research pertaining to geology and biology played a key role in contributing to this study. Three different data analyses contributed to the methodology: island migration, geophysical remote sensing, and subsurface sampling. Each of these was carried out within a study area based on Davies (1980) (Figure 16). The observations and data collected during each phase of the study are reported here.

Figure 16. Investigation area selected for surveying based on Davies (1980).
Island Migration

Florida Bay flooded around 5,500 B.P. and according to the Fairbridge (1974) sea level curve, near present sea level was achieved around 3,500 B.P. This is supported by radiocarbon dates from collected freshwater peat samples in basal sediment deposits that overlay the Miami Limestone bedrock (Davies 1980). Bedrock in Florida Bay reflects a microkarst topography that fostered the nucleation and formation of carbonate mudbanks (Wanless and Tagett 1989). Historical navigational charts were evaluated to measure recent changes in the geography of Florida Bay as a proxy for changes that have occurred during the last 3,500 years.

Taylor and Purkis (2012) conducted a more recent analysis of mudbank migration in Florida Bay. Using similar methodology and techniques the results from their study found that the mudbanks in Florida Bay have been migrating southward for the last hundred years. Their 2012 study was used as the foundation for the analysis conducted during this thesis.

Table 2. Georeferenced navigation chart RMS error values.

<table>
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<tr>
<th>Chart</th>
<th>RMS Error</th>
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<td>1895</td>
<td>28.61</td>
</tr>
<tr>
<td>1919</td>
<td>238.27</td>
</tr>
<tr>
<td>1921</td>
<td>78.93</td>
</tr>
<tr>
<td>1937</td>
<td>109.88</td>
</tr>
<tr>
<td>1940</td>
<td>45.83</td>
</tr>
</tbody>
</table>
All historical charts were georeferenced to a 2014 aerial image provided by ESRI geographic information systems (GIS) mapping software. Table 2 shows the RSM errors resulting from georeferencing the navigation charts. The earliest chart evaluated was published in 1895 by the United States Coast and Geodetic Survey for Elbow to Lower Matecumbe Key (Appendix A). As it was published before the Overseas Railway was constructed by Henry Flagler, there were few landmarks to georeference the historical documents. Best judgment was used in these instances. Slight differences were noticeable along areas such as the Black Betsy Keys and Triplet Keys. These differences are likely insignificant due to the questionable accuracy of the charts. It does appear that some key shoreline geometries have changed since 1895; this attributed to changes in channel geometry resulting from recent engineered passages (Figures 17 & 18).

![Figure 17. Northeast section of the study area with island boundaries outlined.](image-url)
Georeferencing results improved with the analysis of the 1921 US Department of Commerce navigational chart, as control points to reference were more prominent. This is largely due to the completion of the Overseas Railroad in 1912. The chart displays much of the new infrastructure established on the Florida Keys (Appendix A). Once again, the Black Betsy Keys do not align with the more recent aerial map. This suggests there possibly may have been some growth of those islands over the past few decades. It may also have to do with the resolution of the method being used to chart the area. When comparing the 1921 chart to the 1895 chart there is little difference noted with the size and shape of the islands and mudbanks in Florida Bay. However, it is clearly evident that the Overseas Railroad had been established in the time period between the two charts.

Figure 18. Southwest section of the study area with island boundaries outlined.
Resolution continues to increase with the next chart, published in 1937 by the US Department of Commerce to illustrate navigation from Alligator Reef to Sombrero Key. It is clear at this point there is additional infrastructure in the area of Florida Bay and the Florida Keys. The Overseas Railway is more evident and there are roads in and around the area Cape Sable, which is the land northwest of Florida Bay. Growth of the Tern Keys, Nest Keys, Eagle Key, and Black Betsy Keys were noted. In addition, an island northwest of Eagle Key that was present in 1921 is no longer present on the 1937 chart. This is illustrated in Figure 17.

The 1940 chart was the simplest to georeference as there were abundant landmarks to which the chart may be georeferenced to. Despite slight discrepancies between the 1940 chart and the 2014 chart both appear to clearly represent the higher elevation features illustrated on the 2014 aerial map. Evidently there has been very little change to the islands in Florida Bay since 1940.

In summary, the GIS-based investigation of migration of the mudflats and islands in Florida Bay appears to be inconclusive (Figure 19). Some of the islands may have grown in size over the past century; however, historical charts provide variable accuracy and it would be inappropriate to report any definitive results without additional data. It is hard to definitely say this examination supports the conclusions drawn from Taylor and Purkis (2012), which identified instances where mudflats had migrated southward between 1890 and 1990.
Figure 19. Outlines of five historical navigational charts over 2014 aerial.

Previous papers have suggested a lack of movement of the mudbanks as they are supported by the microkarst topography (Wanless and Tagett 1989). The microkarst topography in Florida Bay was formed between approximately 100,000 and 20,000 years B.P., which predates any human occupation in the region. Needless to say, this would reinforce the observation of little change to island migration during the time human settlement would have taken place in Florida Bay.

Comparison of the islands also illustrate that several islands have appeared and disappeared within the range of time examined. Figure 17 shows a zoomed imaged of the northeastern portion of the study area. In this image the movement of islands is clear.
However, it also appears some islands are more recent while historic ones are no longer visible. For instance, the small bean-shaped island visible to the north of Club Key was not charted until 1937. The small island to the east of Club Key was charted in 1919 (yellow); however, it was not charted in 1921, 1937, or 1940.

One of the most noticeable changes in this section of the study area is the growth of the Black Betsy Keys. Previous to 1940 these keys were primarily two larger islands with smaller ones scattered between. In 1940 the chart illustrates a much larger landform, which is consistent with present day aerial imagery. Consistently, the outlines of the 1919 chart are to the north of the other charts. This of the result of either the lack of control points to georeference the historic chart properly or due to the resolution and accuracy of the chart when it was originally drawn. Several attempts were made to georeference this chart and each attempt yielded similar results. This data is included to illustrate the variability of accuracy demonstrated with use of historical maps that predate modern means of mapping.

**Geophysical Remote Sensing**

Geophysical remote sensing was conducted to observe changes in the thickness and distribution of sediment deposits and to attempt to potentially identify large-scale archaeological deposits and karst formations indicative of prehistoric freshwater sources. This was the first geophysical remote sensing survey to be conducted within the Everglades National Park boundary of Florida Bay. The survey took place during June 1-10, 2014; a total of 157.62 kilometers of geophysical data were collected. Only one
weather day of field survey was cancelled due to poor weather conditions, which was acceptable because there were issues setting up the Trimble DGPS. Collecting geophysical data using a Chirp sub-bottom profiler was determined to be feasible, though challenging. Five areas (1, 2A, 2B, 3, 4) were surveyed (Figure 20); in almost all cases most of the survey area was accessible given the draft of the R/V Cetacea and the depth at which the Chirp unit was towed.

Only in one instance, Survey Area 2, did modifications have to be made due to shallow water. As a result, Survey Area 2 was divided into Survey Area 2A (Figure 24) and Survey Area 2B (Figure 25), which are separated by a mudbank. Even with a sound survey methodology, weather played an important role in the success of data collection. With the exception of one day, the survey time frame provided ideal weather conditions. Winds ranged from 0-10 kts, increasing throughout the day. Consequently, field work began early with the anticipation of less than ideal conditions by late afternoon. More than a one-foot chop on the Bay resulted in data that had a high frequency wave occurrence on the surficial reflector (Figure 21). One observed advantage to surveying in a very shallow marine environment such as Florida Bay, is water visibility. Visual groundtruthing of the surficial material that made up the seafloor of the Bay was noted for proper interpretation.

In addition, SAV interfered with the acoustic pulses. As a result, in regions with extensive SAV the subbottom records appear blurry at the water-sediment interface (Figure 22). Acoustic penetration of the sediments rarely exceeded 4.0 meters. The
Figure 20. Survey areas and geophysical tracklines within the study area.
The range of frequencies generated by the SB-424, 4 and 24 kilohertz, was not adequate for penetrating the bedrock.

Figure 21. Geophysical data affected by wave chop in Florida Bay (Survey Area 3 Line 26).

Records show very little sedimentation within the basins surveyed. Sediment accumulation increased as tracklines approached mudbanks and islands. Two distinct differences in bottom type were observed: exposed bedrock and loosely packed sediment (Figure 22). In addition, SAV interfered with the acoustic pulses. As a result, in regions with extensive SAV the subbottom records appear blurry at the water-sediment interface (Figure 22). Acoustic penetration of the sediments rarely exceeded 4.0 meters. The range of frequencies generated by the SB-424, 4 and 24 kilohertz, was not adequate for penetrating the bedrock.

Analysis of the geophysical data showed only two of the five survey area, Survey Areas 2B and 4, to have distinguishable subsurface features. Subsurface features were analyzed because they may represent areas of sufficient sediment deposition to preserve buried archaeological material. Survey Area 2B (Figure 25) had four lines and Survey Area 4 (Figure 27) had two lines with intriguing subsurface features.
Figure 22. Exposed bedrock (left), loosely packed sediment (middle), effect of SAV (right).

In Survey Area 2B, the subsurface feature identified in Line 16 is approximately 30.0 cm thick and only about 2.5 meters in length (Figure 28). It is located at the end of the survey line where water depths are 2.0 FT. At this location, the survey line was approaching a mudbank. This mudbank had a well-established vegetation cover consisting of mangroves, grasses, and some terrestrial shrubbery. In addition, exposed limestone and carbonate sediment accumulations were also visible.

Table 3. Geophysical survey lines with subsurface features.

<table>
<thead>
<tr>
<th>Survey Area 2B</th>
<th>Survey Area 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 16</td>
<td>Line 11</td>
</tr>
<tr>
<td>Line 22</td>
<td>Line 21</td>
</tr>
<tr>
<td>Line 24</td>
<td></td>
</tr>
<tr>
<td>Line 27</td>
<td></td>
</tr>
</tbody>
</table>
Figure 23. Survey Area 1 geophysical tracklines.
Figure 24. Survey Area 2A geophysical tracklines.
Figure 25. Survey Area 2B geophysical tracklines.
Figure 26. Survey Area 3 geophysical tracklines.
Figure 27. Survey Area 4 geophysical trackline.
Figure 28. Survey Area 2B, Line 16, subsurface feature (depth in meters).

Line 22 in Survey Area 2B also revealed a subsurface feature at the end of the survey line, one more prominent than that observed in Line 16. As Line 22 approached the mudbank, it revealed an accumulation of sediment on top of the limestone bedrock (Figure 29). Accumulation is less towards the left of the profile line heading into the deeper basin. Sediments overlying bedrock increase in thickness moving towards the mudbank. It is unclear why there is not penetration toward the right of the Figure 29 profile; possibly the acoustic signal was not at the correct frequency to penetrate.

Figure 29. Survey Area 2B, Line 22, subsurface feature (depth in meters).

This same feature is seen on Line 24 as well. Here the profile appears from left to right, moving away from the mudbank. It is more prominent and continues for a longer period of time (Figure 31). It is especially important to note that just before the end of the line
captured in Figure 31, the subsurface reflection ends and a multiple becomes apparent. A multiple results from the acoustic pulse bouncing off the bottom and back to the towfish more than once; multiples are distinguished by their appearance in the subsurface record at twice the distance deeper than the surficial contact (Figure 30).

The multiple visible in Line 24 is faintly there in two locations, one at about 2.0 meters and the other at about 4.0 meters. In general sediment accumulation on top of the bedrock is no more than about 1 meter thick, with the greatest accumulation toward the mudbank island; it thins out as the line approaches the center of the basin.
Line 27 (Figure 32) captures this same feature on approach towards the mudbank, similar to Line 22. On the return line the feature is not as elongated as in Line 24, but is more distinct than in Line 16. This represents the thickest accumulation of sediment. At the layer’s widest the accumulation is estimated to be close to 1 meter; in the other lines it is less than 1 meter in some areas and less than 0.5 meters in others.

Figure 32. Survey Area 2B, Line 27, subsurface feature (depth in meters).

Beyond the four lines containing evidence of subsurface features that are discussed above, most of the remaining geophysical lines in Survey Area 2B illustrate acoustic images of exposed hardbottom. The data show reflection profiles similar to Figure 30. Lines 4, 7, 10, 13, 19 all recorded the similar bottom type (Figure 25). In addition, this area exhibited little to no submerged aquatic vegetation (SAV). This was evident visually from observation of the area during the survey and in the acoustic reflection profile of the survey lines.

Survey Area 4 was the most western area investigated (Figure 27). In general this area contains extensive SAV beds with only small pockets of exposed sandy, clayey bedrock bottom. SAV is evident in the geophysical profiles, such as in Figure 33 towards the left side of the image. As mentioned previously, it is characterized by a blurred appearance just above the surficial reflector.
Lines 11 and 21 (Figs. 33, 34) were the only two in Survey Area 4 to have subsurface reflectors. In Line 11, the reflector was located at the end of the line, nearest an unnamed submerged mudbank to the southwest. Accumulation of sediment over the bedrock surface begins further out toward the basin, increasing on approach into shallower waters. As illustrated in Figure 33, the thickness of accumulation nearing 2.0 meters at the thickest portion.

Figure 33. Survey Area 4, Line 11, subsurface feature (depth in meters).

The same feature in Line 11 can be identified in Line 21 (Figure 34). In this portion of the survey area the thickness of sediment accumulation over the subsurface feature is 2 meters, only several centimeters greater than the thickest section of accumulation in Line 11. The nature of the data gap visible in the middle of the subsurface reflector is unknown. It may be that a harder surface reflected most of the acoustic pulse at that location. Another possibility is a gap in the subsurface reflector that is infilled with sediment. Submerged aquatic vegetation is also visible in this area, which is consistent throughout the entire basin.
No subsurface features were evident in the remainder of the Area 4 lines (1, 16, 26, 31). In addition, two tie lines (4 and 5), located towards the center of the survey area, and did not show any more evidence of subsurface features. Also, there were few reflectors indicative of exposed hardbottom identified in Survey Area 4. This, coupled with the prominence of SAV, suggests there is more sediment accumulation here than in other areas surveyed.

A small channel feature, only 1.0 meter across and 2.0 meters deep, was observed on the geophysical data for Line 1, Survey Area 4 (Figure 35). Many small channels bisect the shoals. Some are maintained by EVER for recreational use while others are maintained by natural processes. From visual observation of the area, sea grass beds overlay only a thin layer of sediment.
Subsurface Sampling

Subsurface sampling by vibracoring was conducted in order to groundtruth the geophysical data and to collect a different dataset in support of this study's hypotheses. Three main data types were sought during subsurface sampling: peat, freshwater flora and fauna, and archaeological material. Vibracores were taken adjacent to mudbanks as well as in basins to ground truth the sediment types hypothesized after collection of the geophysical data. Vibracores were collected from July 7-10, 2014, under favorable weather conditions. Unlike the geophysical survey, collection of vibracores is not weather-dependent. The portable concrete vibrator as the power source for coring was very successful, not only requiring minimal space on the R/V Cetacea, but also providing adequate sediment penetration. In all instances but one, the vibracore penetrated the sediment until hitting the sediment-bedrock contact. This was confirmed by examining the lower end of the aluminum core tube, which would be roughened and jagged. One of
the main benefits of collecting vibracores in a shallow marine environment is the ability
to get out of the boat and position the core exactly where is needed. This minimized time
spent maneuvering the R/V *Cetacea* into position.

A total of sixteen vibracores were collected within the study area (Figure 36). In
each of the four survey areas, at least one vibracore was taken near the center of the basin
to provide a control point for the geophysical data. All other vibracores were positioned
in areas where sediment accumulation over a subsurface feature had been identified by
the geophysical survey. Table 4 presents a summary of general vibracore information
including location and length.

As Table 4 shows, recovery lengths for each of the vibracores were minimal. The
longest vibracore was 130.0 cm while the shortest was only 13.5 cm. In addition, the
greatest depth of penetration was 161.0 cm. There is no correlation between penetration
depth and recovery length other than the greater the penetration the more likely it is to
recover sediment. In all instances, penetration did not equal one hundred percent
recovery; in other words although penetration to underlying bedrock occurred for all but
one vibracore, sediment recovery was not the same as penetration length. This is due to
dewatering and compaction of fine-grained core sediments on recovery.

Two of the vibracores penetrated through and recovered a layer of organic
material, later identified as peat. FBVC-14-01 was collected from Survey Area 1 in 1.74
meters of water just to the east of the Black Betsy Keys. This core was not associated
with an area where visible sediment accumulation had been noted during the geophysical survey. The core, collected near Line 11 in Survey Area 1 penetrated 38.0 cm and recovered 31.5 cm of sediment; as seen in Figure 37, it consisted of mostly shelly clay with varying amounts of root fragments and particulate organic material. A total of 16.0 cm of shelly clay material was observed, which is characterized as marine.

Interestingly, one whole shell from 11cm down core was identified as a freshwater species, most likely *Micromenetus dilatatusavus*, a species of freshwater snail abundant throughout the Florida Peninsula in freshwater habitats (Thompson 2004). This shell was found just above the peat deposit containing wood fragments, silt, and other trace shell fragments. Below the layer of peat, another layer of clay that consisted of clay with shell fragments, wood fragments, and particulate organic material was observed. A 3cm x 5cm limestone rock fragment was recovered from the bottom of the vibracore. In addition, the cutting edge of the core barrel was abraded from contact with the bedrock, the assertion that full recovery of the sediment sequence was achieved.

Radiocarbon dates were acquired for the peat layer. As seen in Table 5, the results of the conventional radiocarbon dates suggest the sediment was deposited first, followed by the establishment of plants in that area. When averaged, the dates are 3320 +/- 30 B.P. Davies (1980:243) reported peat samples from a similar region of the Bay to have an age of 2575 +/- 130 B.P. The sample collected by Davies (1980) was taken on the terrestrial mudflat of Eagle Key, whereas FBVC-14-01 S#2 @ 19.0 cm was collected to the southwest of Eagle Key on the other side of the basin.
Figure 36. Vibracores collected in Florida Bay.
**Table 4. Summary of vibracore information.**

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<th>ID</th>
<th>Y</th>
<th>X</th>
<th>Date</th>
<th>Time</th>
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<th>Penetration (cm)</th>
<th>Length (cm)</th>
<th>Peat Layer</th>
<th>Freshwater Species</th>
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<td>N</td>
</tr>
<tr>
<td>FBVC-14-18</td>
<td>24.98152</td>
<td>-80.83781</td>
<td>7/8/2014</td>
<td>1248</td>
<td>0.82</td>
<td>103.00</td>
<td>91.00</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
This area of Florida Bay flooded prior to Eagle Key, thus supporting the differences in dates exhibited between this study and Davies (1980).

In addition, the layers above the peat were also measured, and interesting, there is a large time difference between the results of S#2 and S#3 in FBVC-14-01. Only ten centimeters separate the samples but 2,540 years (using the conventional radiocarbon age) separate S#2 (plant material) from S#3 in age. The gap in time most likely represents a series of erosional events that have consequently erased 2,540 years of sediment deposition. A similar gap is observed in FBVC-14-07. Samples 1 (plant material) and 2 are separated by 17 cm in depth, but are different ages by 1,640 years (using the conventional radiocarbon age). Once again, the gap in data can be attributed to erosion. Evaluation of the vibracores led to the hypothesis that the farthest southwest vibracore’s (FBVC-14-17) basal sediments should be the oldest since Florida Bay flooded from the southwest. The bottommost layer of the core was measured for radiocarbon and the results were unanticipated. FBVC-14-17 S#1 @ 60.0 cm had a conventional radiocarbon age of 1160 +/- 30 B.P. Since initial flooding of Florida Bay began around 5,000 years B.P. it was expected for Sample 1 to have dates similar to this. Instead, there are about 4,000 years missing from the sediment record. The idea these sediments were eroded is brought forward again by this data.

The second core to contain a peat layer was FBVC-14-07, recovered from 0.85 meters of water on the NE side of Club Key, towards the southwest of the Black Betsy Keys. At this location 161.0 cm of sediment was penetrated but only 95.0 cm were
recovered. This is attributed to dewatering and compaction of the sediments as the core was brought onto the R/V *Cetacea*. FBVC-14-07 was collected in Survey Area 2A near Line 02. Similar to Survey Area 1, Survey Area 2A did not produce any subsurface features. FBVC-14-07 was selected to document any change in sediment type from the basin center its edge along the mudbanks. Two distinct layers were noted in FBVC-14-07 (Figure 38). The upper layer was 89 cm thick, containing mostly marine carbonate clay with shell hash, root fragments, and particulate organic material. The second layer, extending from 89 cm to 95 cm, consisted of organic material identified as peat. The peat also contained marine shell hash and woody root fragments. Freshwater mollusks were not recovered from in this layer as the shell material was fragmented and no longer identifiable. The peat was sampled and radiocarbon analyzed. As outlined in Table 5, the conventional radiocarbon age for the plant material was 3110 +/- 30 B.P. and the organic sediment that made up the matrix of that layer was 3890 +/- 30 B.P. Similar to FBVC-14-01, the sediment was deposited first followed by the addition of plant material. These dates predate those from the layer in FBVC-14-01. This is reasonable as the flooding of Florida Bay proceeded from SW to NE.

In comparison, the study conducted by Davies (1980) recovered a peat sample at Russell Key II, southeast of Club Key. The date Davies obtained at that location was 1065 +/- 160 B.P. When averaging the two values obtained for the sample from FBVC-14-07, the value is 3500 B.P., a difference of 2,435 years with this study. Site locations are one factor attributable to this difference, as one date may reflect initial flooding and the other represents more of a terrestrial environment.
Table 5. Radiocarbon analysis of peat samples from vibracores.

<table>
<thead>
<tr>
<th>Sample Data</th>
<th>Sample Depth</th>
<th>Measured Radiocarbon Age</th>
<th>13C/12C Ratio</th>
<th>Conventional Radiocarbon Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBVC-14-01 S#3 (carbonate shell material)</td>
<td>9.0 cm</td>
<td>30 +/- 30 BP</td>
<td>-0.7 o/oo</td>
<td>430 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-01 S#2 (plant material)</td>
<td>19.0 cm</td>
<td>2960 +/- 30 BP</td>
<td>-24.3 o/oo</td>
<td>2970 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-01 S#2 (organic sediment)</td>
<td>19.0 cm</td>
<td>3650 +/- 30 BP</td>
<td>-23.7 o/oo</td>
<td>3670 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-07 S#2 (carbonate shell material)</td>
<td>75.0 cm</td>
<td>1080 +/- 30 BP</td>
<td>-1.2 o/oo</td>
<td>1470 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-07 S#1 (plant material)</td>
<td>92.0 cm</td>
<td>3130 +/- 30 BP</td>
<td>-26.2 o/oo</td>
<td>3110 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-07 S#1 (organic sediment)</td>
<td>92.0 cm</td>
<td>3730 +/- 30 BP</td>
<td>-15.2 o/oo</td>
<td>3890 +/- 30 BP</td>
</tr>
<tr>
<td>FBVC-14-17 S#1 (carbonate shell material)</td>
<td>60.0 cm</td>
<td>750 +/- 30 BP</td>
<td>0.0 o/oo</td>
<td>1160 +/- 30 BP</td>
</tr>
</tbody>
</table>

In Survey Area 2B, two vibracores were taken where subsurface features had been identified on two of the tracklines during the geophysical remote sensing survey (Figure 39). Both Lines 22 and 27 show subsurface features on their southwest portions, which in those locations encounter an uncharted mudbank. Core FBVC-14-08 was taken on Line 22; it penetrated 141 cm of sediment and recovered 130 cm of material (Figure 40). Two layers were identified within this core. The first was from its top down to 10.0 cm, mostly comprising clay with root shell fragments throughout. The underlying layer, from 10.0 to 130.0 cm, consisted mostly of clay as well. Root fragments present in this layer were more degraded than in the surficial layer.
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>Shelly CLAY, little silt, trace root fragments up to 4.0 cm, shell content are shell fragments, (CL).</td>
<td></td>
</tr>
<tr>
<td>16.0</td>
<td>Shelly CLAY, carbonate, little silt, some root fragments up to 4.0 cm, clay contains pockets of organic material up to 3.0 cm, 2.0 cm whole shell @ 11.0 cm, (CL).</td>
<td>S#1 @ 11.0 cm: whole shell possibly <em>Micromenetus dilatatus avus</em> (freshwater species)</td>
</tr>
<tr>
<td>21.0</td>
<td>ORGANICS, peat with some wood fragments, trace shell fragments, trace silt, wood fragments up to 2.0 cm, (PT).</td>
<td>S#2 @ 19.0 cm: peat/organic plant matter and sediment. Conventional Radiocarbon Age Plant Matter: 2970 +/- 30 B.P. Conventional Radiocarbon Age Sediment: 3670 +/- 30 B.P.</td>
</tr>
<tr>
<td>31.5</td>
<td>CLAY, some organics, little shell fragments, little silt, little wood fragments up to 5.0 cm in length, organic material is in lamina up to 2.0 cm, (3.0 x 5.0 cm) rock fragment @ 30.0 cm, 1.0 cm rock fragment @ 29.5 cm (CL).</td>
<td></td>
</tr>
<tr>
<td>38.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 37. Vibracore log of FBVC-14-01.
This lower layer consists of marine sediments and contained one *Fasciolaria hunteria* (Banded Tulip Snail) shell, a marine species common to the Florida Atlantic and Gulf Coasts (Abbott 1974). Geophysical data from this line showed approximately 1 meters of subsurface accumulation. FBVC-14-08 penetrated until refusal when the bottom of the core tube encountered a hard subsurface.

The sediment deposited overtop of the subsurface is likely to be the material observed in the vibracore. It also was a significant enough accumulation to be distinguished acoustically during the geophysical survey. This was confirmed when examining core FBVC-14-10, which was collected along the northeastern end of Line 22. This core only recovered 17.0 cm of sediment and there is no indication of accumulation observed in the geophysical data.

Line 27 was another trackline that recorded a subsurface reflector towards the southwest of Survey Area 2B. Core FBVC-14-09 was collected to ground truth this line. It penetrated 82.0 cm and recovered 80.0 cm of material (Figure 41). Three distinct layers were noted. The first from 0-11.0cm, consisted mostly of clay with fragments of *Halimeda* calcareous algae found throughout South Florida and the Caribbean (Humann and DeLoach 2002: 206). Root fragments were also present. The second layer extended from 11.0 to 60.0 cm and consisted of clay, root fragments, and particulate organic material. The bottom-most layer extended from 60.0 cm to 80.0 cm and also consisted of clay, but with more shell fragments. The sediment overlying the subsurface feature visible in the geophysical data is approximately one meter at the thickest.
**Figure 38. Vibracore log of FBVC-14-07.**

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell hash, little organics, trace silt, trace whole shell, little root fragments up to 5.0 cm, whole shells up to 1.0 cm, 2.0 cm whole shell @ 61.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>89.0</td>
<td>ORGANICS, little clay, trace shell hash, organic component consists of root fragments, (PT).</td>
<td>S#1 @ 92.0 cm: peat/organic plant matter and sediment. Conventional Radiocarbon Age Plant Matter: 3110 +/- 30 B.P. Conventional Radiocarbon Age Sediment: 3890 +/- 30 B.P.</td>
</tr>
<tr>
<td>95.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>161.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In Survey Area 4, lines 11 and 21 exhibited subsurface features towards their southwest extents. Adjacent to Line 11, a vibracore was taken on Line 6, but it showed no sign of a subsurface feature (Figure 42). On Line 11, 500 meters to the northwest of Line 6, the subsurface feature was 2.0 meters at the thickest portion.

Figure 39. Survey Area 2B geophysical tracklines and vibracore locations.

Core FBVC-14-17 penetrated 83.0 cm and recovered 81.0 cm of material in a water depth of 1.4 m. Two layers were identified in this core. From the top of the core to 25.0 cm, the sediment consisted of mostly clay with little particulate organic material, a few root fragments, and finally a marine shell. The second layer, also consisting of clay, extended from 25 to 81 cm. However, in this layer more shell hash and fragments were present.
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell hash, trace shell fragments, trace silt, 15.0 cm root fragment @ 6.0 cm, shell fragments up to 0.5 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>CLAY, carbonate, little organics, trace shell hash, trace silt, trace whole shell, little root fragments up to 5.0 cm, shell fragments up to 1.0 cm, whole shells up to 1.0 cm, 4.0x2.0 cm whole shell @ 69 cm, 3.0 cm calcified worm tube @ 120 cm, (CL).</td>
<td>4.0x2.0 cm whole shell: <em>Fascolaria hunteria</em> (Banded Tulip Snail)</td>
</tr>
<tr>
<td>130.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>141.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 40. Vibracore log of FBVC-14-08.
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, little organics, little shell fragments, trace silt, trace root fragments up to 3.0 cm, shell fragments are <em>Halimeda copiosa</em>, (CL).</td>
<td></td>
</tr>
<tr>
<td>11.0</td>
<td>CLAY, carbonate, little organics, trace shell fragments, trace silt, little root fragments, shell fragments up to 1.0 cm, 2.0 cm whole shell @ 42.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>60.0</td>
<td>CLAY, carbonate, some shell hash, little shell fragments, trace silt, trace whole shell, whole shells up to 1.0 cm, shell fragments up to 1.0 cm, 3.0x2.0 cm shell fragment @ 78.0 cm, 6.0x5.0 cm shell fragment @ 79.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>80.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>82.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 41. Vibracore log of FBVC-14-09.
along with additional whole shells. These data correlate with observations made in Survey Area 2B.

FBVC-14-17 was the furthest core to the southwest in the study area and a sample of the sediments in the bottom layer of the core was submitted to Beta Analytic for radiocarbon dating. As seen in the vibracore log (Figure 43), the sediment is marine carbonate mud, as verified through the identification of various marine mollusk shells. As mentioned previously, FBVC-14-17’s basal sediments were measured for radiocarbon in order to see if the material represented the initial flooding of Florida Bay. As the results revealed, there measured conventional age was 1160 +/- 30 BP, which is considerably younger than anticipated. In addition, it is considerably younger than the peat deposits identified in FBVC-14-01 and FBVC-14-07.

Consideration of all the analyses conducted in the study yield limited data to support the survival of submerged cultural resources in Florida Bay. Though it appears the islands and mudbanks in Florida Bay have changed size and shape throughout the last century, the results are insufficient to definitely confirm such a statement. Geophysical remote sensing data provided evidence that there is little accumulation of sediments in the basins of Florida Bay; however, accumulation becomes greater upon approach towards mudbanks and islands. Specifically, towards the western edge of the basins a majority of cores showed the greatest recovery. The geophysical data yielded no results suggesting the existence of inundated archaeological features. Only two vibracores exhibited layers containing peat and these samples correlate with the flooding of the Bay.
More data are necessary to create a predictive model. Based on the findings thus far, results suggest the areas of interest should not be the submerged environments of Florida Bay but present-day terrestrial environments. This conclusion will be explained within the following Discussion section.

Figure 42. Survey Area 4 geophysical tracklines and vibracore locations.
**Figure 43. Vibracore log of FBVC-14-17.**

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, little organics, little shell fragments, little silt, little root fragments up to 3.0 cm, 2.0 cm whole shell @ 1.0 cm, 0.5 cm whole shell @ 11.0 cm, (CL).</td>
<td>S#1 @ 60.0 cm: carbonate shell material. Conventional Radiocarbon Age: 1160 +/- 30 BP</td>
</tr>
<tr>
<td>81.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>83.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 7
Discussion

Identifying inundated prehistoric archaeological material has challenged archaeologists for decades. As evaluation of both prehistoric and historic archaeological sites is required for cultural resource management, there is a clear need to predict where prehistoric sites may be located. As previous attempts have shown, this is not an easy task because no technology exists exclusively capable of detecting prehistoric archaeological material. Therefore much research, data collection, and creative analysis are required to develop a very educated guess. From the beginning, the odds of finding submerged inundated prehistoric archaeological material anywhere in Florida Bay were miniscule. Actually, the odds of finding submerged prehistoric archaeological material anywhere is unlikely; a needle in a haystack. Even with using a predictive model approach that employs a strategy based on indirectly related features associated with settlement patterns, expectations were not high.

Background research revealed the basins of Florida Bay had thin carbonate mud sediment accumulation. The microkarst topography suggests the basins were filled with freshwater during the Holocene and identified basal peat layers further support this. The lack of thicker sediment accumulations also does not provide an environment conducive for preservation of prehistoric archaeological material. Thus based on the results from this study with the support of previous studies, it is hypothesized that the likely areas to find prehistoric archaeological remains in Florida Bay are beneath mud banks and mangrove islands that create the present day terrestrial habitats. Further data collection
of sediments on these higher elevation and thick sediment regions could offer additional support to this theory. The formation of these regions occurred during the Holocene sea level transgression. Enos and Perkins (1979) suggest that they formed via “island nucleation”, which is one of the fundamental processes for island formation.

The question remaining is whether artifacts left behind by prehistoric cultures are preserved in the basal sediments of these islands. John Griffin (2002: 43) states in his book *Archaeology of the Everglades*, Florida Bay “was an area that probably never had much to attract aboriginal occupation”. Previous research has identified prehistoric archaeological remains found within the sediments of the Florida Everglades, to the north, on tree islands (Schwadron 2006) and shell work sites on the Ten Thousand Islands (Schwadron 2010). Considering many studies have suggested that Florida Bay was probably like the present day Everglades around 5,000 years ago, it would seem likely that prehistoric cultures would have settled in Bay region prior to flooding. The question remains, where is the evidence?

Only in two instances were basal peat sediments observed during this survey. One core was collected in Survey Area 1 that contained basal peat along with an identified freshwater mollusk shell and the other was identified in Survey Area 2A. The existing peat layers accompanied by freshwater clay sediments supports Florida Bay, at around 5,000 year ago, was a freshwater swamp habitat and an extension of the current Everglades (Griffin 2002: 42).
The lack of basal peat in the study area introduces the idea that initial transgressive flooding of the Bay eroded most of the organic rich layers that may have once existed. It is likely the same fate may be true for prehistoric archaeological material. Paleoindian and Archaic Period people used tools that were made of natural materials such as wood, bone, clay, seeds, and shells. Given that these items are not very heavy it would be very easy for the smallest of wave interactions to erode deposits. The investigation did not identify any archaeological material in the form of either small isolated deposits or large-scale archaeological features such as shell work sites.

Florida Bay Island Migration

Many of the islands in Florida Bay have been there either since initial Holocene flooding or formed during sea level transgression (Burns and Swart 1992). Stratigraphy of mudbanks and mangrove dominated islands illustrate both Pleistocene and Holocene sediment sequences. These are not consistently exhibited in Florida Bay but generally such depositional sequences are similar throughout the Bay (Davies 1980). Since these islands are supported by elevated karst topography significant prehistoric migration of these islands is not likely. Instead, it is more likely that they have changed minimally over time due to variances in sediment transport and water flow patterns. Analysis of several historic navigational charts dating from 1895 to present day proved to be inconclusive. No significant variations were noted and those that were reflected anthropogenic modifications to improve navigation.
The amount of useful information that could be drawn from analysis of island migrations was limited. This type of data would not sufficiently support any model for predicting potential inundated archaeological sites in Florida Bay. However, this method has proved useful in other locations. Modern navigational charts when combined with remote sensing data can illustrate changes in paleolandscape (Faught 2014). In fact, this method has successfully assisted with identifying prehistoric archaeological remains in near the Hillsborough River on the west coast of Florida (Faught and James 2007).

**Geophysical Remote Sensing**

A common tool for underwater archaeologists is remote sensing, and more specifically, acoustic remote sensing techniques. A strategy for locating prehistoric sites is to recognize paleolandforms and sedimentology suggestive of freshwater sources. These may include river channels, sink holes, and lakes. Prior to this study, a sub-bottom geophysical remote sensing study in the Everglades National Park boundary of Florida Bay had never been conducted. Therefore, in order to satisfy this portion of the project sub-bottom data was collected. The shallow nature of Florida Bay along with the draft of the R/V *Cetacea* made data collection complicated. The Edgetech SB-424 had a tow point directly below the hull, only 30 cm below the water’s surface. The resulting data collected was of moderate quality.

The results illustrated from the geophysical survey proved there is little sediment accumulation in Florida Bay. The basins exhibited little or no sediment accumulation and only areas skirting the mudbanks and mangrove islands had increased accumulation.
The geophysical remote sensing survey also illustrated the extents of submerged aquatic vegetation. This data could later be digitized for future SAV management. The difference between SAV and exposed bedrock was apparent on the reflection profile. Beds of submerged aquatic vegetation appeared fuzzy at the surficial acoustic contact whereas exposed bedrock was a sharp dark line. Areas with sediment accumulation had a less defined acoustic reflection with a faint distinction of the bedrock below. Interestingly, in some instances it was noticeable that the bedrock trended to higher elevation when approaching the mudbanks and mangrove islands. This, of course, supports the formation of the islands and mudbanks via nucleation in areas where the karst topography of the Miami Limestone was more elevated.

**Subsurface Sampling**

The sediments collected in the vibracores showed the sediments in Florida Bay are dominated by fine grained carbonate sediment. The vibracores provided ground truthing for the geophysical remote sensing data and, as mentioned above, mostly accumulation of sediments was very little. The greatest accumulation of sediment was observed in FBVC-14-08 with 130 cm of material. Once again, only in two instances was basal peat collected: FBVC-14-01 and FBVC-14-07. These layers had radiocarbon dates of 2790 and 3110 years BP, respectively, and are consistent with Davies (1980) for the same areas of the Bay. Davies concluded the youngest basal peat layers were toward the northwest portion of Florida Bay (i.e. Survey Area 1) and the oldest towards the southwest. FBVC-14-17 was the most southwest core location and the basal peats from this location measured 1160 years BP. This is several thousand years different from the
dates suggested by Davies for the same area. In addition to identifying basal peat, a freshwater mollusk shell was also identified in FBVC-14-01 as to be likely *Micromenetus dilates avus*.

Both FBVC-14-01 and FBVC-14-07 support Florida Bay was once a fresh body of water and an extension of the Everglades. The lack of basal peat in FBVC-14-17 and relatively recent marine sediments support many stratigraphic sequences have been eroded.

**Summary and Conclusions**

The study was initiated to support the mission of the National Park Service. This mission is to preserve both natural and cultural resources for the enjoyment, education, and inspiration of this and future generations (NPS.com 2014). In order to be preserved, cultural resources need to be identified and assessed. The scope of this study was to investigate potential submerged prehistoric cultural resources in Florida Bay, Everglades National Park. The results yielded can vastly improve EVER’s cultural resource management strategies. The findings indicate, the karst basins in Florida Bay were formed while the Bay was an extension of the Everglades. These basins do not provide a depositional environment ideal for preservation of prehistoric archaeological material. This is drawn from two conclusions. The first, little sediment accumulation was observed in all the basins investigated. The only significant accumulation was on approach to mudbanks and mangrove islands. The second, in only two locations were basal peat layers identified. Peat has been located as basal sediments previous to this
study beneath the islands that form the terrestrial regions of the Bay. The lack of basal peat in the basins also supports that much of the stratigraphic sequences in Florida Bay have been eroded.

It is believed the basins were sources of freshwater as they formed by dissolution of the Miami Limestone during exposure to freshwater. Thus, the more likely areas to contain archaeological deposits would be beneath mudbanks and mangrove islands. Since these features are topographic highs formed prior to sea level flooding Florida Bay, they would have been dry land when the basins still contained freshwater. These topographic high points would have served as ideal locations for human settlement. This is supported by research conducted on tree islands in the Shark River Slough of the Everglades (Schwadron 2006). Tree islands are also topographic highs and archaeological deposits have been found in sediments beneath these islands.

Since results from this study suggest much of the basal peat layers in Florida Bay have been eroded. It is likely sea level rise was the force driving this erosion. It is also notable to point out that sea level rise could have cause the same fate for prehistoric archaeological material that may be currently deposited beneath mudbanks and islands. In addition to sea level rise, researchers who conduct work in Everglades National Park may also pose a threat. Much of the previously collected sedimentological data examined for this study was from either mudbanks or mangrove islands. Were any cultural resource investigations conducted prior to these projects to ensure there was no damage
to potential sites? It is important, moving forward, for focus to be places on these terrestrial locations so potential cultural resources may be avoided.

One very important realization came about from this study. A proper understanding of Florida Bay’s geology was integral to this research. In fact, it is vital to all prehistoric archaeological research. The geology of Florida Bay painted a picture of how the environment was created and changed over time. Proper understanding of the paleolandslapes should form the foundations of any predictive model. A lack of understanding can lead to inaccurate interpretations of the sediment stratigraphy and depositional sequences. In addition, it can affect the context in which identified archaeological material is being interpreted.

Recommendations for Future Research

One of the initial goals of the study was to produce a probability map of Florida Bay to illustrate which areas were most likely to contain prehistoric archaeological material. This, however, was not produced due to a lack of data. Considering there is little evidence to support any archaeological material exists submerged in Florida Bay, more data needs to be collected in terrestrial areas of the Bay. Thus, I would recommend EVER conducting an investigation into the survival of prehistoric cultural resources beneath the mudbanks and mangrove islands. Collection of both submerged and terrestrial data would provide enough of a framework required to develop an accurate probability model. This model should be assembled using ArcGIS, or another
comparable mapping software, and a probability matrix. The probability matrix defines and demonstrates which factors are weighed most heavily in the model. The model could be generated as a map for which researchers and National Park Service employees can use when engaged in future work within Florida Bay. This would be the most comprehensive approach to ensure avoidance of prehistoric cultural resources in Florida Bay and to ensure their survival for this and future generations.
REFERENCES


APPENDIX A

Historical Navigation Charts
Figure 44. 1895 chart
Figure 45. 1919 chart.
Figure 46. 1921 chart.
Figure 47. 1937 chart.
Figure 48. 1940 chart.
APPENDIX B

Vibracore Logs
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Shelly CLAY, little silt, trace root fragments up to 4.0 cm, shell content are shell fragments, (CL).</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>Shelly CLAY, carbonate, little silt, some root fragments up to 4.0 cm, clay contains pockets of organic material up to 3.0 cm, 2.0 cm whole shell @ 11.0 cm, (CL).</td>
<td>S#1 @ 11.0 cm: whole shell possibly <em>Micromenetus dilatatus avus</em> (freshwater species)</td>
</tr>
<tr>
<td>16.0</td>
<td>ORGANICS, peat with some wood fragments, trace shell fragments, trace silt, wood fragments up to 2.0 cm, (PT).</td>
<td>S#2 @ 19.0 cm: peat/organic plant matter and sediment. Conventional Radiocarbon Age Plant Matter: 2970 +/- 30 B.P. Conventional Radiocarbon Age Sediment: 3670 +/- 30 B.P.</td>
</tr>
<tr>
<td>21.0</td>
<td>CLAY, some organics, little shell fragments, little silt, little wood fragments up to 5.0 cm in length, organic material is in lamina up to 2.0 cm, (3.0 x 5.0 cm) rock fragment @ 30.0 cm, 1.0 cm rock fragment @ 29.5 cm (CL).</td>
<td></td>
</tr>
<tr>
<td>31.5</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>38.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, some shell hash, trace silt, trace root fragments up to 3.0 cm, 1.0 cm whole shell</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@ 4.5 cm, 2.0 cm whole shell @ 6.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>CLAY, carbonate, little whole shell, trace shell hash, some root fragments up to 5.0 cm,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>whole shells up to 1.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>50.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>64.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell hash, trace root fragments, 1.0 cm whole shell @ 4.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>CLAY, carbonate, trace shell fragments, little root fragments up to 10 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>58.0</td>
<td>CLAY, some shell fragments, trace whole shell, trace root fragments, whole shells up to 10.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>73.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>88.0</td>
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<td></td>
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<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>Shelly CLAY, carbonate, some whole shell, some root fragments up to 6.0 cm, shell component is shell hash, whole shells up to 1.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>11.0</td>
<td>CLAY, carbonate, some shell hash, some root fragments, (CL).</td>
<td></td>
</tr>
<tr>
<td>28.0</td>
<td>CLAY, little shell hash, trace whole shell, some root fragments, root fragments decrease with depth, whole shells up to 1.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>128.5</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>140.0</td>
<td></td>
<td></td>
</tr>
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<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell fragments, little whole shell, trace silt, little root fragments, whole shells up to 1.0 cm, shell fragments up to 0.5 cm, 5.0 cm pocket of shell hash @ 2.0 cm, 40 cm pocket of some organics @ 35.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>69.0</td>
<td>CLAY, carbonate, some shell fragments, little organics, trace whole shell, 6.0 cm root fragment @ 71.0 cm, 7.0 cm root fragment @ 71.0 cm, whole shells up to 1.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>94.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>141.0</td>
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<td></td>
</tr>
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</table>
**Vibracore Log**

<table>
<thead>
<tr>
<th>Project</th>
<th>Coordinate System &amp; Datum</th>
<th>Horizontal Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaeological Investigation Florida Bay, FL</td>
<td>Geographic (Lat/Long) WGS 1984</td>
<td>NAD 1983</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boring Designation</th>
<th>Location Coordinates</th>
<th>Designation of Drill</th>
<th>Boring Date</th>
<th>Total Recovery of Boring</th>
<th>Initials of Geologist</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBVC-14-06</td>
<td>25.110313, -80.67126</td>
<td>Portable Vibracore</td>
<td>7/7/2014</td>
<td>59.0 cm</td>
<td>LGC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Depth of Boring</th>
<th>Initials of Geologist</th>
</tr>
</thead>
<tbody>
<tr>
<td>146.0 cm</td>
<td>LGC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Classification of Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>CLAY, trace organics, trace shell fragments, trace silt, some root fragments up to 8.0 cm, 2.0 cm lamina @ top of core of clayey shell hash, (CL).</td>
<td></td>
</tr>
<tr>
<td>59.0</td>
<td>no recovery.</td>
<td></td>
</tr>
<tr>
<td>146.0</td>
<td>no recovery.</td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell hash, little organics, trace silt, trace whole shell, little root fragments up to 5.0 cm, whole shells up to 1.0 cm, 2.0 cm whole shell @ 61.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>89.0</td>
<td>ORGANICS, little clay, trace shell hash, organic component consists of root fragments, (PT).</td>
<td>S/1 @ 92.0 cm: peat/organic plant material and sediment. Conventional Radiocarbon Age Plant Matter: 3110 +/- 30 B.P. Conventional Radiocarbon Age Sediment: 3890 +/- 30 B.P.</td>
</tr>
<tr>
<td>95.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>161.0</td>
<td></td>
<td></td>
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<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell hash, trace shell fragments, trace silt, 15.0 cm root fragment @ 6.0 cm, shell fragments up to 0.5 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>CLAY, carbonate, little organics, trace shell hash, trace silt, trace whole shell, little root fragments up to 5.0 cm, shell fragments up to 1.0 cm, whole shells up to 1.0 cm, 4.0x2.0 cm whole shell @ 69 cm, 3.0 cm calcified worm tubes @ 120 cm, (CL).</td>
<td>4.0x2.0 cm whole shell: <em>Fascolalia hunteria</em> (Banded Tulip Snail)</td>
</tr>
<tr>
<td>130.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>141.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, little organics, little shell fragments, trace silt, trace root fragments up to 3.0 cm, shell fragments are <em>Halimeda copiosa</em></td>
<td>(CL).</td>
</tr>
<tr>
<td>11.0</td>
<td>CLAY, carbonate, little organics, trace shell fragments, trace silt, little root fragments, shell fragments up to 1.0 cm, 2.0 cm whole shell @ 42.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>60.0</td>
<td>CLAY, carbonate, some shell hash, little shell fragments, trace silt, trace whole shell, whole shells up to 1.0 cm, shell fragments up to 1.0 cm, 3.0x2.0 cm shell fragment @ 78.0 cm, 6.0x5.0 cm shell fragment @ 79.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>80.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>82.0</td>
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<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell fragments, some silt, trace organics, trace root fragments up to 6.0 cm, one stalk of SAV @ 1.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>11.0</td>
<td>CLAY, carbonate, some organics, little shell fragments, trace silt, (CL).</td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>20.3</td>
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<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>Silty SHELL HASH, surficial sediments containing SAV, (ML).</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>Silty SHELL HASH, trace organics, 5.0 cm root fragment @ 11.0 cm, (ML)</td>
<td></td>
</tr>
<tr>
<td>13.5</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>18.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell fragments, some silt, little organics, trace root fragments up to 4.0 cm in length, 3.0 cm shell fragments @ 10.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>16.0</td>
<td>Clayey SHELL HASH, carbonate, little organics, little silt, (SC).</td>
<td></td>
</tr>
<tr>
<td>22.0</td>
<td>Shelly CLAY, shell content are shell fragments, 2 (2.5 cm) whole shells @ 29.0 cm, 1.0 cm lamina @ 34.0 cm of siltier organic material, (CL).</td>
<td></td>
</tr>
<tr>
<td>38.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>41.0</td>
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<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>Silty CLAY, some shell hash, trace whole shell, some root fragments up to 10.0 cm in length, whole shells up to 1.0 cm, (ML-CL).</td>
<td></td>
</tr>
<tr>
<td>27.0</td>
<td></td>
<td>No Recovery.</td>
</tr>
<tr>
<td>30.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, some shell fragments, little silt, some root fragments up to 5.0 cm in length, (CL).</td>
<td></td>
</tr>
<tr>
<td>7.0</td>
<td>Shelly CLAY, carbonate, little organics, shell content are shell fragments, 3.0 cm root fragment @ 20.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>CLAY, carbonate, some shell fragments, 2.5 cm whole shell @ 32.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>42.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>43.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, little organics, little shell fragments, little silt, little root fragments up to 3.0 cm, 2.0 cm</td>
<td>Ssl @ 60.0 cm: carbonate shell material. Conventional Radiocarbon Age: 1160 +/- 30 BP</td>
</tr>
<tr>
<td>81.0</td>
<td>whole shell @ 1.0 cm, 0.5 cm whole shell @ 11.0 cm (CL).</td>
<td></td>
</tr>
<tr>
<td>83.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>Classification of Materials</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>0.0</td>
<td>CLAY, carbonate, trace shell fragments, some root fragments up to 4.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>11.0</td>
<td>CLAY, carbonate, some organics, trace shell fragments, trace silt, little root fragments up to 3.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>26.0</td>
<td>CLAY, carbonate, some organics, trace shell fragments, trace silt, trace root fragments, 3.0x2.0 cm whole shell @ 39.0 cm, 3.0x2.0 cm shell fragment @ 38.0 cm, 3.5x2.0 cm shell fragment @ 56.0 cm, (CL).</td>
<td></td>
</tr>
<tr>
<td>91.0</td>
<td>No Recovery.</td>
<td></td>
</tr>
<tr>
<td>103.0</td>
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</tr>
</tbody>
</table>
APPENDIX C

Vibracore Photographs
Figure 49. FBVC-14-01
Figure 50. FBVC-14-02.
Figure 51. FBVC-14-03.
Figure 52. FBVC-14-04.
Figure 53. FBVC-14-05.
Figure 54. FBVC-14-06.
Figure 57. FBVC-14-09.
Figure 58. FBVC-14-10.

17.0 cm
13.5 cm

Figure 59. FBVC-14-12.
Figure 60. FBVC-14-13.
Figure 61. FBVC-14-14.
Figure 62. FBVC-14-15.
Figure 63. FBVC-14-17.
Figure 64. FBVC-14-18.
APPENDIX D

Radiocarbon Results
# REPORT OF RADIOCARBON DATING ANALYSES

Ms. Leah Colombo  
Report Date: 10/20/2014  
Material Received: 10/14/2014

<table>
<thead>
<tr>
<th>Sample Data</th>
<th>Measured Radiocarbon Age</th>
<th>13C/12C Ratio</th>
<th>Conventional Radiocarbon Age(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta - 392869</td>
<td>3130 +/- 30 BP</td>
<td>-26.2 o/oo</td>
<td>3110 +/- 30 BP</td>
</tr>
</tbody>
</table>
| SAMPLE : FHVC-14-07 941 @ 92cm plant  
ANALYSIS : AMS-PRIORITY delivery  
MATERIAL/PRETREATMENT : plant material: acid/alkali/acid  
2 SIGMA CALIBRATION : Cal BC 1435 to 1290 (Cal BP 3385 to 3240) |
| Beta - 392870     | 2960 +/- 30 BP           | -24.3 o/oo    | 2970 +/- 30 BP                  |
| SAMPLE : FHVC-14-01 812 @ 19cm plant  
ANALYSIS : AMS-PRIORITY delivery  
MATERIAL/PRETREATMENT : plant material: acid/alkali/acid  
2 SIGMA CALIBRATION : Cal BC 1265 to 1110 (Cal BP 3215 to 3060) |
| Beta - 393508     | 3730 +/- 30 BP           | +15.2 o/oo    | 3890 +/- 30 BP                  |
| SAMPLE : FHVC-14-07 941 @ 92cm organic sediment  
ANALYSIS : AMS-PRIORITY delivery  
MATERIAL/PRETREATMENT : organic sediment: acid washes  
2 SIGMA CALIBRATION : Cal BC 2470 to 2285 (Cal BP 4420 to 4235) |
| Beta - 393509     | 3650 +/- 30 BP           | -23.7 o/oo    | 3670 +/- 30 BP                  |
| SAMPLE : FHVC-14-01 812 @ 19cm organic sediment  
ANALYSIS : AMS-PRIORITY delivery  
MATERIAL/PRETREATMENT : organic sediment: acid washes  
2 SIGMA CALIBRATION : Cal BC 2140 to 1935 (Cal BP 4090 to 3905) |

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (555600) and calculated using the Libby 14C half-life (5688 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard. The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotope fractionation calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.  

Page 2 of 6
Figure 65. FBVC-14-01 S#2 @ 19.0 cm pretreated organic sediment

Figure 66. FBVC-14-01 S#2 @ 19.0 cm pretreated plant material.

Figure 67. FBVC-14-07 S#1 @ 92.0 cm pretreated plant material.

Figure 68. FBVC-14-07 S#1 @ 92.0 cm pretreated organic sediment.
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -25.2 c/ooo : lab. mult = 1)

Laboratory number Beta-382669

Conventional radiocarbon age 3110 ± 30 BP

2 Sigma calibrated result Cal BC 1436 to 1290 (Cal BP 3386 to 3240)
95% probability

Intercept of radiocarbon age with calibration curve Cal BC 1405 (Cal BP 3355)

1 Sigma calibrated results Cal BC 1420 to 1385 (Cal BP 3370 to 3335)
68% probability Cal BC 1340 to 1315 (Cal BP 3320 to 3265)

Database used INTCAL13

References
Mathematics used for calibration scenario
References to INTCAL13 database
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -24.3 o/oo, lab. mult. = 1)

Laboratory number Beta-302670

Conventional radiocarbon age 2970 ± 30 BP

2 Sigma calibrated result Cal BC 1265 to 1110 (Cal BP 3215 to 3060)
95% probability

Intercept of radiocarbon age with calibration curve Cal BC 1210 (Cal BP 3160)

1 Sigma calibrated results Cal BC 1225 to 1155 (Cal BP 3175 to 3105)
68% probability Cal BC 1145 to 1125 (Cal BP 3095 to 3075)

Database used
INTCAL13

References
Mathematics used for calibration scenario
References to INTCAL13 database
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -15.2 o/oo : lab. mult = 1)

<table>
<thead>
<tr>
<th>Laboratory number</th>
<th>Beta-383308</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional radiocarbon age</td>
<td>3890 ± 30 BP</td>
</tr>
</tbody>
</table>

2 Sigma calibrated result  
Cal BC 2470 to 2285 (Cal BP 4420 to 4235)  
95% probability

1 Sigma calibrated results  
Cal BC 2480 to 2335 (Cal BP 4410 to 4285)  
68% probability

Database used
INTCAL13

References
Mathematics used for calibration scenario
References to INTCAL13 database
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -23.7 ofoo. lab. mult = 1)

Laboratory number  Beta-393309

Conventional radiocarbon age  3670 ± 30 BP

2 Sigma calibrated result  Cal BC 2140 to 1965 (Cal BP 4090 to 3905)
   95% probability

Intercept of radiocarbon age with calibration curve  Cal BC 2030 (Cal BP 3980)

1 Sigma calibrated results  Cal BC 2130 to 2085 (Cal BP 4090 to 4035)
   68% probability
   Cal BC 2045 to 2020 (Cal BP 3995 to 3970)
   Cal BC 1990 to 1980 (Cal BP 3940 to 3930)

Database used  INTCAL13

References
Mathematics used for calibration scenario

References to INTCAL13 database

Beta Analytic Radiocarbon Dating Laboratory
4965 S.W. 74th Court, Miami, Florida 33155 • Tel. (305) 607-3187 • Fax: (305) 603-0964 • Email: beta@radiocarbon.com
Page 6 of 6
### REPORT OF RADIOCARBON DATING ANALYSES

**Ms. Leah Colombo**

**Report Date:** 11/5/2014

**Material Received:** 10/28/2014

<table>
<thead>
<tr>
<th>Sample Data</th>
<th>Measured Radiocarbon Age</th>
<th>13C/12C Ratio</th>
<th>Conventional Radiocarbon Age(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta - 394509</td>
<td>30 +/- 30 BP</td>
<td>-9.7 o/oo</td>
<td>430 +/- 30 BP</td>
</tr>
<tr>
<td>SAMPLE : FBVC-14-01 S/3 @ 9.0cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANALYSIS : AMS-PRIORITY delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATERIAL/PRETREATMENT : (shell) acid etch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 SIGMA CALIBRATION : Cal AD 1890 to Post 1950 (Cal BP 60 to Post 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta - 394510</td>
<td>940 +/- 30 BP</td>
<td>-1.4 o/oo</td>
<td>1350 +/- 30 BP</td>
</tr>
<tr>
<td>SAMPLE : FBVC-14-01 S/3 @ 27cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANALYSIS : AMS-PRIORITY delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATERIAL/PRETREATMENT : (shell) acid etch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 SIGMA CALIBRATION : Cal AD 1035 to 1185 (Cal BP 915 to 765)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta - 394511</td>
<td>1080 +/- 30 BP</td>
<td>+1.2 o/oo</td>
<td>1470 +/- 30 BP</td>
</tr>
<tr>
<td>SAMPLE : FBVC-14-07 S/2 @ 75cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANALYSIS : AMS-PRIORITY delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATERIAL/PRETREATMENT : (shell) acid etch</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2 SIGMA CALIBRATION : Cal AD 900 to 1035 (Cal BP 905 to 915)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta - 394512</td>
<td>750 +/- 30 BP</td>
<td>0.0 o/oo</td>
<td>1160 +/- 30 BP</td>
</tr>
<tr>
<td>SAMPLE : FBVC-14-17 S/1 @ 60cm</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ANALYSIS : AMS-PRIORITY delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATERIAL/PRETREATMENT : (shell) acid etch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 SIGMA CALIBRATION : Cal AD 1225 to 1310 (Cal BP 725 to 640)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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Dates are reported as RCYBP (radiocarbon years before present, “present” = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (51995C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 standard deviation; statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotope fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by **a**.

The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -0.7 ± 0.06 ; Delta-R = 33 ± 16 ; Glob res = -200 to 500 ; lab. mult = 1)

Laboratory number Beta-304609

Conventional radiocarbon age 430 ± 30 BP

397 ± 34 Adjusted for local reservoir correction prior to calibration

2 Sigma calibrated result Cal AD 1680 to Post 1950 (Cal BP 60 to Post 0)
95% probability

Intercept of radiocarbon age with calibration curve Post AD 1950 (Post BP 0)

1 Sigma calibrated results Post AD 1950 (Post BP 0)
68% probability

Database used MARINE13

References
Mathematics used for calibration scenario

References to MARINE13 database
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -1.14 o/oo ; Delta-R = 33 ± 16 ; Glob res = -200 to 500 ; lab. mult = 1)

Laboratory number  Beta-394510

Conventional radiocarbon age  1330 ± 30 BP

1297 ± 34 Adjusted for local reservoir correction prior to calibration

2 Sigma calibrated result  Cal AD 1035 to 1185 (Cal BP 915 to 765)

95% probability

Intercept of radiocarbon age with calibration curve  Cal AD 1090 (Cal BP 860)

1 Sigma calibrated results  Cal AD 1055 to 1160 (Cal BP 886 to 790)

68% probability

Database used  MARINE13

References
Mathematics used for calibration scenario

References to MARINE13 database

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -1.2 a/o : Delta-R = 33 ± 16 : Glob res = -200 to 500 : lab. mult = 1)

Laboratory number Beta-394511

Conventional radiocarbon age 1470 ± 30 BP

1437 ± 34 Adjusted for local reservoir correction prior to calibration

2 Sigma calibrated result Cal AD 900 to 1035 (Cal BP 1050 to 915)
95% probability

Intercept of radiocarbon age with calibration curve Cal AD 985 (Cal BP 965)

1 Sigma calibrated results Cal AD 940 to 1010 (Cal BP 1010 to 940)
68% probability

Database used MARINE13

References

References to MARINE13 database
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

Variables: $^{13}C/^{12}C = 0$ a/o; $\Delta$E = $33 \pm 16$; $\Delta$L = $-200$ to $500$; lab. mult = 1

Laboratory number: Beta-394512

Conventional radiocarbon age: 1160 $\pm$ 30 BP

$1172 \pm 34$ Adjusted for local reservoir correction prior to calibration

2 Sigma calibrated result: Cal AD 1225 to 1310 (Cal BP 725 to 840)
95% probability

Intercept of radiocarbon age with calibration curve: Cal AD 1280 (Cal BP 670)

1 Sigma calibrated results: Cal AD 1260 to 1285 (Cal BP 660 to 665)
68% probability

Database used: MARINE13

References:
Mathematics used for calibration scenario

References to MARINE13 database

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