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ANALYSIS OF A SEDIMENT CORE FROM TRIANGLE POND, SAN SALVADOR ISLAND, BAHAMAS: POLLEN, PALEOCLIMATE, HUMAN IMPACTS, AND INSIGHTS INTO LUCAYAN LIFEWAYS

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ABSTRACT. Relatively little is known about the impacts of the prehistoric Lucayan peoples on the flora of San Salvador Island, Bahamas. Previous palynology studies provide suggestive evidence of human disturbance of vegetation (Pacheco and Foradas, 1987; Jones, 1997), but this study is the first collaboration between and archaeologist and a palynologist aimed specifically at studying human alterations of the past vegetation on the island. In May 2005, a 57-cm long sediment core was obtained from Triangle Pond on San Salvador Island. Triangle Pond is located near the Minnis-Ward archaeological site (SS-3). The core was collected in order to provide information about paleoclimatic and paleobotanical conditions near the site in prehistoric times. Based on shells and shell fragments in the lowest portion of the core and bedrock encountered at the base of the core, Triangle Pond appears to have been open to the ocean between about 2700 and 2100 BP. Radiometric dates taken from the core are used to help address this and other chronological issues. Around 1000 ± 40 BP (cal AD 970-1160) and somewhat earlier, nearby terrestrial archaeological deposits of *Cerion* gastropod shells suggest local environmental conditions were generally similar to those of the present day, perhaps more humid. The presence of *Cerion*, as a paleoclimatic indicator, suggests there was a moist leaf litter environment associated with the ground surface. A significant increase in charcoal concentrations in Triangle Pond sediments at 35 cm depth, around 950 BP (ca. AD 1000, age-depth model estimation), is explicable by prehistoric Lucayan slash-and-burn agricultural practices; evidence for later burning at 28-30 cm depth may be attributable to English colonial farming practices, which were radiocarbon dated to 180 ± 20 BP (cal AD 1730-1810). Identification of pollen represented throughout the sediment core indicates the presence of many taxa that were available as utilitarian plants to the Lucayans (various mangrove, myrtle, palm, and other species used for wood, firewood, medicine, fiber, thatch, etc.); other pollen taxa (sedges, grasses, including *Zea mays*, and disturbance indicators) indicate human alteration of the local vegetation from prehistoric to historic and modern times (ca. 950-0 BP, or AD 1000-1950).

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INTRODUCTION

Paleoecological studies show clear indications that the Lucayans, the pre-Columbian inhabitants of the Bahamas, had a detectable impact on the environment of the Bahamas. One of the first of such studies was conducted by Kjellmark (1996) on Andros Island, Bahamas. He found evidence of a distinct spike in charcoal and a shift from hardwood coppice to pinewoods vegetation in sediments dating to ca. 800 BP (ca. AD 1150). Kjellmark also found indications that these changes were preceded by modest increases in charcoal and pinewoods flora ca. 1000-900 BP (AD 950-1050). Slayton (2010) found evidence of a similar shift from hardwoods to pinewood vegetation on Abaco

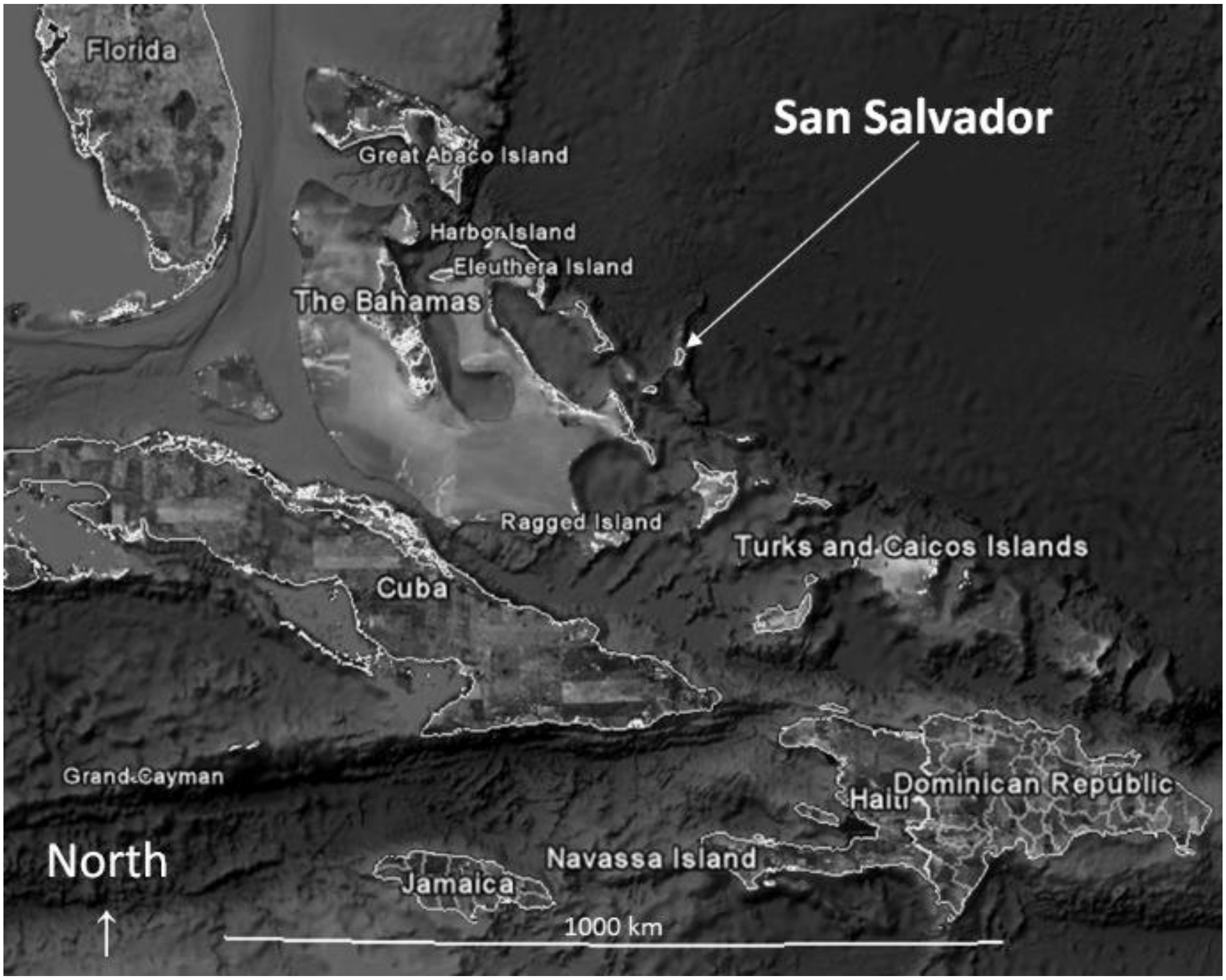

Figure 1. Map of the Bahamas showing location of San Salvador in east-central Bahamas (2012 GoogleEarth image modified by J. Blick).

Island, Bahamas in sediments dating to ca. 1000 BP with the highest levels of charcoal occurring in sediments dating to ca. 800-600 BP (AD 1150-1350). Evidence of Lucayan colonization of San Salvador Island, Bahamas (Figure 1) dates to somewhat earlier than colonization of the more northerly islands. Berman and Gnivecki (1995) and Berman and Pearsall (2000) suggest that the earliest colonization of San Salvador by Lucayans dates to ca. 1300-1100 BP. Niemi, et al. (2008) report an increase in concentrations of trace elements in sediments from San Salvador dating to ca. 1300-1100 BP which they attribute to increased soil erosion resulting from land disturbance associated with the arrival of the Lucayans on the island. Numerous archaeological studies on San Salvador indicate Lucayan presence on the island during the period ca. AD 650-1500 (Berman and Gnivecki, 1995; Berman and Pearsall, 2000; Blick, 2007; Shaklee, et al., 2007; Berman and Pearsall, 2008; Blick, et al., 2010; Blick, 2012; to name just a few). This study represents one of a very few collaborations between a palynologist and an archeologist specifically aimed at studying the impacts of the prehistoric Lucayans on the vegetation and fire history of San Salvador Island (see also Pacheco and Foradas, 1987; Jones, 1997).

METHODS

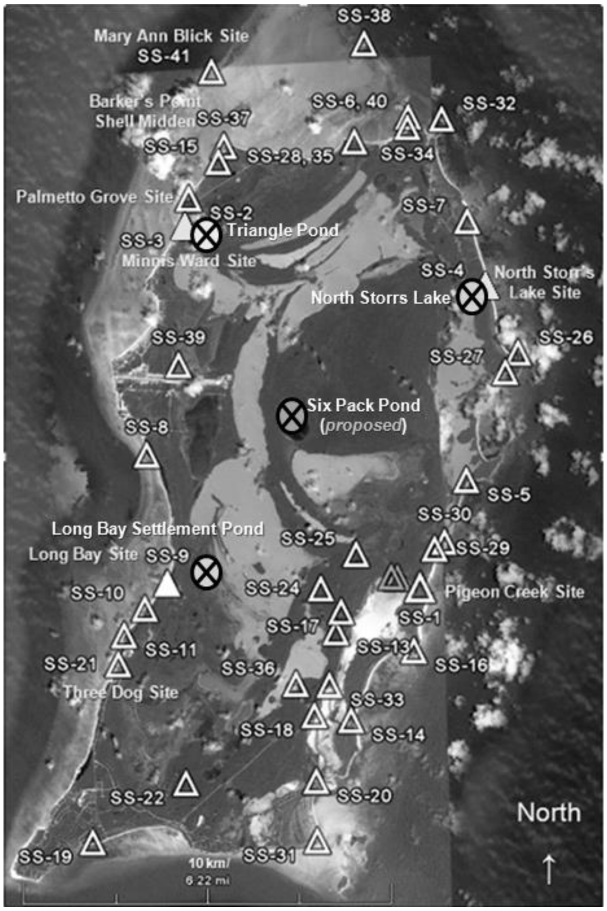

Figure 2. Map of San Salvador showing archaeological sites (triangles) and pollen core sample sites (⊗). Triangle Pond is located in the NW corner of the island near the Minnis-Ward archaeological site (SS-3). So far, we have obtained five sediment cores for pollen analysis: one each from Triangle Pond, Long Bay Settlement Pond, North Storr's Lake (May 2005), and, most recently, two from Six Pack Pond (June 2012) (2012 GoogleEarth image modified by J. Blick).

Kjellmark and Blick began a paleobotanical and palynological project on San Salvador in May of 2005. Kjellmark sampled several lakes and ponds (Figure 2) and successfully recovered sediment cores using a modified Livingston piston coring device fitted with 1.5 inch (3.81 cm) Schedule 40 PVC pipe (Figure 3). Cores were obtained from North Storr's Lake, Long Bay Settlement Pond, and Triangle Pond near the Minnis-Ward site archaeological site. After the cores were raised, their ends were sealed and they were prepared for transport. The cores ranged from 57 cm to 110 cm in length.

Figure 3. Eric Kjellmark returning to shore with sediment core obtained using a hand-held modified Livingston piston coring device (photo by J. Blick).

This paper focuses on the results from the analysis of the core taken at Triangle Pond (Figures 4 and 5). This core was 57 cm long and includes the complete sediment succession down to bedrock. Triangle Pond is a small hypersaline water body (up to 4x saltier than seawater) and about 60 cm (2 feet) in average depth at the time it was cored (2005 was an unusually dry year on San Salvador). Park (2012), in her model of lake formation on carbonate platforms, classifies Triangle Pond as a cutoff lagoon, similar to Storr's Lake.

The sediment cores were transported to Florida Southern College for analysis. The Triangle Pond core was opened in February 2006 by cutting the PVC pipe lengthwise with a circular saw. The

Core Depth (cm)	Radiocarbon Age BP (±1σ) & Lab No.	cal Date (2σ)	Material
11	0 (modern) (UGAMS 10495)	AD 1950	leaf fragment
28-30	180 ± 20 (UGAMS 10496)	AD 1730-1810	bark fragments
35	---	~AD 1000	charcoal fragments
43	2450 ± 25 (UGAMS 10497)	360 BC-AD 100	articulated bivalve* (clam)
50-53	2090 ± 25 (UGAMS 12731)	180-50 BC	peat
54	2360 ± 25 (UGAMS 12732b)	250 BC-AD 240	articulated bivalve* (clam)
54	2610 ± 25 (UGAMS 12732a)	570-40 BC	gastro-pod* (snail)

*Table 1. Radiocarbon ages, depths, calibrated dates (BC/AD), and materials dated from the Triangle Pond sediment core. Radiocarbon ages and calibrated dates have been rounded to the nearest decade according to convention. *The marine reservoir correction has been applied to all dates on shell (ΔR = 25, ± = 91, based on average marine correction of the three nearest Bahamian sites) (Calib 6.0).*

sediments were then split with a knife and the appearance of the core was immediately recorded. The color variations in the sediments were noted by comparison to a Munsell soil color chart (Munsell, 2000). Two cubic centimeters (cc) of sediment were removed at 5 cm intervals from the top of the core down to the 55 cm level. The sediments were processed for palynological study using the methods described in Faegri and Iversen (1989). Slides were prepared from the sediment residues and pollen grains were counted at 400x magnification by scanning back and forth across the slide. At least 400 pollen grains were counted at each level unless one pollen type made up more than 50% of the total. In such cases, pollen counts continued at that level until at least 200 pollen grains other than the dominant pollen type were encountered. The percentage of each pollen type is reported for each sampling level. One pollen type, *Salicornia*-type, was overwhelmingly abundant at several levels. To prevent *Salicornia*-type from obscuring the patterns of other pollen types, the percentage of *Salicornia*-type was calculated using the total pollen counted at each level while the percentages of all other pollen types were calculated using the total for non-*Salicornia*-type pollen.

Pollen grains were identified to the lowest taxonomic classification possible by comparing grains in the sediment samples to reference slides of known pollen types from the Bahamas, the Caribbean, and Central America. The Key to the Pollen Flora of the Bahamas (Snyder, et al., 2007) was also used extensively as a resource. Taxonomy follows Correll and Correll (1982). Some commonly encountered pollen types were not positively identified. In such cases, the pollen type was given a label such as “Unknown 12” and the total for that particular pollen type was tracked in the same manner as the known pollen types.

To count charcoal particles, the core was resampled in July of 2010 at the same 5 cm intervals, but this time only 1 cc of sediment was removed and processed. Charcoal counts continued at each level until the entire residue from each 1 cc sample was exhausted. The total counts from each level were used to calculate the amount of charcoal particles per cc. Only opaque, black particles with jagged edges were counted as charcoal particles to distinguish them from pyrite particles also found in the sediment.

Two sets of AMS radiocarbon dates were obtained from the University of Georgia Center for Applied Isotope Studies. In the first set, one date

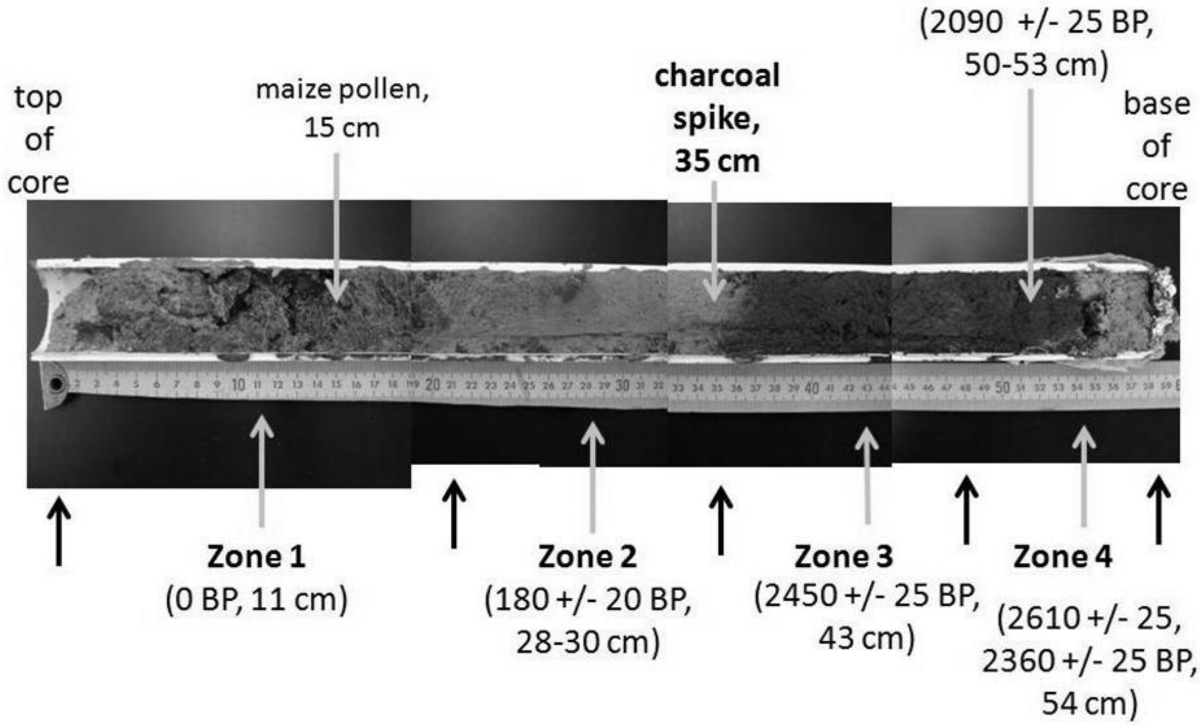

Figure 4. Triangle Pond sediment core showing pollen zones and radiocarbon dates. Black arrows indicate pollen zones; lighter arrows indicate radiocarbon dates or other points of interest (e.g., charcoal spike). Photos by E. Kjellmark modified by J. Blick.

was from a leaf fragment at 11 cm depth, a second was from bark fragments at 28-30 cm depth, and the third was from a small bivalve (clam) shell at 43 cm depth. The second set of dates was obtained on organic peat from 50-53 cm depth, and one date each on a gastropod (small snail) and another small bivalve (clam) shell, both from 54 cm depth. The mollusks have not been identified to genus or species.

RESULTS

Core Description & Radiocarbon Dates

Figure 4 shows the lithology and Table 1 shows the six radiocarbon dates for the Triangle Pond sediment core. The sediment from the base of the core, 57-54 cm, is composed of medium tan calcareous sand (2.5YR 6/3, all colors are Munsell wet colors). Both halves of an articulated marine bivalve (clam) shell and several specimens of a benthic marine foraminifer (provisionally identified by Blick as *Rotorbinella rosea*, d'Orbingy, 1839; FEUPT, 2012; Gupta, et al., 2009) (Figure 6) were found in the basal sandy sediments. If the foraminifer species found in the lowest sediments is indeed *Rotorbinella rosea*, it is a Holocene, benthic marine, reef-dwelling, algae-eating species, that typically lives in ca. 5-20 m of water. *R. rosea* is considered a good environmental indicator, with known distribution in the Caribbean and in the western North Atlantic (Bahamas, Cuba, Florida, Puerto Rico, Georgia, North Carolina) (Beach and Trumbull, 1981; Jones, 1994; Hayward, 2012). Furthermore, its reported relatively large size makes it less likely to be re-deposited, for example, in a storm surge (Beach and Trumbull, 1981).

The bivalve from 54 cm depth dates to 2360 ± 25 BP and the gastropod shell from 54 cm depth dates to 2610 ± 25 BP (see Table 1 for lab nos.). The sediment from 54-48 cm is composed of dark brown (10YR 2/1) peat. Peat from 50-53 cm

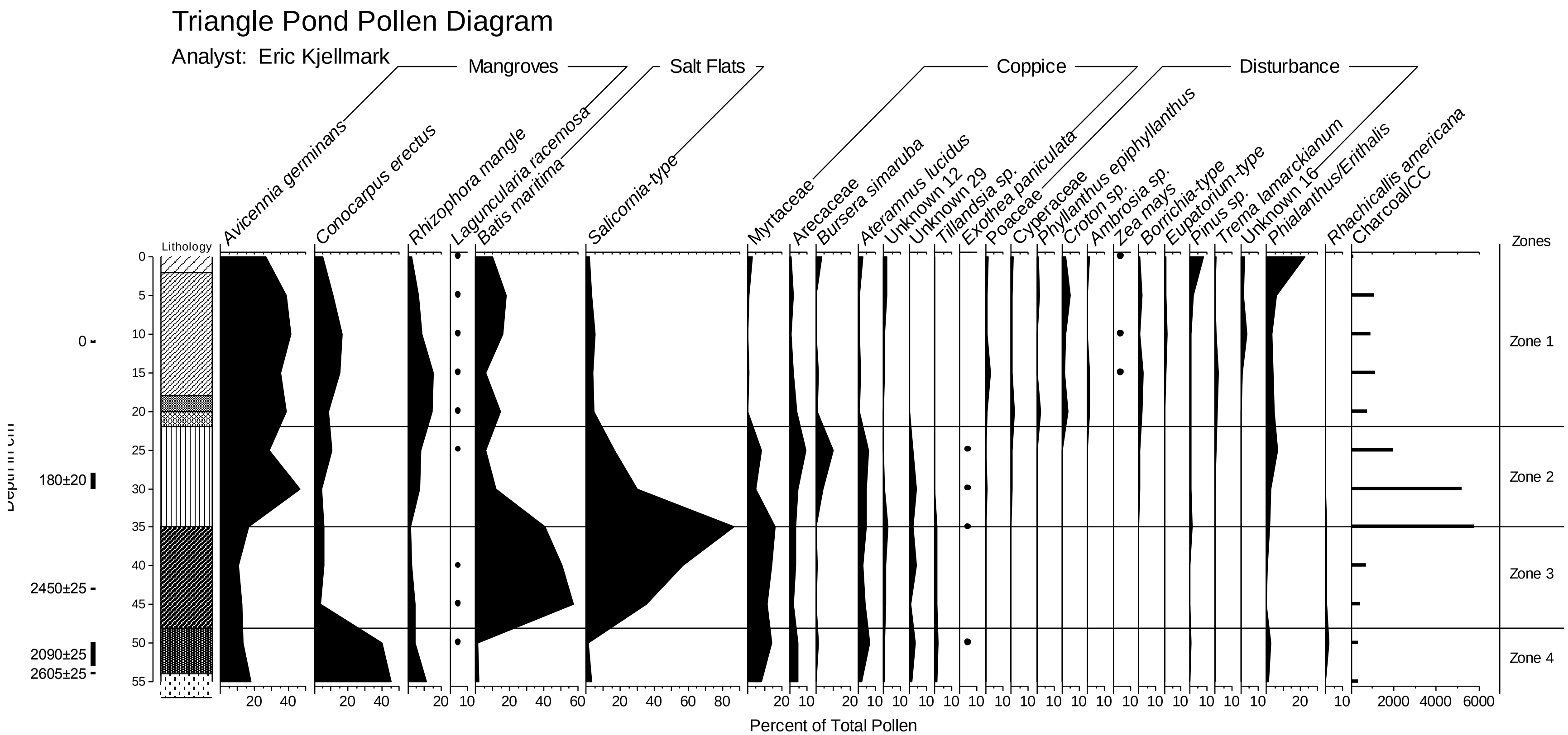

*Figure 5. Pollen diagram for Triangle Pond. The Y axis of the pollen diagram indicates the depth of the core in centimeters. The "Lithology" graph next to the Y axis indicates the changes in sediment type with depth (see text for detailed description of sediment types). The X axes on next series of vertical graphs shows the percentages of each indicated pollen type with depth. Pollen types represented by dots rather than graphs, i.e., white mangrove (*Laguncularia racemosa*), butterbough (*Exothea paniculata*), and corn (*Zea mays*), were rare but significant pollen types, indicated by presence only rather than percentage. The last graph (far right) shows the number of charcoal grains counted per cc of sediment. Pollen types are grouped into community associations based on the known habitats of the different species. Horizontal lines indicate qualitative zones based on distinct changes in the pollen percentages. NOTE: The percentage for* Salicornia-*type pollen was calculated separately from all other pollen types, therefore the total percentages add up to more than 100.*

depth dates to 2090 ± 25 BP. The sediment just above this at 48-35 cm is composed of brown (7.5YR 2.5/1) peat. The bivalve extracted from 43 cm depth dates to 2450 ± 25 BP. Above 35 cm, there is a distinct shift to calcareous mud with sediments from 35-22 cm depth being medium tan

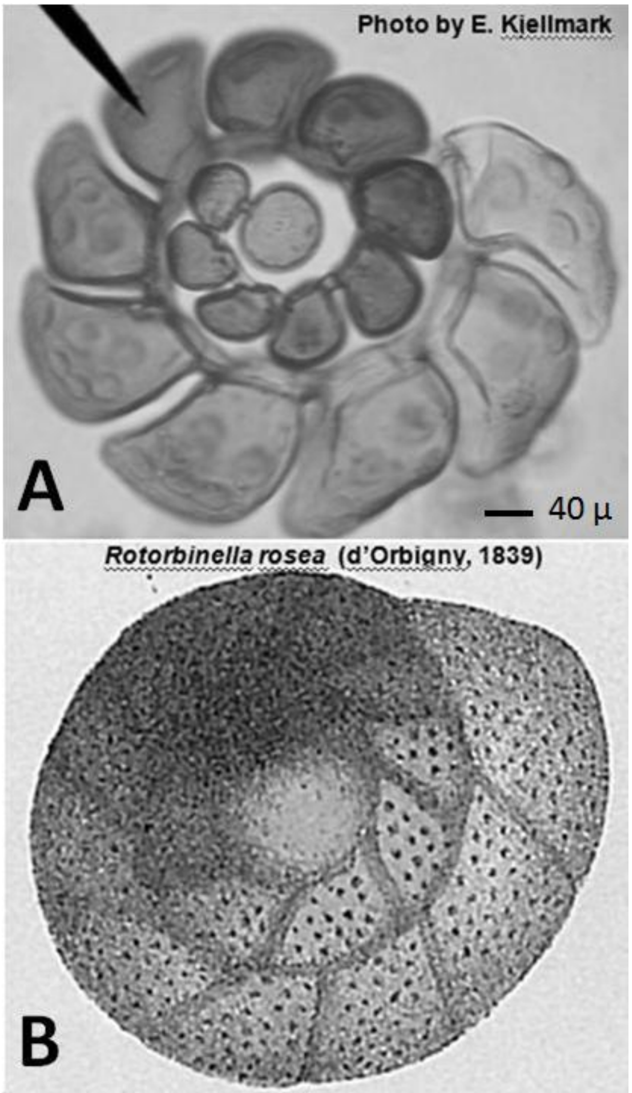

Figure 6. Foraminifera images. A. Microscopic image of endocast of foraminifera recovered by Kjellmark during pollen analysis of Triangle Pond sediments (scale approximately 40 μ long, photo by E. Kjellmark). B. Sketch of the foraminifera Rotorbinella rosea *(from Jones, 1994, Pl. 96, Fig. 1, no scale provided in original for illustration B) for comparison to the Triangle Pond foraminifera.*

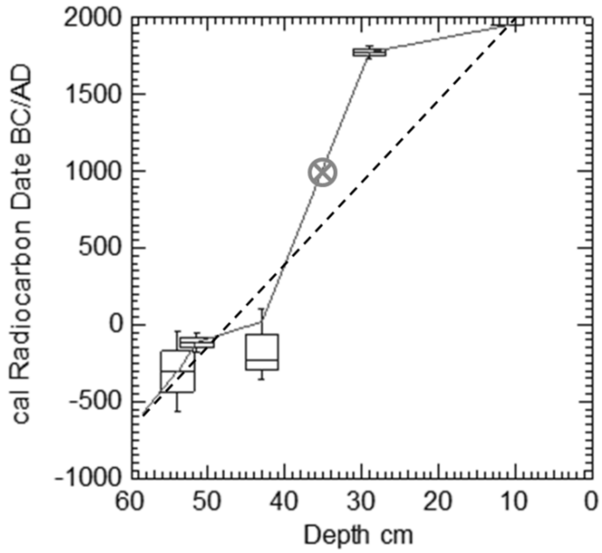

Figure 7. Age-depth model for Triangle Pond sediment core. Calibrated AMS radiocarbon dates (boxes) are placed in order by depth (excluding the outlying 2360 ± 25 BP date at 54 cm for clarity) within their 95% confidence intervals (solid line). The dashed line represents a linear sedimentation rate. In the age-depth model, the charcoal spike at 35 cm (⊗) occurs ca. 950 BP (ca. AD 1000), likely coincident with Lucayan agriculture. Note the rapid increase in sedimentation occurring 180 ± 20 BP (cal AD 1730-1810), possibly as a result of European-style agricultural practices (age-depth model based on Blaauw and Christen, 2011:465, 467, Figures 2 and 3).

in color (10YR 5/3). The bark fragments extracted from 28-30 cm depth date to 180 ± 20 BP. From 22 to 20 cm depth, the sediment is paler brown (2.5Y 3/2), then there is a darker band from 20-18.6 cm (10YR 2/2). At 18.6-18.5 cm there is lighter colored band (10YR 5/3) followed by a dark brown band from 18.5-18 cm (2.5YR 2.5/1). From 18-2 cm, the sediment is gray-brown in color (2.5YR 3/3) with the leaf fragment extracted from 11 cm depth dating to 0 BP. The top 2 cm of sediment are pinkish tan in color (10YR 5/3).

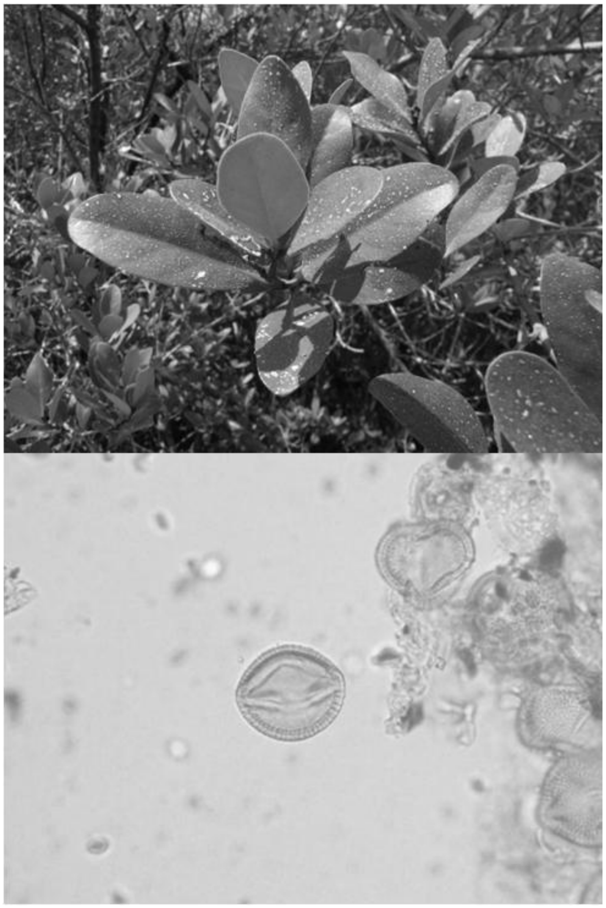

*Figure 8. Black mangrove (*Avicennia germinans*) and its pollen (photos by E. Kjellmark).*

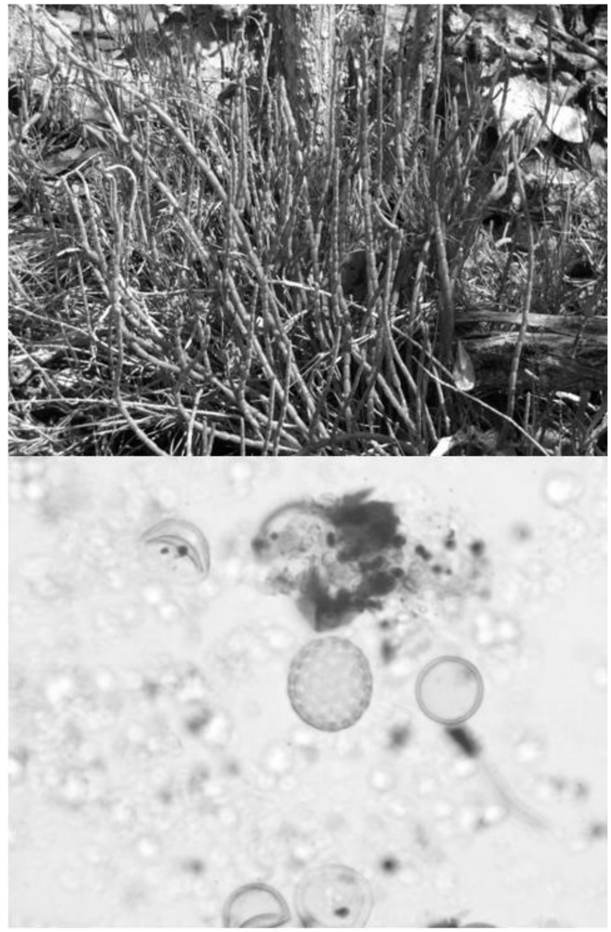

*Figure 9. Glasswort (*Salicornia perennis*) and its pollen (photos by E. Kjellmark).*

Sedimentation Rate

Using AMS radiocarbon dates and the distance in cm of depth between those dates, it is possible to calculate the sedimentation rate (SR) in the core. Knowing the SR allows calculation of the approximate ages of given depths or the ages of certain events represented by changes in sediment type, charcoal abundance, etc., in the core. Calculating a linear (average) SR from the midpoint of the highest (most recent) known date in the core (at 11 cm) to the deepest (oldest) known date in the core (at 54 cm depth) yields a SR of 1 cm/52 yr. For example, the linear sedimentation rate results in an age estimate for the charcoal spike of ca. 1120 BP (midpoint) or approximately AD 790-870.

Since there are numerous caveats to using a linear SR (e.g., Bennett, 1999; Ramsey, 2006; Blaauw and Christen, 2011; etc.), calculation of the approximate ages of given depths was made using an age-depth model (Figure 7). The age-depth model is based on calibrated AMS radiocarbon dates and their 95% error ranges placed in order by depth (excluding the statistically outlying 2360 ± 25 BP date, one of two dates from 54 cm depth), yielding an approximate age of the charcoal peak at 35 cm depth of 950 BP (ca. AD 1000) (Figure 7). The compaction rate in the core appears to be negligible or minor due to the shallow nature of the core (less compaction) and based on comparison to another core from Triangle Pond of a similar depth (Ameis and Niemi, 2012).

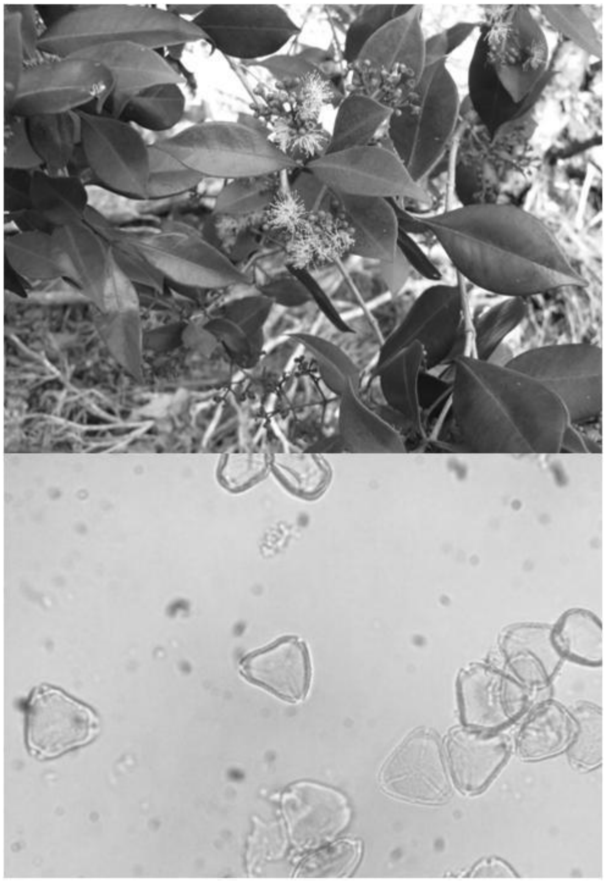

*Figure 10. Spicewood (*Calyptranthes pallidus*), Myrtaceae, and its pollen (photos by E. Kjellmark).*

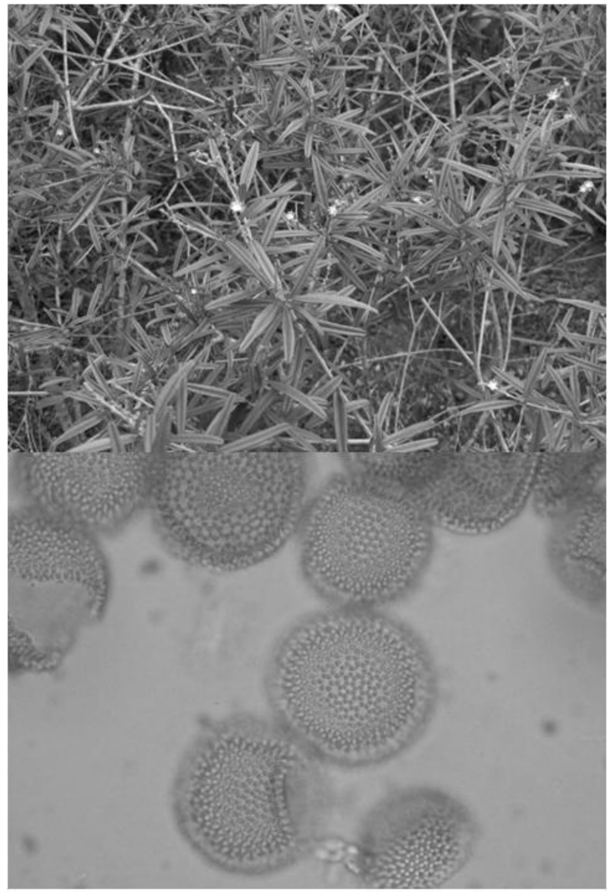

*Figure 11. Grannybush (*Croton linearis*) and its pollen (photos by E. Kjellmark).*

Noteworthy in the core is the dramatic increase in sedimentation rate 180 ± 20 BP (cal AD 1730-1810) likely attributable to Loyalist agricultural and animal husbandry practices (Figure 7). The SR between 180 BP and 0 BP (modern) is 1 cm/10 yr (18 cm in a 180-year period), more than 5x the average SR in the core. A Caprinae (Barbadan sheep?) bone found at the nearby Minnis-Ward archaeological site in the 10-20 cm level, dated to 170 ± 40 BP (cal AD 1720-1890) (Blick, et al., 2010), would seem to indicate historical-era farming practices and the presence of grazing animals perhaps responsible for the increased sedimentation during historic times.

Chronology of the Core

The chronology of the core spans some 2500 years (2610 ± 25 to 0 BP, i.e., cal ~500 BC to modern) whether based on radiocarbon yr BP or calibrated dates. Using the SR of 1 cm/52 yr, the base of the core (57 cm depth) calculated downward from the earliest AMS date would be dated to cal 470 BC (midpoint) or perhaps as old as cal ~730 BC. The presence of several specimens of a benthic marine foraminifer (Figure 6) at 57 cm depth and a gastropod and an articulated marine bivalve at 54 cm depth indicates that Triangle Pond was open to the ocean around 2450 BP ± 250 yr. At the 50-53 cm level, a sample of peat was dated to 2090 ± 25 BP (cal 180-50 BC) indicating that Triangle Pond had been sealed off from the ocean prior to this time and had become a quiet mangrove pond similar to those commonly found on San Salvador today. A second articulated bivalve, this one from within the peat layer at 43 cm depth dated to 2450 ± 25 BP (cal 360 BC-AD 100), although technically out of chronological order, can be successfully placed within the age-depth model (Figure 7), particularly given the wide error range of the calibrated date (460 yr). One caveat regarding the AMS dates on shell is the fossil carbon uptake from the carbonate substrate (Keith and Anderson, 1963). If the gastropod at 54 cm depth is a terrestrial snail and if the bivalve is truly marine, then the marine reservoir correction factor can be calculated as approximately 250 yr (2610 ± 25 BP minus 2360 ± 25 BP) (Doug Dvoracek, personal communication), i.e., the shell dates may appear to be about 250 yr older than their actual age. The peak in charcoal concentration at 35 cm depth is estimated to date to ca. AD 790-870 (midpoint AD 830) using a best fit line method, or to ca. AD 1000 using the age-depth model (Figure 7). In either calculation, the charcoal spike appears to be pre-Columbian. The bark fragments from the 28-30 cm zone are dated to 180 ± 20 BP (cal AD 1730-1810) and thus correlate in time with the historical Loyalist period on San Salvador, ca. AD 1780-1834. The 0 BP date at 11 cm depth seems to date the top of the core to recent times, although modern debris pushed downward by the coring device could be an explanation for this late date.

The Triangle Pond Pollen Diagram

The pollen diagram (Figure 5) is based on data collected from the Triangle Pond sediment core. The pollen types are grouped into community associations based on the typical habitats of each species. If a pollen type was not identified to species, it was grouped into the community that had the most similar pattern of percentages over time. There are four groups. The first group, "Mangroves," includes the four mangrove species found on San Salvador: black mangrove (*Avicennia germinans*) (Figure 8), buttonwood (*Conocarpus erectus*), red mangrove (*Rhizophora mangle*), and white mangrove (*Laguncularia racemosa*). The second group, "Salt Flats," includes two herbaceous plants that are characteristic of wet salty mudflats: saltwort (*Batis maritima*) and glasswort (*Salicornia*-type) (Figure 9). While saltwort pollen can be positively identified, pollen in the family to which glasswort belongs is very similar among many species and genera, so this pollen type cannot be identified to species level with certainty. Given the habitat, and the current abundance of glasswort around the site today, *Salicornia* sp. is the most likely source of this pollen, so this pollen type is referred to as glasswort while recognizing that other genera cannot be ruled out. The third group, "Coppice," includes species that typically grow in hardwood stands on San Salvador such as tourist tree (*Bursera simaruba*), butterbough (*E. paniculata*), Myrtaceae (Figure 10) (impossible to identify species), and palms (Arecaceae, difficult to identify species). These stands are called "coppices" in the Bahamas. A species of the bromeliad *Tillandsia* (likely wild pine, *Tillandsia utriculata*) is also included in the "Coppice" association. Wild pine is often abundant in tall coppices, though it is also commonly found as an epiphyte in taller mangrove swamps. Two of the pollen types are unidentified, but the pattern of variation in their percentages closely matches that of the other coppice pollen types so they are included in this group. The fourth group, "Disturbance," includes species that are characteristic of, or more common on, disturbed land or areas that are frequently burned. Among the numerous species in this category are grasses (Poaceae, impossible to identify to genus or species level with rare exceptions), sedges (Cyperaceae, also generally difficult to identify genus or species), ragweed (*Ambrosia* sp.), *Croton* sp. (likely grannybush, *Croton linearis*) (Figure 11) and of particular interest, corn (*Zea mays*). The pine pollen (*Pinus* sp.) found in the core is almost certainly from long-distance transport from either the northern Bahamas or the southeastern U.S. Bahamian pine (*Pinus caribaea* var. *bahamensis*) is typical of frequently burned area on the northern pine islands. The last two pollen types on the diagram were relatively well-represented in the sediments, but did not conform to the variations in percentages of any of the four designated community associations. One of these pollen types is *Phialanthus/Erithalis*. Pollen from *Phialanthus myrtylloides* and *Erithalis fruitcosa* (both Rubiaceae) is very similar and cannot be reliably distinguished. Both of these species are low to medium size shrubs that typically grow on open disturbed sites or in low coastal coppices. The other pollen type is from *Rhachicallis americana*, a small, slender, salt-tolerant shrub typical of sunny coastal rockland or rocky edges of tidal creeks and lakes.

The horizontal lines across the pollen diagram indicate qualitative zones that represent significant shifts in percentages of pollen in the different community associations. In Zone IV, buttonwood dominates the pollen spectrum while black mangrove, red mangrove, and Myrtaceae pollen are also well-represented. In Zone III, buttonwood pollen declines to much lower levels, black mangrove, red mangrove, and Myrtaceae pollen remain relatively steady, while pollen from saltwort and glasswort increases to dominate the pollen spectrum. In Zone II, black mangrove more than doubles in abundance, becoming the dominant species in the pollen spectrum, while buttonwood remains relatively low, and red mangrove gradually increases. Both saltwort and glasswort decline through Zone II as does pollen from Myrtaceae. In Zone I, black mangrove remains the dominant species in the pollen spectrum while red mangrove and buttonwood gradually increase, then slowly decline toward the top of the diagram. Glasswort and saltwort pollen are both present at low to modest levels, but pollen from all species in the coppice group is at lower levels than in any other zone. Pollen types from species in the disturbance group either appear for the first time or increase to low, but significant, abundances in Zone I.

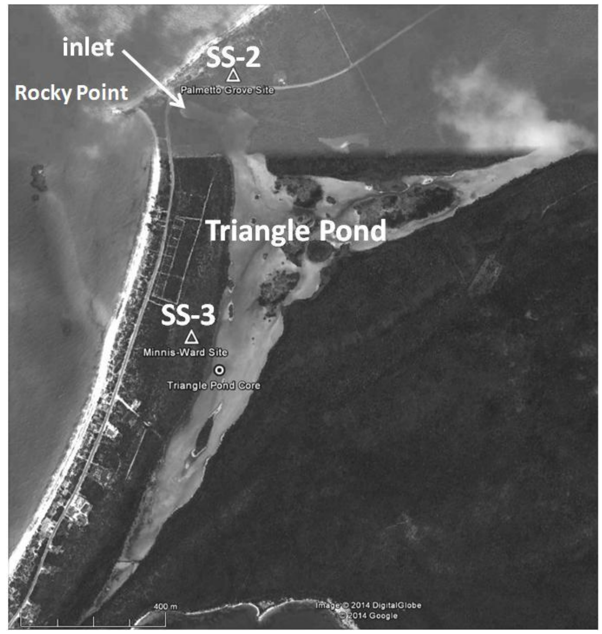

Figure 12. Location of Triangle Pond in relation to nearby archaeological sites, Minnis-Ward (SS-3) and Palmetto Grove (SS-2). The ancient inlet from the ocean to Triangle Pond entered north of Rocky Point and WSW of Palmetto Grove (north is at top of map, distance between SS-2 and SS-3 is ca. .77 km) (2014 GoogleEarth image modified by J. Blick).

Other species present in the core, but not listed on the diagram include low pollen producers, rare species, and some pollen or spore types blown in from afar. Among these are the giant leather mangrove fern (*Achrosticum* sp., probably *A. aureum*), a high intertidal zone species; *Bumelia* sp. (probably *B. americana*), a coppice/coastal shrub, and a pioneer species, wax myrtle (*Myrica cerifera*), which has medicinal properties; the irritant poisonwood (*Metopium toxiferum*); West Indian mahogany (*Swietenia mahogani*), likely used for making dugout canoes and wooden objects; and *Cordia* sp. (perhaps *C. sebastina* or *C. bahamensis*).

Charcoal Results

The number of charcoal particles per cc varies with depth in the Triangle Pond core (Figure 5). In Zones IV and III, charcoal particles show a gradual increase from 327 grains per cc at 55 cm depth to 731 grains per cc at 40 cm depth. At the base of Zone II, 35 cm depth, charcoal particles spike to a high of 5829 particles per cc. Charcoal particles remain abundant, but gradually decline through Zone II decreasing to 5195 per cc at 30 cm depth and then to 2019 per cc at 25 cm depth. Charcoal particles vary between approximately 700-1100 per cc in Zone I, reaching a low of 144 per cc at the top level of the core.

DISCUSSION

Lithology of the Triangle Pond Core

Shifts in the sediment texture and type in the Triangle Pond sediment core indicate that the pond has experienced significant changes over time (Figure 5). During processing, the sandy sediment sample from 55 cm depth showed vigorous reaction during treatment with 10% HCl indicating high levels of carbonates. A calcareous sandy substrate, with mollusk shell fragments, an articulated shell from a marine bivalve, and benthic marine foraminifers likely *Rotorbinella rosea* (Figure 6) in the bottom of the core suggest that Triangle Pond was once a tidal lagoon connected to the ocean via an opening northwest of the pond and north of Rocky Point (Figure 12). This interpretation agrees with that of other geologists whose teams have also recently cored Triangle Pond and other ponds on the island (Niemi, et al., 2008; Dalman and Park, 2010; Ameis and Niemi, 2012; Park 2012).

All samples from 50 to 35 cm depth, the peat zone, showed very little reaction to HCl, indicating very low levels of carbonates. The peat layer extending from 54 to 35 cm depth may have two possible origins. The water level in Triangle Pond may have been lower than today with herbaceous plants and wetland shrubs growing on a mudflat and shedding leaves and branches directly on the coring site. Alternatively, the pond may have been a mangrove swamp with a dense canopy of mangrove trees shedding leaves and branches into shallow water at the core site. In either case, there is little indication of erosion of calcareous sediments or clays into Triangle Pond at this time since the sediment is composed almost entirely of organic matter. Furthermore, the lack of coarse grains in the sediment indicates that the pond was a quiet, enclosed water body not subject to strong currents as is suggested by the presence of sandy sediments below the peat.

All samples of the tan muds from the 35 cm level and above showed vigorous reaction during treatment with 10% HCl, indicating high levels of carbonates in the sediment. The calcareous mud from 35 cm depth to the surface is typical sediment for an enclosed, shallow, hypersaline pond with open surface water, which is the current condition of Triangle Pond. There are currently no mangroves or other emergent plants growing in the water away from the shore of the pond.

Triangle Pond Pollen Analysis

The changes in the percentages of the pollen types indicate changes in the pond, as well as the land immediately surrounding it. Among the four species of mangroves present in the Bahamas, black mangrove and red mangrove are the most tolerant of continuous sea water inundation. These are well represented in the pollen diagram from Triangle Pond (Figure 5). Buttonwood mangrove is less tolerant of continuous inundation than the other mangroves, but produces pollen more abundantly than black or red mangrove. It currently grows away from the very salty water of the pond.

The pollen from Zone IV, the 50 and 55 cm sampling levels, shows buttonwood mangrove at its highest level with black mangrove also well-represented, while saltwort and glasswort are at low levels (Figure 5). As mentioned above, buttonwood is less tolerant of continuous inundation than black or red mangrove. The high abundance of its pollen along with the different sediment in the lowest part of the core suggests that the water in the pond was shallower than today or that a broad, rarely flooded, mudflat was present at the core site. The modest amounts of black mangrove pollen in these lowest two levels suggest that this species was common around the core site, perhaps growing in the permanently inundated parts of the pond. The very low levels of glasswort and saltwort suggest that either the water depth was too great for these species or that these high-light requiring plants were being shaded by a dense growth of shrubs or trees, most likely buttonwood and black mangrove. It is noteworthy that while there is a distinct shift in sediment type from calcareous sand and shell fragments to peat between 55 and 50 cm depth, the pollen spectrum remains relatively stable. This suggests that the change in sediment was not the result of a significant shift in climate or other factors that would have altered the vegetation in and immediately around the pond. One explanation for the shift in the sediment, but not in the vegetation, is that the opening of what may have been a lagoon with active water flow was closed off (ca. 2090 ± 25 BP or earlier), resulting in a quieter water body that allowed leaf litter and organic debris to accumulate on the bottom.

Three radiocarbon dates suggest that the calcareous sands in the lowest part of the core date to earlier than ca. 2100 BP. A bivalve shell from 54 cm depth dates to 2360 ± 25 BP and a gastropod shell from the same level dates to 2610 ± 25 BP. Peat taken from 50-53 cm depth dates to 2090 ± 25 BP. While the mollusk shells are significantly older than the peat just above them, it is possible that the mollusks were incorporating fossil carbon from the carbonates in the sandy sediments below (Keith and Anderson, 1963) or that they were re-deposited from older sediments.

There is a subtle shift in the color of the peat in the core at 48 cm depth, the bottom of Zone III. Unlike the change from sand to peat at 54 cm, the shift in peat color at 48 cm is accompanied by a distinct shift in the pollen spectrum (Figure 5). Buttonwood pollen declines sharply while black mangrove pollen remains relatively stable. Glasswort pollen and saltwort pollen go from low percentages to become the dominant pollen types in Zone III, suggesting that these were the dominant species growing around the core site. Today on San Salvador, saltwort and glasswort can form extensive, very dense monocultures on salty mudflats. The two species often grow commingled. They cannot tolerate inundation and they cannot compete with plants in well drained sites. The overwhelming abundance of glasswort pollen at 40 and 35 cm depth suggests that this species was growing directly on, or very close to, the core site rather than washing in or blowing in from some distance away. A bivalve shell from 43 cm depth dates to 2450 ± 25 BP, older than the peat from 50-53 cm, but, as mentioned above, the shell may have been incorporating older carbon from the sediments at the bottom of the pond or the shell may have been re-deposited into the peat from older sediments.

All three mollusk shells dated from the lower portion of the core fall between approximately 2600 and 2300 BP. If these mollusks are indeed incorporating fossil carbon, it suggests that the carbonate sediments below the peat are no younger than 2600 to 2300 BP. As the bottom of the peat dates to 2090 ± 25 BP, it suggests that what was a lagoon open to the ocean became a closed off pond by ca. 2100 BP. However, the lowest sediments have not been bulk analyzed to test this hypothesis.

At the 35 cm level, the bottom of Zone II, there is another distinct shift in sediment type from peat to calcareous mud (Figure 5). The sediment sample extracted for pollen analysis came from the top of the peat layer. The pollen spectrum shows a shift above this point with black mangrove rising to dominance while both saltwort and glasswort decline significantly. The most noteworthy change in Zone II, however, is the spike in charcoal particles in the sediments (Figure 5). Charcoal particles show a gradual increase from 327 grains per cc at 55 cm to 731 grains per cc at 40 cm depth. At the 35 cm level, charcoal particles spike to a high of 5829 particles per cc. Charcoal particles remain abundant, but gradually decline through Zone II to 5195 per cc at 30 cm depth and then 2019 per cc at 25 cm depth. A sudden spike in charcoal particles in sediments followed by a gradual decline over several levels is correlated with the arrival of the Lucayans on Andros Island (Kjellmark, 1996) and Abaco Island (Slayton, 2010). Berman and Gnivecki (1995) and Berman and Pearsall (2000) suggest that the earliest colonization of San

Salvador by Lucayans dates to ca. 1300-1150 BP (ca. AD 650-800), so the charcoal spike in the Triangle Pond sediment core probably dates to the same period. Occupation of the nearby Minnis-Ward site dates to 1000-520 BP, that is to AD 950 or earlier, up until at least AD 1430, and perhaps a little later (Blick, et al., 2010: 26, Table 2).

Though the significant increase in charcoal particles suggests an increase in fire on San Salvador, the pollen spectrum from Zone II does not show major changes in the coppice or disturbance species, indicating that most of the vegetation around Triangle Pond was not affected in a detectable way by the Lucayan presence. One species does show an interesting change however. Pollen from *Tillandsia* sp., likely wild pine (*Tillandsia utriculata*) is present in modest amounts until the charcoal spike, above which it was no longer found in the sediment. Wild pine is slow-growing epiphyte or understory plant and cannot tolerate fire. Its absence above the charcoal spike suggests that the stature or density of the vegetation may have been changed even if the species composition was not detectably altered.

The rise in black mangrove pollen and the decline in saltwort and glasswort pollen reflect changes occurring in the pond or on its shoreline. Both saltwort and glasswort are edible plants and may have been harvested by the Lucayans, accounting for their decline in the pollen spectrum. Alternatively, the increase in black mangrove may suggest an increase in water depth in the pond which would have flooded the mudflats where glasswort and saltwort grew, perhaps due to increasing rainfall/moisture ca. 950 BP suggested by other evidence for this time period (Kjellmark, 1996; Baldini, et al., 2007; Hearty and Kaufman, 2009; Hearty, 2010). This might also explain the shift in sediment type in Zone II. Deeper water would not allow dense stands of glasswort and saltwort to grow and accumulate organic peat. These species would have retreated to the shoreline leaving black mangrove as the only source of organic matter in the pond. If the water were deep enough, even black mangrove would retreat, leaving open water that would accumulate calcareous mud rather than organic peat.

The change from peat to calcareous mud that occurs just at the point where the charcoal spikes might reflect the influence of Lucayans on the landscape around Triangle Pond. Niemi, et al. (2008) report an increase in concentrations of trace elements in sediments from Salt Pond, San Salvador dating to 1100-1200 BP, proximate to the date of the earliest evidence of Lucayan arrival on the island. They attribute the increase to higher rates of soil erosion from land disturbance associated with the arrival of Lucayans on the island. If the Lucayans were clearing land around Triangle Pond at the time of the charcoal spike, there is little indication of this in the pollen spectrum. The major increase in pollen from disturbance species occurs higher in the core, closer to 20 cm depth (Figure 5).

Bark fragments extracted from 28-30 cm depth in Zone II date to 180 ± 20 BP. Assuming this date is accurate and that the charcoal spike in the Triangle Pond core dates to ca. 950 BP (ca. AD 1000 or somewhat earlier), there would have to have been a dramatic increase in sedimentation rate between 30 and 11 cm depth (possibly as a result of the introduction of agriculture by Loyalist farmers). Alternative explanations for the 180 BP date (ca. AD 1770) so deep in the core is that the bark fragments came from a branch that fell into the shallow pond, driving younger organic matter deep into the sediment or that a mangrove root grew through older mud, leaving younger organic matter in older sediments. A similar issue occurs with a leaf fragment extracted from 11 cm depth. It dates to 0 BP. One possible explanation for this modern date at 11 cm is that the leaf fragment was caught on the edge of the coring device and dragged deeper into the sediments.

At the bottom of Zone I, there is a distinct transition from a greater abundance of coppice species to a greater abundance of disturbance species (Figure 5). While there are changes in the color of the sediment between these levels, the basic sediment type remains fine calcareous mud suggesting that the water quality or depth of the pond had not changed significantly at this time. The species in both the coppice and the disturbance group are upland plants that are probably not responding to changes in the pond itself. One explanation for their shift in relative abundance could be a change in rainfall. However, the presence of corn (*Zea mays*) pollen in the upper 15 cm of the core is an unambiguous indicator that humans were present near the pond. Corn is not indigenous to the Bahamas (although recent work by Berman and Pearsall (2008) indicates that corn was indeed grown on San Salvador in prehistoric times) and can only grow when cultivated by humans. The change in the vegetation surrounding the pond is therefore likely associated with human disturbance. Increased erosion from land clearing around the pond would also account for the shifts in sediment color between 22 and 18 cm depth. Though some increase in erosion may have occurred, there is little indication in the sediments of a significant increase in clay content, which would be expected with a high level of soil erosion.

Effects of Sea Level Changes on Triangle Pond

Review of literature indicates a general acceptance in the late 1960s to the late 1980s of a ca. 2 m lower than present sea-level in the middle and late Holocene (ca. 4000-2000 BP) in the Bahamas and Florida (Boardman, et al., 1988; Scholl, et al., 1969; Neumann, 1972). This prevailing view began to change in the late 1980s. The debate as to whether there was a middle to late Holocene sea-level rise in the Gulf Coastal region, Florida, Virgin Islands, Bahamas, Brazil, at or above modern sea-level, although not yet fully resolved, seems to have gained more support in the last three decades or so (Beach and Trumbull, 1981; Wanless, 1982; Dominguez, 1987; Dominguez and Wanless, 1991; Wanless, et al., 1994; Balsillie and Donoghue, 2004; Toscano and MacIntyre, 2003, 2006; Milne, et al., 2005; Jessen, et al., 2008; Milliken, et al., 2008; Englehart, et al., 2009; Englehart, et al., 2011). Some scholars suggest minor (≤1-2 m), 200-400 yr-long mid-Holocene sea-level pulses (e.g., Wanless, 2012). In fact, the synthetic sea-level curve for the Gulf of Mexico presented in Balsillie and Donoghue (2004) indicates a number (perhaps as many as five) of small (1-2 m) sea-level pulses during the last 5000 yr BP. However, there is disagreement on the applicability of a pan-Bahamian, Floridian, or pan-Caribbean sea-level curve as applied to such a large-scale region, and it is more likely that sub-regional or individual island sea-level curves may be more accurate than pan-Caribbean curves. That Triangle Pond was open to the ocean in the past seems obvious. Evidence for this includes a calcareous sandy substrate, shell fragments, an articulated shell from a marine bivalve, and several specimens of a benthic marine foraminifer, likely *Rotorbinella rosea* (Figure 6) that were found at the base of the core. Whether the opening and closing of Triangle Pond to the ocean is due to sea level rise or to processes of beach progradation, etc., it is the timing of this opening between Triangle Pond and the ocean that is in question. Radiometric dates from the sediment core at Triangle Pond can assist in answering this question.

Two sea-level oscillations shown in Balsillie and Donoghue's (2004) sea-level curve for the Gulf of Mexico indicate that a possible ~2-5 m sea-level pulse occurred around 2500 BP (also see the sea-level curve in Siddall, et al., 2003, Fig. 2) with another minor pulse (≤2 m) just after 2000 BP. The ca. 2500 BP sea-level oscillation may have raised the water level in what was an open lagoon, flooding the core site. Not long after, coastal processes may have affected the connection of Triangle Pond to the ocean bringing about the change from an open lagoon to a closed lake and initiating the deposition of peat. Evidence from Tague Bay, St. Croix, suggests several marine incursions at 3500, 3100, and 2800 BP (Parsons-Hubbard and Hubbard, 2012), the latter of which is proximate in time with the postulated flooding of the core site in Triangle Pond. On San Salvador, Wronkiewicz (2012) reports a 2360 ± 70 BP date for an encrusted tree root in Storr's Lake, suggesting that Storr's Lake filled (i.e., was sealed off from the ocean) around 2400 BP.

Interpretations of Temperature & Humidity

Cerion watlingense (peanut snail) is a useful indicator of past vegetation, paleotemperature, moisture and rainfall (Baldini, et al., 2007). Modern *Cerion* tolerates a temperature range of ca. 24-28ºC (Florida to Inagua) and today occupies a relatively stable isotherm of 25ºC±0.5ºC (Hearty and Kaufman, 2009). *Cerion*'s preference for humid areas and humid leaf litter suggests that San Salvador was somewhat more humid in the archaeological past. Large quantities (n ≈ 14,000) of *Cerion* shells in a 2x2 m archaeological excavation at the nearby Minnis-Ward site from Levels 4 to 8 (30-80 cm below surface) indicate that the environmental conditions at the site were conducive to the presence of *Cerion*, perhaps resulting in a larger *Cerion* population than that of today for a similar area. These deposits of *Cerion* are dated to approximately 1000 ± 40 BP, an age that fits well with other paleoclimate interpretations of a more humid period in the Bahamas around this time (Kjellmark, 1996; Hearty and Kaufman, 2009; Hearty, 2010). In short, these characteristics suggest that *Cerion* occupied a habitat generally similar to that of the present day. *Cerion* and/or other gastropods present at the site may also have been altered or introduced by humans: Quitmyer, (2003) refers to them as "camp followers" or commensals common around human settlements. The presence of large numbers of *Cerion* in and around a human occupation site may also suggest that humans were altering the vegetation and soil chemistry at the site making the location more attractive to these land snails.

Insights into Lucayan Lifeways

The current study provides a good paleovegetation record from the Triangle Pond core that allows insights into how the Lucayans may have lived and adapted to their environment *vis-à-vis* plants. Utilitarian plants are considered below within their community associations as determined in the pollen diagram (Figure 5).

Mangroves

Black mangrove (*Avicennia germinans*) (Figure 8) is one of the most dominant species in the pollen core. Black mangrove prefers wet shores, coastal tidal areas, sheltered shores, inland lakes, and inlets, much like Triangle Pond was when it was connected to the ocean near Rocky Point (Figure 12). Black mangrove provides a dark wood that may have been of use to the Lucayans for making wooden tools and handles, tannins as a dye, a preservative, and as a source of medicinal products. Black mangrove has properties that make it useful as an antidiarrheal, anti-tumor, astringent, tonic (energizer), and insect repellent (McCormack, et al., 2011).

Buttonwood (*Conocarpus erectus*) occupies brackish and tidal lagoons, or freshwater swamps. It prefers full sun, and tolerates salty conditions. Buttonwood is useful for fuel wood, for smoking meats, and for tannins (dye). Berman (1992) and Berman and Pearsall (2000) report buttonwood as the second most common wood recovered from the Three Dog archaeological site (SS-21), likely used as firewood and as a possible insect repellent. Medicinal uses of buttonwood are based on its antibacterial, antidiarrheal, astringent, and febrifuge (anti-fever) properties (McCormack, et al., 2011).

Red mangrove (*Rhizophora mangle*) prefers to be close to the water, is salt tolerant, and occurs in brackish and saltwater areas along creeks, bays, and lagoons. Red mangrove is also useful as a fuel wood, for tannins, and as an ingredient in fish poison, and has many medicinal usages as an analgesic, anti-asthmatic, and as a reputed aphrodisiac (McCormack, et al., 2011). The stems are also used to produce a red dye for clothing or wood products (Randolph, 1994).

White mangrove (*Laguncularia racemosa*) inhabits coastal areas, bays, lagoons, and tidal creeks, but usually resides well above the high tide line. White mangrove can grow to 12-18 m in height. White mangrove is useful for its heavy wood, the making of tool handles, and as a source of tannin. Medicinal uses of white mangrove include its use as an astringent, febrifuge, and tonic (McCormack, et al., 2011).

Salt Flats

Saltwort (*Batis maritima*), aka turtleweed, is salt tolerant, and prefers low lying areas near seashores or salt lakes, and is a fast colonizer often found in areas of sandy soils. Saltwort can endure waterlogged soils, but is intolerant of shade and is thus found more often in open areas. The leaves and seeds of saltwort are edible (Marcone, 2003).

Glasswort (*Salicornia* sp.) (Figure 9) is a salt tolerant plant that is found in salt marshes, mangrove swamps, and near beaches. It is edible, but contains bitter tasting toxic saponins that must be processed (washed) out of the plant before it is eaten (Glenn et al., 1998).

Coppice

The Myrtle family, Myrtaceae, is well-represented in the pollen core from Triangle Pond. This plant family is highly varied, but contains such useful edible foods and spices such as guava (*Psidium guayava*) and allspice (*Pimenta dioica*) (it is not possible to say based on the pollen that these particular plants were in fact present around Triangle Pond). The most likely candidate for the Myrtaceae pollen in the core is spicewood (*Calyptranthes pallens*) (Figure 10). Most species in the family Myrtaceae contain volatile oils that have medicinal properties. For example, many species in the Myrtaceae are used in the Bahamas for digestive ailments. They are often referred to as "stoppers," i.e., red stopper (*Eugenia foetida*) and white stopper (*Eugenia axillaris*) are used to stop diarrhea. Also leaves of guava (*Psidium guajava*) and Sweet Margaret (*Psidium longipes*) are used for diarrhea (Randolph, 1994). All four of these species could have been present around Triangle Pond, though *Psidium guajava* would have to have been introduced as it is the only one of the Myrtaceae listed that is not native to the Bahamas. Note that allspice was taken back to Spain by Columbus as a gift presented to King Ferdinand and Queen Isabel la Católica. Myrtaceae wood is also good for smoking meat in barbeques (*barbacoa* is a Taíno word and cooking technique) and imparts its taste to meat via smoking. General medicinal uses of some species in this family (e.g., guava) are based upon their antibacterial, antidiarrheal, anti-dyspeptic, astringent, and stomachic properties (McCormack, et al., 2011).

The palm family, Arecaceae (Palmae), is present in the lake sediment core. Members of the palm family grow on San Salvador today including silver top palm (*Coccothrinax argentata*), sabal palm (*Sabal palmetto*), thatch palm (*Thrinax morrissii*) and the introduced coconut palm (*Cocos nucifera*). Silver top palm prefers coastal coppice, limestone rock, and dry and exposed areas (such as the area northeast of Rocky Point today near the location of the Palmetto Grove archaeological site). Thatch palm is typically found in the understory of high coppice or pinewoods (on the pine islands), while sabal palm is more often found in or near seasonal freshwater wetlands. Palms were likely used for fiber, mats, and for making the thatched roofed houses of the Lucayans. Modern San Salvadorans report eating the heart of *C. argentata* during hard times (McCormack, et al., 2011). Residents of Andros use silver top palm leaves for basket weaving and thatch palm for thatching small shelters (Randolph, 1994).

The gumbo-limbo tree (*Bursera simaruba*), also nicknamed the "tourist tree" because of its peeling red bark, is not tolerant of soggy soils, and makes good firewood and even a natural glue and resin (e.g., for waterproofing canoes). Modern Bahamians have many medicinal uses for gumbo-limbo. The sap is used to treat poisonwood, the bark or roots are used in love tea, and the leaves are tied to the head to cure headaches (Randolph, 1994). The loose bark of the tree also is also the origin of its use to treat constipation (loosens the bowels) (Randolph, 1996).

Ateramnus lucidus (synonym: *Gymnanthes lucida* [Correll and Correll, 1982], crab bush), is a flowering member of the spurge family, Euphorbiaceae, which inhabits sandy open flats and coppice areas on sandy and rock ridges. The tree is native to the Bahamas and can grow to a height of 6 m (20 feet). Crab bush is used to treat upset stomach (Randolph, 1996). It is also made into a tea or chewed as a quid for its analgesic (toothache), anti-dyspeptic, and antitussive (anti-cough) properties; it is also used to manufacture wooden objects (tool handles, etc.) due to the hard and dense nature of its wood (McCormack, et al., 2011).

Disturbance Indicators

The grass family (Poaceae) is also represented in the Triangle Pond pollen core. Grasses comprise what has been called the most important family of plants for humankind (Simpson and Ogorzaly, 2000). The grasses include many staple foodstuffs, including most of the world's grains, including *Zea mays*, maize or Indian corn (see below).

Sedges (Cyperaceae) are grass-like plants that grow in shallow or moist soils and usually occur in tussocks. They are typically very difficult to identify to species. Sedges are commonly used to manufacture cordage, baskets and sieves and are known for their bright colors and various smells (Grieve, 2014).

Phyllanthus epiphyllanthus (hardhead, aka rockbush) is a member of the spurge family, and is found throughout the Caribbean on islands such as the Bahamas Archipelago down to the Turks & Caicos, and the islands of the Greater Antilles. Medicinal uses of hardhead are based on its analgesic (pain, sore throat), anti-dyspeptic, carminative, and stomachic properties, and its effectiveness in treating skin conditions such as sores, burns, and rashes; Native Americans of the Amazon Basin reportedly use this plant for many different medicinal purposes (McCormack, et al., 2011). It is also used as a strength tonic and aphrodisiac by modern Bahamians (Randolph, 1996).

Croton sp., likely either granny bush (*Croton linearis*) (Figure 11) or possibly sweetwood (*Croton eluteria*), are both found commonly in coastal sands, coastal thickets, and dry scrubby areas much like the present environment of the Minnis-Ward site. Granny bush is also considered to be a disturbance indicator and may be a signal of deforestation or clearing due to agricultural practices. A species of *Croton* was identified among the charred wood fragments from Three Dog site, possibly used as firewood (Berman, 1992; Berman and Pearsall, 2000). Granny bush is noted for its astringent, sedative, anti-rheumatic, and antiseptic properties; it is also used for menstrual and post-partum treatments, for coughs, joint pain, and skin sores (McCormack, et al., 2011).

Ambrosia (a relative of ragweed), of which the species *A. hispida* (bay geranium) is native to San Salvador, is an invasive weedy plant that is wind pollinated, prefers dry, sunny, grassy plains, and sandy soils. Many species of *Ambrosia* are adapted to arid conditions and are commonly found in ruderal areas of disturbed soils and in cleared, burned, or abandoned fields. Specifically, bay geranium has anti-dyspeptic, antihistamine, anti-hypertensive, antitussive, diaphoretic, febrifuge, and stomachic properties; it is also used to treat colds, flu, and can be made into soap (Randolph, 1996; McCormack, et al., 2011).

Corn or maize (*Zea mays*) is a cultigen that appears later in the sediment core from Triangle Pond, and may indicate the onset of large-scale European agriculture with the arrival of the Loyalists in the 1780s. Although there is evidence that maize was being grown and processed in pre-Columbian times on San Salvador (Berman and Pearsall, 2008), the late presence of maize in the pollen core suggests a later time period for its cultivation, an interpretation borne out by radiocarbon dating.

The *Borrichia*-type pollen is probably bay marigold, bull horse bush, or one of its relatives. It prefers sandy coastal areas and saline soils which generally characterize the Minnis-Ward site. *B. arborescens* (bay marigold) has analgesic properties used to treat muscle pain and strain. It has been reported to have anti-mycobacterial properties which can limit the growth of the tuberculosis bacterium; the leaves can also be eaten as salad greens (McCormack, et al., 2011).

Eupatorium is a genus of the aster family (Asteraceae) and its species have many medicinal qualities. Bahamians use jackamada (*Eupatorium villosum*) for worms and intestinal problems as well as making a tea of the leaves to treat fever, stomach ache, pain, and poor appetite (Randolph, 1994).

Trema lamarckianum (West Indian trema), or "bit-root," is a pioneer species that likes disturbed and open areas on sedimentary rocks in areas that receive minimally 1200 mm of annual rainfall (San Salvador receives ca. 1000-1900 mm per year – Shaklee, 1996). *Trema* is also intolerant of shade, and therefore would not prosper in dense forest with lots of cover from tropical foliage. Bit-root is reportedly used, usually in a mixture with other plants, as a reputed aphrodisiac, and to restore the libido. The stems and leaves are boiled to treat colds and the bark is used to make rope or string (Randolph, 1994).

Human Impacts on the Environment: A Brief Review

Our interpretations of the Triangle Pond sediment core record suggest that there were a number of apparent human impacts on the local environment (if not the whole island), some more obvious than others. First of all, it is possible to detect some alteration of the vegetation in and around Triangle Pond. The most noteworthy change (at the beginning of Zone II) is the spike in charcoal particles in the sediments (Figure 5). At the 35 cm level, charcoal particles spike to a high

*Figure 13. View of 2x2 m excavation at Minnis-Ward archaeological site (SS-3), near Triangle Pond, in June 2010. The dark black soil at the top of the stratigraphic profile is anthropogenic in nature (anthrosol, "*terra preta do indio*") – full of charcoal, animal bones, shellfish, and other food remains (photo by J. Blick).*

of 5829 particles per cc and likely indicate increased burning of vegetation as part of the indigenous slash-and-burn agricultural practice. A similar spike in charcoal particles in sediments followed by a gradual decline over several levels coincides with the arrival of Lucayans on Abaco (Slayton, 2010) and Andros islands (Kjellmark, 1996). Berman and Gnivecki (1995) and Berman and Pearsall (2000) suggest that the earliest colonization of San Salvador by Lucayans dates to ca. 1300-1100 BP (ca. AD 650 or somewhat later). The peak in charcoal concentration at 35 cm can be estimated to ca. AD 790-870 (midpoint AD 830) using a best fit line method, or to ca. AD 1000 using the age-depth model (Figure 7).

Second, an increase in disturbance indicators begins almost imperceptibly in prehistoric times at around the 35 cm level (Figure 5) with slight rises in the presence of *Pinus* (Caribbean pine) and Poaceae (grasses). Most of the disturbance indicators, however, appear post 180 ± 20 BP (cal AD 1730-1810) and include *Ambrosia*, *Croton*, sedges, etc. Many species of *Ambrosia* are commonly found in ruderal areas of disturbed soils and in cleared, burned, or abandoned fields; *Croton* (granny bush), another disturbance indicator, may be a signal of deforestation or clearing due to agricultural practices. *Zea mays* (corn) found in levels from 15 cm to near the top of the core clearly suggests more extensive European-style agricultural practices. The presence of colonial-era Caprinae (Barbadan sheep?) bone (from a level dated to 170 ± 40 BP or cal AD 1720-1890) can be taken as another sign of European land disturbance via animal grazing.

Third, an alteration of soils in the Triangle Pond sediments is marked by a change from peat to calcareous mud just at the point of the charcoal spike (35 cm depth) which might reflect the influence of Lucayans on the landscape around Triangle Pond. If the Lucayans were clearing land around Triangle Pond at the time of the charcoal spike, it is likely that this land clearance would manifest itself as a change in sediment in the nearby core, although the impact on the pollen regime is negligible. There is a dramatic increase in the sedimentation rate of Triangle Pond ca. 180 ± 20 BP (cal AD 1730-1810) (Figure 7), possibly the signal of the Loyalist plantation period on San Salvador. Proceeding on the face value of the AMS date, European-style agricultural practices would seem to be the most likely explanation for this increase in sedimentation rate.

Lastly, archaeological deposits at the nearby Minnis-Ward site suggest alteration of the local fauna, notably the land snail, *Cerion*. According to Hearty (2010), “The great variety of shell forms over the past 1000-2000 years suggests that humans may have played a role in the introduction and redistribution of *Cerion* across the [pan-Caribbean] region.” Quitmyer’s (2003) classification of *Cerion* and other gastropods as commensal “camp followers” suggests that humans may have transported these snails from island to island, in soils or on cuttings (or in other ways). It is also a possibility that humans, via alteration of vegetation via slash-and-burn and alteration of soils via organic enrichment due to settlement (deposition of animal bones, charcoal, feces, food remains, urine, i.e., the creation of an anthropogenic soil or anthrosol) (Eidt, 1984) (Figure 13), transformed the local environment to be more attractive to these “camp following” land snails. Human impacts on the environment of San Salvador are also visible in prehistoric household trash middens and their faunal remains, some genera of which show signs of overharvesting such as land crab, sea bass (grouper), parrotfish, and West Indian top shell, to name a few (Blick, 2007, 2012).

CONCLUSIONS

AMS radiocarbon assays and calculation of sedimentation rates allow dating of events in the Triangle Pond core from San Salvador Island, Bahamas. Major dated events in the core include: marine influence at base of core (ca. 2600 and prior to 2100 BP); sealing off of the pond and the formation of a peat layer ca. 2100 BP; a peak in charcoal frequency ca. 950 BP (AD 1000) or earlier; historic agricultural practices (180 ± 20 BP, ca. AD 1730-1810); and recent deposits near the top of the current hyper-saline pond (0 BP). The age-depth model for the Triangle Pond sediment core, using calibrated AMS radiocarbon dates with their 2σ error ranges, places the dates in correct chronological order by depth, indicating that the radiocarbon dates are reliable.

Basal sediments in the core suggest a period of sea level rise of 1-2 m ca. ≥2600 BP, but before ca. 2100 BP, a finding that is in agreement with the Mid-Late Holocene sea level rises postulated by other scholars. On San Salvador, other lakes such as Storr’s Lake appear to have been open to the ocean before ca. 2400 BP (Wronkiewicz, 2012), a date consistent with the evidence from the Triangle Pond core.

Cerion in nearby archaeological deposits at Minnis-Ward (SS-3), and pollen evidence of similar vegetation around the site for at least the last 2000 years, suggest a climate similar to or slightly moister than today’s ca. 1000 BP or somewhat earlier. Studies on other islands in the Caribbean and Bahamas suggest that *Cerion* populations may have been altered via slash-and-burn of vegetation and/or by creation of anthropogenic soil at the nearby Minnis-Ward site (Figure 13); some suggest that *Cerion* and other land snails may have been introduced by humans via accidental transport from other islands in soil, plant cuttings, etc. Human impacts recorded in the core include vegetation alteration, increased fire frequency, soil alteration via the creation of an anthrosol, an increasing sedimentation rate, and a rise in disturbance indicators. Finally, pollen from Triangle Pond has yielded evidence of useful plants available to the Lucayans on San Salvador including medicinal, utilitarian, and edible species. The pollen core thus provides information about ancient environments prior to and coeval with the Lucayans, and also allows insights into Lucayan lifeways and how the Lucayans interacted with their island environment via plants during the period ca. 1300-500 BP (ca. AD 650-1500).

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