A PAELEOENVIRONMENTAL RECONSTRUCTION FROM THE ISLAND OF GRENADA, CARIBBEAN ENVIRONMENTS DURING THE TIME OF HUMAN OCCUPATION

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of EMILY JANE BENZ find it satisfactory and recommend that it be accepted.

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A PAELEOENVIRONMENTAL RECONSTRUCTION FROM THE ISLAND OF GRENADA, CARIBBEAN ENVIRONMENTS DURING THE TIME OF HUMAN OCCUPATION

Abstract

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Paleoenvironmental analyses are some of the most important contributing studies when attempting to understand prehistoric cultural groups within the archaeological record. Particularly in regions lacking strong archaeological framework, paleoenvironmental reconstruction can be a useful starting place for modeling the beginnings of human occupation and settlement. The use of fossil pollen grains for analysis and environmental interpretations can be particularly beneficial in regions where artifact preservation is poor and the archaeological record is incomplete. The Caribbean is a region which often exhibits poor archaeological preservation, and a significant lack of well developed and completed archaeological research projects. Therefore, the Caribbean region would benefit greatly from paleoenvironmental analysis to help fill in and support what is currently known of the anthropological record. One of the islands with the least amount of archaeological information available is the island of Grenada, located in the southern portion of the Caribbean island chain.

This study consists of an in-depth analysis of 44 stratigraphic pollen samples selected from a 493cm core recovered from Meadow Beach, a coastal mangrove swamp on the

northeastern section of Grenada. This site is located only a few kilometers north of the documented archaeological site known as Pearls. Sediments that have accumulated over the last 6,000 years provide ample pollen data for analysis, and effectively allow for a thorough and comprehensive paleoenvironmental study of this region. The data collected for this study has been used to indicate periods of environmental change, as well as the initial human occupation of the island and human interaction with the surrounding environment including possibilities for the use of agricultural subsistence methodologies.

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CHAPTER ONE

Introduction

Throughout the history of archaeological research in the New World, certain ideas and regions have captured the interest of both researchers and sponsors. This trend is often associated not only with monumental architecture, complex political and social systems and high value items such as jade and gold, but also with the development of agriculture, the deciphering of complex writing systems and astronomical determinations. The development of New World archaeology has provided historians, researchers, educators, and the general public with an evolved and detailed idea of what the peopling of the Americas may have looked like from early hunter gatherers to the complex civilizations present during the arrival of the Spanish explorers.

Despite the intensive and often exhaustive research that has been performed in New World archaeology, several regions and groups of people remain largely unexplored. The islands in the Caribbean have recently begun to elicit increased interest from the academic sphere, to the conclusion that we really know very little about this centrally located island chain. While research has continually grown over the last two decades in particular, there is still much to be done in order to establish baseline data to serve as a tool for future analysis. This thesis is ultimately an attempt to more fully understand ecological change on the island of Grenada including human settlement history and environmental influence throughout the timeline of human occupation.

The Caribbean Coring Project

In a project sponsored by the National Science Foundation and the National Geographic Society, a research team led by Dr. Peter Siegel of Montclair State University and Dr. John G. Jones of Washington State University has set out to reconstruct the paleoenvironment on a series of islands in the Lesser Antillean chain. The Lesser Antilles chain is made up of the southern portion of the Caribbean chain, extending from the northern coast of Venezuela to Puerto Rico. These islands are further subdivided into pods of islands based upon their location within the chain, as well as proximity to one another. The Windward Islands, including Dominica, Saint Lucia, Saint Vincent, the Grenadines, Grenada, Martinique, Barbados, Trinidad and Tobago, contain some of the larger islands within the Lesser Antilles, and create a stepping-stone like system from Venezuela up to the larger islands of the Greater Antilles.

Fieldwork was conducted during the summers of 2007 through 2009. The focus of the summer 2008 field season was to collect sediment cores from a series of these islands in order to perform pollen, phytolith, soil and chemical analyses. The sediments collected along with their eventual analysis were intended to provide a more detailed understanding of the environmental development of these islands alongside the arrival of migratory and permanent human populations. Five islands were visited during the season, and sediment cores were collected on each to aid in the creation of a paleoenvironmental record for the region. The islands in the 2008 study include Trinidad, Grenada, Barbados, Martinique and Marie-Galante, all located in the southernmost section of the chain (Figure 1).

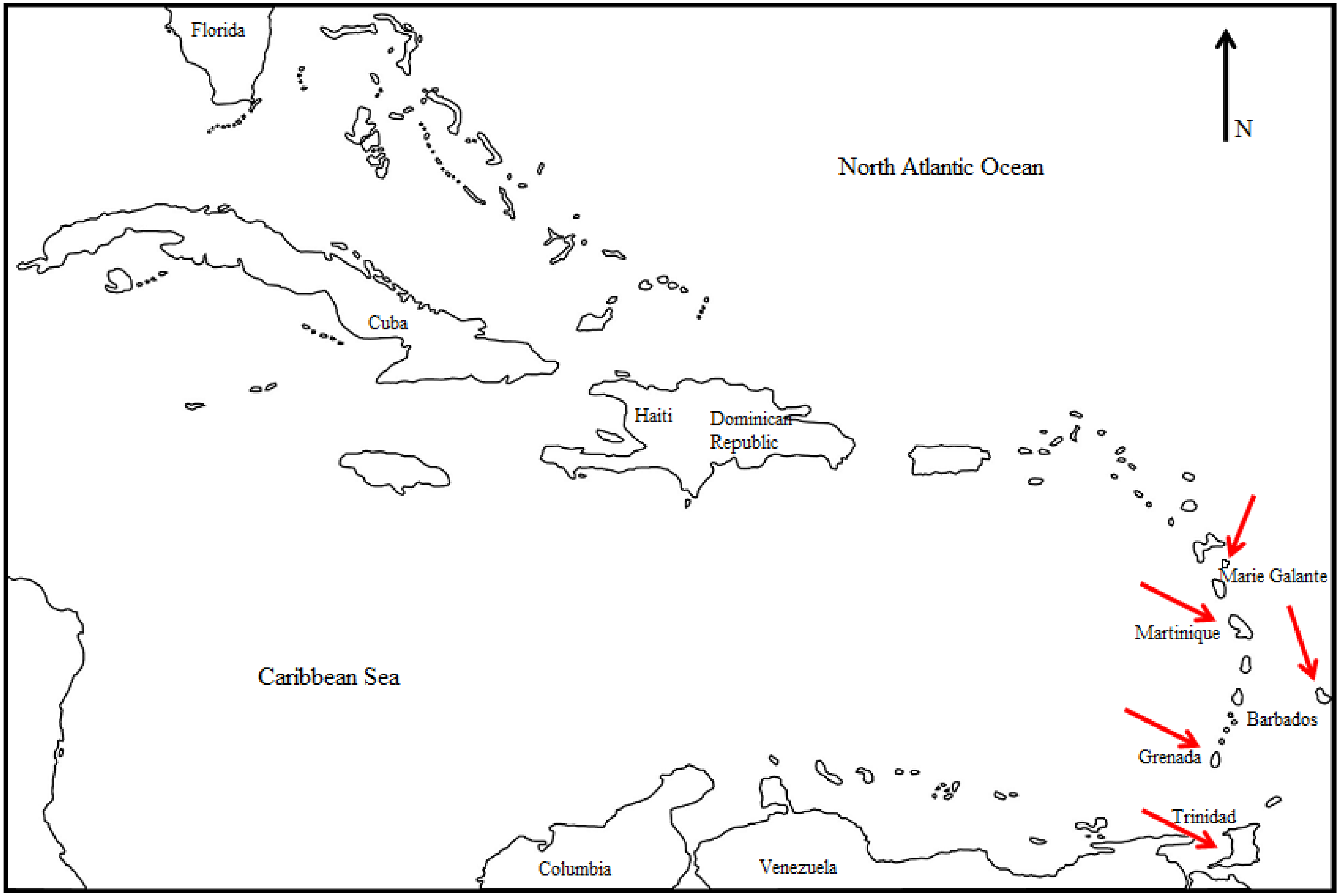

Figure 1. Map of the Caribbean featuring the Lesser Antilles. The islands identified are those where sediment cores were collected for analysis including Trinidad, Grenada, Barbados, Martinique and Marie Galante.

Project Focus

The island of Grenada, the focus of this study, remains one of the greatest mysteries of the island chain. This particular island was selected for this study because of the lack of archaeological and paleoecological research performed on this particular island. A detailed environmental reconstruction of this island will serve as an invaluable stepping stone that will help to illuminate the historic and prehistoric trends of this region. A palynological analysis of sediment collected from this island will help to illuminate past climatic conditions and provide invaluable information on the paleoclimate and the environmental changes that took place during the period of the first human occupation, which appears to have begun sooner than originally expected.

The sediment core used for this study was chosen for its proximity to the nearby Pearls site, one of the few well studied archaeological sites, in order to provide more information on the environment of Grenada during the time of human occupation. The Meadow Beach core (MB08-1) has provided a detailed environmental record of the northeast region of the island. Based on the desire to acquire human chronology of the surrounding region, the Meadow Beach core will provide detailed information that will address several gaps in the archaeology of Grenada. The core will provide a detailed local environmental record during the entire span of known and unknown human history on the island of Grenada, and pollen and charcoal counts will help to put human environmental interactions into a temporal framework.

This thesis has five subsequent chapters. Chapter 2 includes a discussion of the archaeological and culture history of the Caribbean island chain. The chapter provides details including the initial populating of the Caribbean as well as an archaeological history for Grenada and the wider Caribbean region in general. Chapter 3 includes a detailed description of both field and laboratory methods used for the collection, extraction and processing of core MB08-1. Chapter 4 provides information about the different taxa encountered throughout the Meadow Beach core, as well as soil characteristics and limitations of pollen analysis for the interpretation of environmental change. Chapter 5 includes the interpretation and a discussion of the analysis results of the MB08-1 Core. Chapter 6 consists of research conclusions and suggestions for future research.

CHAPTER TWO

Populating the Caribbean: The Debate

Archaeology in the Caribbean Basin has long been a point of interest for academics and researchers in countries across the world. Because of their fortuitous location, the islands in the Caribbean have essentially become viewed as a set of important stepping stones for the arrival of Europeans in the New World, as well as in the migration of Native Central and South Americans. The archaeological and environmental data collected thus far on the islands in the Caribbean Sea provides an important and complex glimpse into one of archaeology's least studied regions; however, there is still a large amount of research to be completed. Taking an in-depth look, not only at the migration of humans into the Caribbean, but also at the environmental and climate changes that occurred within this island system enables researchers to be better prepared to make suggestions for the development and progression of future research for this important and under-studied island chain.

Environmental Background: Setting the Stage for Human Occupation

In order to fully understand and analyze the archaeology of a particular region, it is essential to gain a full appreciation of the environment in order to place the archaeological interpretation into a specific context. One of the most interesting features within the Caribbean Islands is that rather than designate one dominant environmental zone, we must consider multiple environments interacting with each other within a small geographic area. The degree of variety we are faced with makes it difficult and interesting to try to explain how these various zones work together to create such a diverse island ecosystem.

When attempting to classify an island chain into an environmental “bracket,” there are multiple considerations that must be addressed. Some of the questions that arise concerning the classification of island environments are the location of the chain, distance from its neighbors, island size, weather and tidal patterns, and distance from the continental mainland. Because island environments are often unique compared to other environments worldwide, it is necessary to conduct extensive research within a specified region to fully understand a particular system. The Caribbean, as compared to other island chains, has an environmental, climatic, and cultural record unique to the region. Because of this, it is exceedingly difficult to perform comparisons on contemporary island systems, that in turn, makes the amount of data collected to fully understand these island structures that much more important.

The island chains of the Caribbean are strategically located around the Tropic of Cancer, located 23º 26′ 22″ north of the Equator. The majority of the islands in the Caribbean chain lie south of the Tropic of Cancer. The Caribbean island chain, consisting of 7,000+ islands, cays, and reefs, has been divided into four main island groups based on “their size, geological history, proximity to the mainland and other features” (Newsom and Wing 2004). These four sub-regions, are the Greater Antilles, the Lesser Antilles, the Bahamas and the southern Caribbean Islands, and each exhibits specific environmental trends that determine their suitability for human habitation and migration. This region of the earth, classified as “tropical,” is home to some of the most complex and diverse environmental systems in the world. For the purpose of clarity, it is necessary to determine a precise and descriptive definition of a tropical climate.

Kellman and Tackaberry provide an in-depth discussion of what types of environments are typically classified as tropical. They state,

> Unlike in temperate areas, where winter temperatures constrain biochemical processes and the uninhibited growth of biological populations, in the tropics populations can potentially grow until limited by some other factor… We would expect humid tropical environments to support productivities approximately three to four times those of temperate areas if climate were the dominant limiting upon this process (Kellman and Tackaberry 1997:3).

For the purpose of this paper, it is important to have an extensive knowledge of what types of environments may be considered and classified as *tropical.* The Köppen–Geiger climate classification system, was first published during the latter part of the nineteenth century and provides additional information on the classification of tropical climates. The classification, along with subsequent refinements, provides several determining factors that help to define and ultimately clarify what we would expect of a tropical climate (Becker et al. 2006, McKnight and Hess 2000).

More specifically, the Caribbean islands have been classified according to the Köppen–Geiger system not simply as tropical, but as maintaining a “tropical wet and dry savanna climate” (classified Aw), sharing this classification with the majority of the eastern coast of Central America, as well as the northern coast of Venezuela (Figure 1). Additionally and indeed more recently, Spalding et al. (2007) have developed a system of coastal regions known as the Marine Ecosystems of the World (MEOW), consisting of a nested system of 12 realms, 62 provinces and 232 ecoregions, and placing the Lesser Antilles into the Tropical Atlantic realm, the Tropical Northwestern Atlantic province and the Southern Caribbean ecoregion. This region is defined by its high average temperature and humidity, with a mean temperature that generally falls between 24-29 degrees Celsius, and with an average annual precipitation in the northern islands (Hispaniola, Jamaica, Cuba, and Puerto Rico) falling between 200 and 750 mm, with much higher ranges (1000-2000) occurring in the majority of the islands in the Lesser Antilles (Newsom and Wing 2004).

The climate of the Caribbean islands has changed significantly over the last 10,000 years, with multiple wetting and drying periods, droughts, sea level changes and various other climatic trends. One study, conducted by David A. Hodell and colleagues of the University of Florida sought to decode the climatic changes within the Caribbean region using sediment core analysis (Hodell et al. 1991). A sediment core was collected from Lake Miragoane in Haiti by Antonia Higuera-Gundy for use in her dissertation, and based upon the analysis of this core, they established a basic environmental chronology for the region (Higuera-Gundy 1989, 1991). At approximately 10,500-10,000 BP, the climate appears to have been quite arid with increasing levels of evaporation and a significant drop in lake level. Pollen data for this time period shows that the environment was varied with “dry vegetation, characterized by xeric palms and montane shrubs” consistent with the highly arid environment of the Younger Dryas that took place in the north (Hodell et al. 1991). After this intense dry period, a change occurred that resulted in the rise in lake water levels and a corresponding decrease in evaporation suggesting a switch from an arid environment to much more humid conditions. This shift, occurring over an extended period of time (10,000-7,000 BP), can be seen in multiple regions throughout the tropics during the early Holocene, and has been supported with additional pollen evidence (Hodell et al. 1991).

The climate continued to change throughout the Caribbean region, with several significant transformations occurring over the next 7,000 years. From the time period of 7,000-5,300 BP, lake levels were noticeably higher than they are today. Lake levels remained fairly high between 5,200 and 3,200 BP, this "deep water phase of the lake coincided with the development of mesic forests" during the middle Holocene Period (Hodell 1991). At approximately 3,200 BP, Hodell et al. reported that lake levels began to lower again due to an increase in evaporation, that eventually led to a dry period lasting until 1,500 BP. These patterns of humid and dry climatic conditions can be seen echoed in multiple regions worldwide including portions of the African coast, eventually resulting in the climatic conditions represented within these regions today (Hodell et al. 1991).

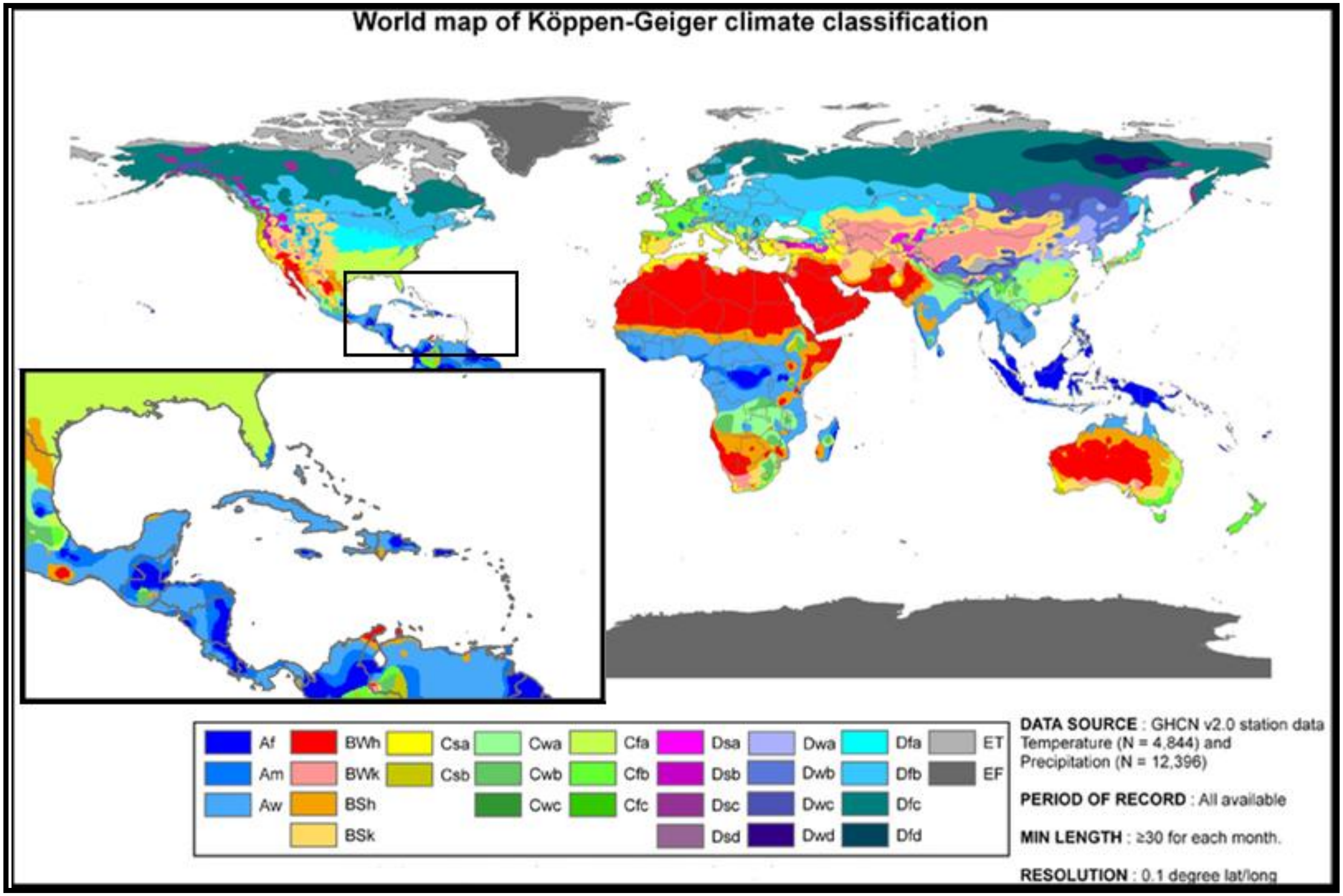

Figure 2. Climate zones and types according to the The Köppen-Geiger System. The Caribbean islands are shown to be part of the Am, Af, BSh and Aw climate zones (McKnight and Hess, 2000).

Currently, the climate of the Caribbean is dominated by humid easterly trade winds that produce large amounts of precipitation, predominately on the northern and eastern portions of the islands, causing these regions to remain moist year-round (Newsom and Wing 2004). Various climatic and environmental considerations must be kept in mind when attempting to understand and reconstruct the past and present conditions of these islands. The effects of hurricanes can be dramatic locally, and various volcanic eruptions often leave fine (and sometimes thick) layers of ash often encountered in the soil stratigraphy. These environmental events can be seen in the archaeological record if soil stratigraphy is well preserved and undisturbed. Pollen and charcoal analysis can be used to determine past environmental events and help determine environmental change resulting from these events (Faegri and Iversen 1989).

The soil morphology of the islands in the Caribbean is consistent with what would be expected of a tropical environment. The islands are primarily constructed of vertisols filled with rich clays (Thomas 1994). Currently, the morphoclimatic zones of the islands that, according to researcher Alistair F. Pitty, are determined by examining at the relationships between geological zones and climatic effects on the local environment, have been characterized both as "peritropical zone of excessive planation" in the northern islands of the chain, and "inner-tropical zone of partial planation" in the southernmost islands of the chain (Pitty 1971, Wirthmann 1987). Because of the humid nature of the islands themselves, most of the sediments and soils are relatively moist and stable. Erosion on the islands is primarily a factor of aeolian and fluvial processes as well as modern anthropogenic influence including irrigation and cultivation. The thick peaty-like deposits that form on these islands in these coastal swamps are a direct result of a significant quantity of organic matter, deposited in an anoxic environment with a high level of groundwater.

Typical of island locations, the degree of environmental and climatic variability on a single island can be quite dramatic. An examination of these island environments reveals as many as 13 different “life zones” as defined by the Holdridge Life Zone Classification system (Murphy and Lugo 1995). In this system each life zone is characterized not only by the vegetation found within a particular region, but also by the entire ecosystem (Newsom and Wing 2004). The 13 life zones of the Caribbean detail the degree of variability that can be seen within these isolated islands, and serves to explain the detailed climatic conditions that may be experienced within each of the 13 “life zones” (Table 1).

Of paramount significance when considering vegetation within an island system is a region’s salinity. Because of the nature of islands (surrounded on all sides by sea water) the introduction and removal of salt from the ocean is a major element to consider when trying to understand island ecosystems. Large levels of salt in soils will negatively impact most types of vegetation. The increased levels of salts within island soil systems can make it extremely difficult for many species of plants to grow (Cardona and Botero 1998). The salt often acts as a type of osmotic seal that prevents plant roots from accessing groundwater, ultimately resulting in the mass extinction of many plant species. Thus island vegetation is often very specific in the type of plants that can survive in a highly saline environment. Similar to human survival,

Holdridge System		**Bioclimatic**	**Parameters**	
Life Zones	Total Annual Precipitation (mm)	Mean Annual Biotemperature (C)	Humidity Province	Potential Evapotranspiration Ration
Tropical Desert Scrub	125-250	>24	PerArid	8.00-16.00
Tropical Thorn Woodland	250-500	>24	Arid	4.00-8.00
Subtropical Thorn Woodland	250-500	<24	Semiarid	2.00-4.00
Tropical Very Dry Forest	500-1000	>24	Sermiarid	2.00-4.00
Subtropical Dry Forest	500-1000	<24	Subhumid	1.00-2.00
Tropical Dry Forest	1000-2000	>24	Subhumid	1.00-2.00
Subtropical Moist Forest	1000-2000	<24	Humid	0.50-1.00
Tropical Moist Forest	2000-4000	>24	Humid	0.50-1.00
Subtropical Wet Forest	2000-4000	<24	Perhumid	0.25-0.50
Lower Montane Wet Forest	2000-4000	<24	Perhumid	0.25-0.50
Montane Rain Forest	2000-4000	<24	Superhumid	0.125-0.25
Lower Montane Rain Forest	4000-8000	<24	Superhumid	0.125-0.25
Subtropical Rain Forest	4000-8000	<24	Superhumid	0.125-0.25

Table 1: Major life zones found in the Caribbean with coinciding environmental parameters according to the Holdridge Life Classification System (after Newsom and Wind 2004).

the larger islands can support increased numbers of plant species. Larger islands are not only more likely to have adequate sources of fresh water, but they may also have topography that is favored by an increased number of plant species. High elevations, most often seen in the Greater Antilles, effectively move vegetation up and away from the influence of ocean tides and flooding. These high elevation species rely on rain water and precipitation from low-level cloud’s, and submontane cloud forests. The lack of an adequate amount of freshwater on many of these islands, ultimately determines what species of plants and animals are capable of thriving within these particular environments (Newsom and Wing 2004).

The vegetation found on the Caribbean islands is incredibly diverse. It is thought that the West Indies contain “an estimated 2,500 genera of seed plants, and 12,000 to 13,000 species of vascular plants” (Fritsch and McDowell 2003). Because of the degree of climatic and habitat diversity found within individual islands, it is necessary to understand the dominant vegetation types found within specific island zones. Environmental conditions in the various zones allow for a variety of plant taxa growth specific to that region. On marine shorelines, including shallow brackish swamps and brackish inlets, species such as *Avicennia germinans* (black mangrove), *Rhizophora mangle* (red mangrove) and *Coccoloba uvifera* (sea grape) thrive. Freshwater systems such as ponds, streams, or freshwater swamps often boast species of seaweed such as *Cabomba* and *Ceratophyllum*, while grassland areas can support species including *Byrsonima* (nance) *Croton* and Poaceae (grasses). Multiple other plant species are found in a variety of environments all over the islands, include rainforest, cloud forest, evergreen and deciduous forest, dry evergreen forest and disturbed secondary forest (Newsom and Wing 2004).

With the habitats created by the climate and vegetation present within the island environments, a surprising amount of wildlife can be found on the various Caribbean islands. The vertebrate fauna that have inhabited the West Indies over the last several thousand years are incredibly diverse, and include birds, mammals, and especially rodents and reptiles. These animals most likely colonized the islands from nearby Central and South America. Extinction and species introduction are often seen as important contributors to island ecosystems, and because of the fragile nature of island habitats, large environmental processes can wipe out entire populations incredibly quickly.

The human introduction of plant and animal species can also have an enormous effect on island environments and effectively wipe out hundreds of local species of plant and animal life. Birds, bats, mammals, reptiles, and marine life make up the inhabitants of the various island ecosystems and present a surprising natural array of species variety and density. Some of the species that can be found on the islands include sea turtles, iguanas, rice rats, agoutis, hutias, terns, snakes, frogs and monk seals. Hundreds of fish species as well as various insects, mollusks and annelids can be found on these islands, creating an astounding array of wildlife that both thrives and is dependent upon on these isolated island habitats (Newsom and Wing 2004).

Because of the degree of plant and animal diversity that can be seen within the Caribbean island chain, it is remarkable to think of adding human populations to these delicate environments. While researchers know that people have populated the Caribbean islands for the last several thousand years, little remains known about how they managed to be so successful while living within such a delicate and fragile landscape, or even what drew them to the islands in the first place. One of the greatest controversies within the field of Caribbean archaeology over the past several decades has been on the movement and migration of humans to and from the islands within the Caribbean chain, how they arrived, where they came from, and whether or not they stayed.

Human Arrival and Occupation

The peopling of the Caribbean islands presents an interesting question for researchers worldwide. Like all other animal species on the planet, humans have certain biological needs that must be met in order to survive and thrive within a particular environment. While we are certainly an adaptive and inventive species, it does not change the fact that certain resources are an absolute necessity for the continuation of human life. Islands in general only possess a finite amount of resources available to humans, and it is often difficult and sometimes disastrous to try to change or add to these resources through the introduction of non-native plants and animals, or through the burning of local environments for the purpose of agriculture.

For an island to support a human population, there are several requirements that must be met. The first necessary requirement for human habitation and survival has to do with island size. Despite the abundance of resources that can often be found on small islands, human populations need to have enough space to allow local resources to replenish themselves naturally in order for the islands to sustain themselves and the local wildlife. Larger islands are also more likely to possess adequate fresh water supplies, as well as wood for both fuel and building material (Newsom and Wing 2004). Another factor to consider when determining if an island is habitable is the availability of food resources. The Caribbean islands possess a large variety of protein resources similar to mainland environments. As we would expect of a marine environment, a large portion of the protein collected and hunted by island populations may have come from sea life surrounding the islands, as well as mammals and birds found within the island’s forests. Protein sources would have included small and medium sized mammals such as agoutis, multiple species of rodents and various bird species, and large marine species including turtles, seals and manatees as well as smaller marine resources including large amounts of fish, shellfish and crabs (Newsom and Wing 2004).

There are several theories that have developed over the last several decades detailing the movement of people in the Caribbean. One of the most interesting conflicts that has arisen throughout this discussion has been whether the people originated in the north and worked their way south onto the island chain or originated in South America and worked their way north (Allaire 1980, Berman et al. 1995). It might possibly have been a combination of the two migration patterns. Additionally, some researchers have suggested the possibility of humans migrating into the Caribbean islands from the coast of Central America and the Yucatan Peninsula into the islands from the east (Allaire 1980, Berman et al. 1995, Davis and Goodwin 1990, Keegan 1995).

Perhaps one of the most interesting points to consider in regard to human migration is the proximity of one island to the next. While the majority of the islands in the chain are a visible jump from each other, the island of Grenada is not visible from the larger land masses to the North (St. Lucia) or to the South (Trinidad). Lower sea levels may have been a factor in the initial colonization of the islands, an increase in the size of the islands would have slightly lessened the distances between the islands. Other suggestions have included accidental and uncontrolled discovery of some of the islands. Louis Allaire (1997) remarks that the most significant jump would have occurred between Trinidad and Grenada, and that "from Grenada, with all other islands visible from each other, exploration and colonization must have progressed rapidly."

Despite the distinct disadvantages and dangers that accompanied island migration and colonization, there are multiple advantages that would have increased the appeal of living on a limited piece of land. While sea travel would indeed have been risky, the original inhabitants of the Caribbean apparently were experienced maritime travelers. Trade throughout much of the Caribbean would have been incredibly effective without harsh and impassable landscapes to cross; instead, cargo and trade goods could be transported by sea in canoes effectively and without intensive and time consuming physical labor. Island life may also have afforded the inhabitants a greater degree of protection from enemy or hostile neighbors. With multiple groups living in relatively close proximity to one another, the ability to protect an entire community located within a confined location would have been invaluable (Newsom and Wing 2004).

The majority of the research that has been conducted within the Caribbean region suggests that the original habitation of pottery-using peoples took place predominately between 2,500 and 3,000 years ago (Moore 1991). However, the earliest radiocarbon dates that indicated signs of occupation were recovered from Haiti and show an early occupation date of 5580+80 BP. Many of the larger islands located within the northern portion of the island chain contain pre-ceramic settlements. Within the Greater Antilles, occupation appears to have begun much earlier than in the southern islands, however, it was not until later that any type of advanced site formations began to take place (Moore 1991). By the time the Europeans made their way across the ocean and ended up in the region, almost every Caribbean island was occupied (Keegan 1995). These cultures all possessed the skill to produce well made pottery, and most relied on agriculture to some extent, but had not yet achieved an advanced level of civilization--possibly as a result of the limitations presented by an island environment (Keegan 1995, Rouse 1964)

One of the most interesting and comprehensive studies that seeks to answer the question on the origin of the Caribbean inhabitants provides a concise look at the different groups populating the island chain. According to Irving Rouse (Rouse 1948, 1964), three separate groups occupied various islands over the course of several thousand years. The Marginal (Archaic) group, the Arawak and the Carib peoples all have claim to various sections of the island chain, and all possibly originated in different regions. The Marginal group, which consisted mainly of the Warrau and Ciboney tribes, inhabited various regions of the islands including the mouth of the Orinoco River in coastal Venezuela and the westernmost portion of Cuba. It is thought that this group was eventually pushed to these locations as a result of other peoples moving into and occupying the area, causing the Marginal tribes to move into more isolated and constricted locations. Most of the discussion, however, concerns the movement and relationships of the Arawak and Carib peoples.

The Arawak people were a large group that inhabited a portion of mainland South America as well as a series of the islands directly off of the northern coast of Venezuela. They may have been responsible for the crowding that forced the Marginal peoples into various portions of the islands along with the Carib groups. While the Arawak people had agriculture and well made pottery as well as an established and relatively complex religion, they did not approach the level of cultural complexity that has been seen in contemporaneous mainland Central America and the western coast of South America. According to historical documentation from the time of the European arrival in the West Indies, the Arawak peoples were said to have been attacked and harassed by the Carib groups living in the same region. The Caribs appear to have been much more concerned with warfare than the other Caribbean groups (Rouse 1964).

The Carib people are thought to have been one of the fiercer cultures inhabiting the coast of South America and the Caribbean. The Carib peoples informed European explorers that they were recent inhabitants of the Lesser Antilles when Columbus arrived at the end of the fifteenth century. They claimed to have moved into the island chain from South America, fighting and conquering the Arawak peoples as they went. It was recorded that they kept Arawak women as wives when they conquered a group and cannibalized the defeated Arawak warriors to gain and maintain their strength as fighters (Rouse 1964). Interestingly, the Carib peoples spoke an Arawakan language, probably reinforced by their Arawak wives, and that language eventually replaced their own Cariban language (Rouse 1964).

While most researchers assume that at least one group of people migrated into the Caribbean from South America, there has been much debate concerning their exact place of origin. Recently, speculation has arisen that the Carib peoples were originally native to modern day French Guiana, where they eventually worked their way into the island chain, eventually conquering large groups of Arawakan peoples (Rouse 1964, Allaire 1980). It has also been suggested that the Marginal people may have originated in Florida, although it has been exceedingly difficult to establish this particular connection (Berman and Gnivecki 1995).

Much of what we currently know about Caribbean migrations has been achieved through extensive ceramic analysis. Multiple researchers have worked through ceramic assemblages in an attempt to achieve greater clarity for the movement of Caribbean peoples (De Booy 1917, Rouse 1964, Curet 1996, Allaire 1995, Wilson et al. 1998). Accordingly, “archaeological investigations in the region have emphasized a culture-historical paradigm in which similarities in pottery modes (or other artifacts) are grouped into classes called series” and are then subjected to rounds of radiometric dates and then charted and compared in “time and space” (Keegan 1995). Keegan notes that “settlement patterns were influence by the physical, biogeographically and social environments in which population movements took place”, reminding us that there is no one cause and effect factor that influenced the population movements throughout the Caribbean region (Keegan 1995).

Ceramic assemblages have been used to establish and clarify multiple migrations as well as group interactions; however, a study of preceramic collections has allowed for a strengthening of the connection between the Yucatan and the Caribbean. Lithic studies suggest that at least one phase of the occupation of the Caribbean may have occurred as a result of groups from Belize or the Yucatan Peninsula moving eastwards at least as far as the islands of Cuba, Haiti and the Dominican Republic. The "similarities in macroblade technology between the two areas" suggest that some type of connection may have been established; however, there have been some question as to the comparison of chronologies (Wilson et al. 1998). Similarly, it has been argued that while the artifact data connecting the Yucatan and the Caribbean is sketchy and incomplete at best, it must be carefully considered because of the lack of a convincing argument of an early connection emerging from either South America or Florida. Coe (1957) argues that all small connections must be taken into account and considered, in his case, a blade that originated in Central America and was discovered in Haiti. While it remains a tenuous business at best to establish migration patterns with single artifacts, it is necessary, particularly in an understudied region, to take all possibilities into account. While the amount of research completed at this point in time is much more impressive than when Coe first protested the lack of attention paid by Caribbeanists to small assemblages and clues, the fact still holds true today that we do not know enough about Caribbean occupation and migration history to ignore any kind of potential evidence.

In summary, there appear to have been multiple population movements within the Caribbean from various locations beginning at least be 5500 B.C. These movements continued until the time of European arrival in the late fifteenth century. It is most probable that groups of people traveled into the Caribbean from South America, Central America, and North America at various times and interacted with each other as well as other populations on the mainland's, and eventually formed cultures specific to the island chain.

Palynological and Paleoclimatic Research

Past palynological and environmental analyses have been conducted in the surrounding region with an emphasis on the regional and coastal development (Graham 1995, McAndrews 1996, Ramcharan 1980, 1981, 2004, Ramcharan and McAndrews 2006, Rull et al. 1999 and Woodroffe 1981). One series of sediment cores has been collected from the island of Trinidad for the purpose of pollen analysis (Ramcharan 1980, 1981, 2004 and Ramcharan and McAndrews 2006). These analyses have contributed to what is known about the changing and developing environment of the Caribbean islands, as well as fluctuating sea levels during the Mid-Holocene. The island of Grenada, specifically, has not been the site of many palynological and environmental studies. Researcher John McAndrews collected a 430cm core from Levera National Park on the island in 1992 providing some data related to the changing environment of the island (McAndrews 1996). McAndrews study, which centers on a discussion of environmental change as a result of fluctuating sea levels, was based on abbreviated levels of 100 pollen grain counts per sample (McAndrews 1996). Additional environmental studies have been conducted in the surrounding region, including several studies of mangrove swamps in an effort to determine changing Holocene environments and sea level fluctuations (Ellison and Stoddart 1991, Graham 1995, Parkinson et al. 1994, Rull 1999, Woodroffe 1981, Woodroffe and Grindrod 1991).

Various paleoclimatic studies in the Caribbean, while scarce, provide interesting data about the region's biodiversity, and the changes that occurred in climatic patterns during the Holocene. A study of a pollen core by Higuera-Gundy et al. (1999) from Lake Miragoane in Haiti shows that prior to 10,000 BP the environment within the Caribbean was generally cool and dry. Additional studies, such as that conducted by Street-Perrott et al. (1993) on a series of cores from Wallywash Great Pond in Jamaica, support the conclusions reached by Higuera-Gundy, and demonstrates a forest expansion that occurred around 7,000 BP. This change has been determined to be the result of higher average temperatures and increased moisture that remained until approximately 3,200 BP (Street-Perrott et al. 1993). According to Hodell et al. (1991), after 3,200 BP the climate of the Caribbean region became significantly drier, however, evidence collected on St. Martin for roughly the same time period showed slightly wetter conditions locally (Fitzpatrick and Keegan 2007). With the arrival of humans and the intensification of land use, local vegetation experienced some dramatic changes including increased mangrove development within the region, resulting in often dramatic changes in resource availability (Keegan et al. 2003).

While environmental research within the Caribbean has recently experienced an increase of academic interest, the island of Grenada remains largely untouched, and a thorough analysis will fill in a significant gap within the environmental record of the Caribbean region.

Archaeological Background

Previous archaeological research completed on the island of Grenada includes excavations at the Savanne Suazey site as well as stratigraphic tests and surface collection at Salt Pond, Westerhall Point, Caliviny Island and the Pearls site (Bullen 1964, 1965). The majority of information recovered from these archaeological sites relies on an interpretation of the ceramic sequences found on the island. All of the sites discussed are located either on the northeast section of the island, while the Caliviny Island site is located just off of the southern coastline. Work at the Pearls site uncovered the *Simon-Saline Series* (Pearlsy Period) of ceramics, believed to be the earliest pottery recovered from the island of Grenada, and was followed chronologically by pottery of the Caliviny Series, eventually being replaced by pottery from the Suazey Series (Figure 2)(Cruxent and Rouse 1958).

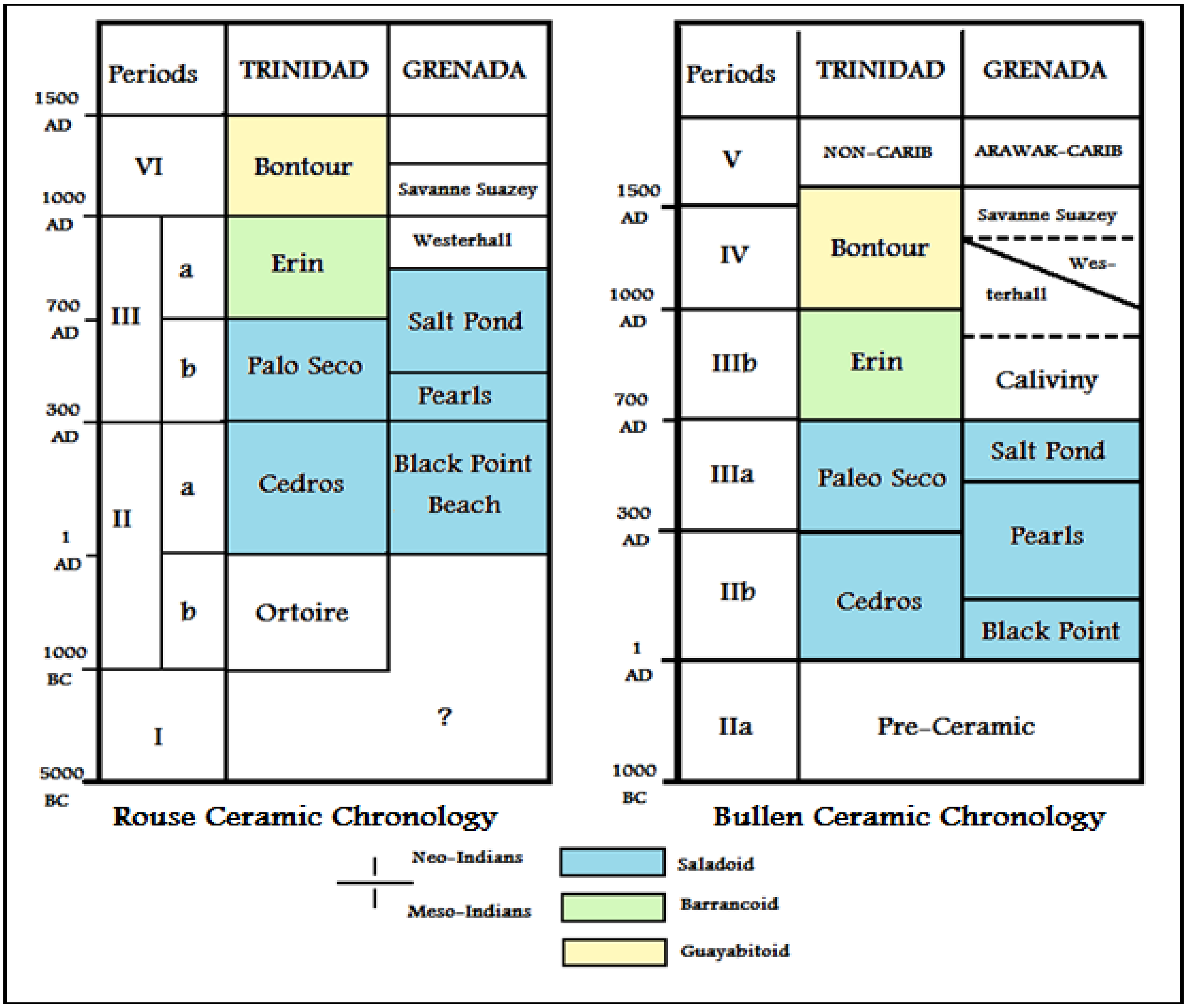

Figure 3. A comparison of the ceramic chronologies established by Rouse (1964) and Bullen (1964) for the islands of Grenada and Trinidad.

The excavations at the Savanne Suazey site resulted in the discovery of five separate burials. These burials showed substantial dental decay that was determined to be the result of a high carb diet. In addition to the burials, several sherds of Spanish pottery and some iron were discovered in the same area. This site has been identified as a point of European contact,that would eventually lead to the introduction of Old World sugar cane plantations (Bullen 1964). This site remains the most intensively excavated archaeological site on the island, and has provided a small glimpse of the archaeological possibilities for the surrounding area. One problem with data collection at the series of sites located on the northeast portion of the island has been the effects of erosion due to the sites' proximity to the Atlantic Ocean (Bullen 1964). The Savanne Suazey site was highly eroded, and a section of the site appears to have been completely removed from the coastline as result of ocean tides (Bullen 1964, 1965).

The Pearls Site, located south of the Savanne Suazey Site and the nearest excavated site to sediment core MB08-1, has experienced a different kind of destruction. The site, that may have originally covered as much as 25 acres, has been partially paved over by the Pearls Airport making excavation of the site difficult. Because of the less than ideal condition at the site, the work that has been completed at the Pearls Site mainly consists of surface collection and shallow stratigraphic tests rather than extensive excavation (Bullen 1964, Keegan 1991). With the closing of the Pearls airport in the mid 1980's, a series of excavations by Keegan took place at the Pearls Site in an effort to try to determine the age and function of the site. The previous decade had seen a significant amount of looting of ceramic artifacts at this particular site. Prior to the excavations, some small, carved green-stone pendants were discovered on the tourist market, eliciting interest in establishing the archaeological context for this particular region (Keegan 1991). Keegan's study of the Pearls Site began in 1989 and objectives were defined in an effort to provide maximum information in this poorly studied region. The research plan consisted of a series of analyses, including "the analysis of aerial photographs and the topographic mapping of surface features combined with an electromagnetic study of soil conductivity across the site in conjunction with horizontal and test excavations", all of which were particularly relevant to the region and environment of the particular site (Keegan 1991:4).

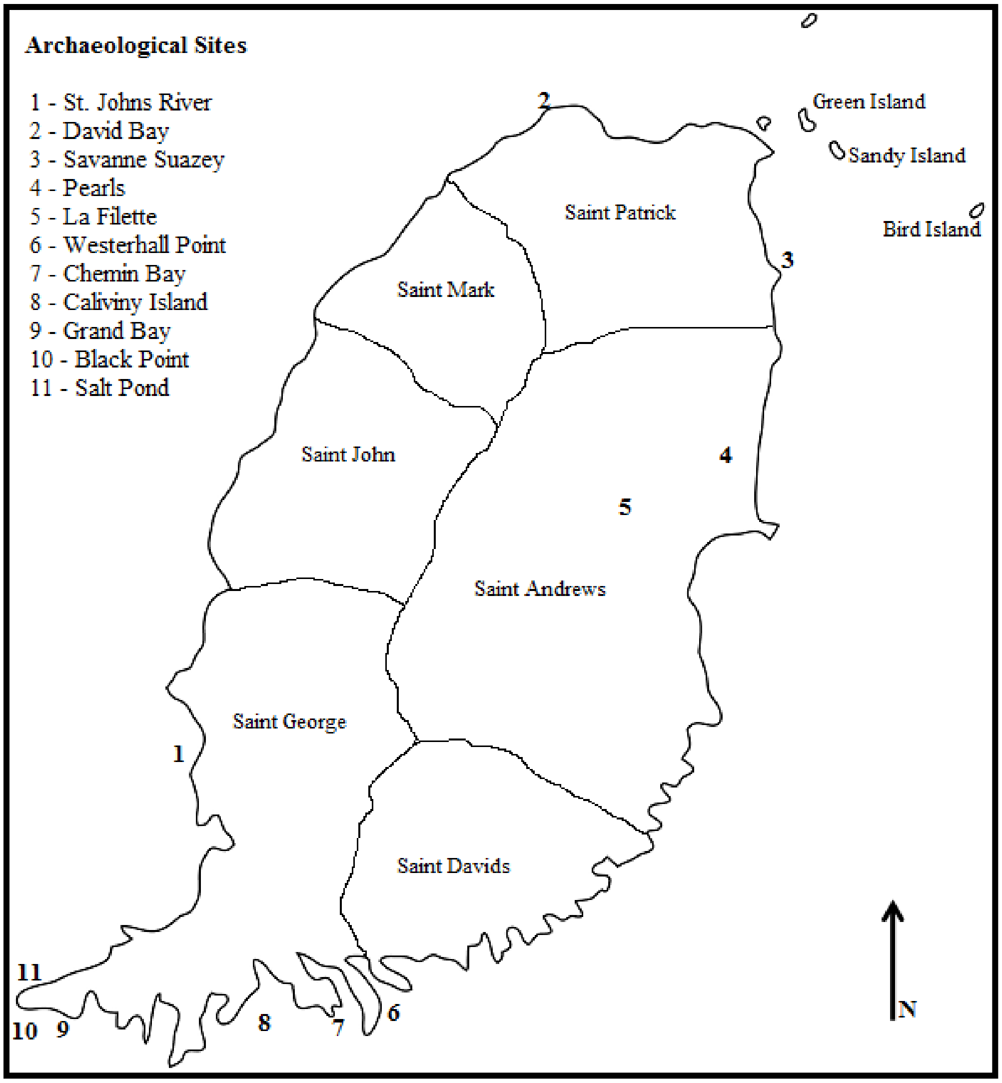

Figure 4. Known sites on the island of Grenada.

Large numbers of ceramic sherds were recovered from the work completed at the Pearls Site, that appear to be very similar to the Saladoid-Barrancoid tradition found in Venezuela. The ceramics recovered from the Pearls site have greatly contributed to the understanding of the ceramic chronology of the island as well as the cultural development of this region (Bullen 1964, Rouse 1964). In addition to the work conducted at Sazanne Suazey and the Pearls Site, surface collections were recovered from multiple sites including La Filette, Simon Beach and Big David

Bay. These collections supported the chronology established by sherd collection from Pearls, and has helped to strengthen the interpretation of the cultural changes that occurred within this region (Bullen 1964).

The southern coast of Grenada has been subjected to a small degree of archaeological examination that has produced some interesting results. The Caliviny Island and Westerhall Point Sites have both been subjected to surface survey as well as shallow stratigraphic testing in an attempt to determine the ceramic chronology of the southernmost portion of Grenada. Both sites produced large quantities of both Suazey Series and Caliviny Series ceramics with a marked lack of Pearls Series. These results suggest a slightly later occupation than that of the northern region, and do not markedly change the ceramic chronology of the island (Bullen 1964). In addition to the small-scale stratigraphic testing completed on the southern coast of Grenada, surface collections have been made at multiple different sites including Chemin Bay, Salt Pond, Grand Bay Site, Black Point and St Johns River Site, all of these collections have contributed to the development of a ceramic chronology (Bullen 1964).

Research in the Caribbean has been an ongoing challenge for archaeologists over the last several decades, and has recently been experiencing a revival of interest within the academic sphere. A critique, completed by Caribbean archaeologist Antonio Curet (2003), provides an interesting compilation of the research projects and papers that focus on both the history, methodology and research gaps that currently exist within the archaeological spectrum. The fluctuating interest in the Caribbean has long been a point of concern for archaeologists determined to create a thorough archaeological record of this island region. Curet states that,

> when Columbus landed on a small island in the Bahamian archipelago in 1492, he was expecting to find the subjects of the Great Khan or perhaps people from Sipango (Japan). Instead, he encountered Tropical Forest groups that spoke a dialect of the Arawak family of languages from South America. The news of the "discovery" of new people spread quickly throughout Europe, and for a few decades these indigenous groups were the best-known New World societies among European scholars (Curet 2003).

This interest in the Caribbean was short lived as the indigenous inhabitants of the islands were absorbed into the European system of colonization, and important cultural histories were lost. Interest in Caribbean archaeology experienced a revival in the early 1900's as archaeologists and historians again expressed a desire to uncover the mysteries of these pre-Hispanic societies (Curet 2003, Fewkes 1907, Loven 1935, Rouse 1939, 1948).

The history and prehistory of the Caribbean islands is very complex and includes various migrations as well as cultural interactions and development. While much of this sequence remains unclear, there is evidence that the Archaic groups that previously inhabited the Caribbean island chain may have been far more advanced than previously thought. These conclusions have been supported by the examination and presence of ceramic artifacts that can be classified within Rouse's chronologies (Curet 2003, Rouse 1964). Curet continues with his discussion of the archaeological history of the Caribbean, stating that while the Greater Antilles chain provides the majority of the archaeological data recovered, "The situation of the Lesser

Antilles for this period is more elusive, in part because of the scarcity of archaeological work, but also because some of the sites are located underwater" (Curet 2003).

Despite the difficulties concerning research in the Lesser Antilles chain, it is necessary to continue to work towards gaining an archaeological understanding of these under-represented islands. Not only will additional data collections provide enlightening facts on the archaeology of these particular islands, it will also aid in creating a thorough and comprehensive view of the Lesser Antilles chain.

Archaeology of the Caribbean: Where It Has Been, Where It Is Going

When examining the archaeology of the Caribbean, it becomes apparent that in comparison to other regions, the Caribbean has not received the same degree of attention. It seems as if one of the underlying factors that has contributed to the neglect of the Caribbean may be its proximity to the Maya mainland. Belize and the Yucatan Peninsula, like so many other regions rich in archaeological sites and data, has overshadowed the islands off of the coast for some time. Sites with massive architecture, advanced cultural complexity and a writing system tend to distract from other, less advanced but equally important groups of peoples. The archaeology of the Caribbean holds interesting clues as to the first impression the Spanish had of the New World before they reached the mainland, as well as the effect that the Spanish arrival had on the local population and culture. As described by Ricardo Alegria,

> the Antilles, having been the first center of Spanish colonization in the New World, felt the impact of the European conquest more keenly than any other area in America. So

> devastating was this impact that fifty years after the encounter, the aboriginal population of the Greater Antilles had almost entirely disappeared. (Alegria 1997)

To say that archaeological studies of the Caribbean have not been as prolific as in mainland Central America would be a gross understatement. While some researchers developed an interest in the archaeology of the Caribbean at an early date, such as Theodore De Booy, it was not until Irving Rouse began a 70 year career in anthropology, writing his dissertation on the prehistory of Haiti in 1939, that serious archaeological attention was paid to the cultures within the Caribbean (Keegan 2007). In 1917, De Booy conducted one of the first archaeological research projects on the island of Trinidad. The result of this project focused mainly on the ceramic assemblages rather than archaeological interpretation of the actual site. However, it did serve as a starting point for archaeological research within this region.

Rouse began a series of excavations in the Caribbean in 1935, and proceeded to excavate and publish throughout the region including Cuba, Haiti and Venezuela. He eventually published as a series of handbooks on the native tribes of the Caribbean region. Rouse's research (and extensive publishing) has consisted primarily of the construction of a ceramic chronology that can be used to help archaeologists define different groups of people and their subsequent cultures, as well as the peopling of the Caribbean as a result of different migratory routes (Rouse 1939, 1952, 1964, 1986, 1992). Rouse's work reached a culmination with the publication of fifty years of Caribbean research in *The Tainos: Rise and Decline of the People Who Greeted Columbus* (Rouse 2007). Some of the more interesting work completed by Rouse has been his work on the migration of populations living within the Caribbean region. His presentation of archaeology in the West Indies helped to both summarize and discuss the work that has been done in the area, as well as offer insights into what needs to be done to provide a usable record of the pre-history of this particular region. Rouse claims that one of the problems hindering Caribbean archaeology was the lack of well-preserved archaeological data. Because of the environment and the highly oxidizing conditions of the region, organic preservation is poor. The majority of materials used in the West Indies, including materials used in house construction, is organic and thus nearly invisible in the archaeological record. Rouse states that “when archaeology began in the West Indies, it was assumed that, as in our own civilization, the aborigines lived in relatively permanent houses, cleaned them thoroughly, and deposited their refuse elsewhere in neat piles” (Rouse 1977:6). Eventually it was determined that because the dwellings were composed primarily of organic materials, they were perishable and the native peoples frequently moved. Rouse concludes that, archaeologically,

> The divisions between components tend to be horizontal rather than vertical and are often blurred by the haphazard nature of the process of deposition. Furthermore, a sharp vertical break between components does not ordinarily mean that a new group of people occupied the site… (Rouse 1977:6).

While the archaeological work being conducted in the Caribbean continues to improve with the aid of studies such as that conducted by Rouse, there are still large steps that must be taken in order to achieve the desirable results of having a complete and dependable archaeological record that is comparable to the archaeology of the surrounding regions.

Recently, there has been a renewed interest in Caribbean archaeology. Researchers have taken an interest not only in material studies and migration patterns, but also in the general history and chronology of the peoples of this understudied region. In the last decade archaeological excavations have taken place on many of the larger islands within the chain, including Dominica, St. Croix, and in the French West Indies including Marie-Galante, Martinique and Guadeloupe (Honychurch 1997, Kelly 2004, Norton 2007). While it is a positive thing to see that archaeological investigation is continuing within the Caribbean region, there are several trends that seem to be appearing within these recent works. One of the most obvious trends is the emphasis on historical archaeology in the Caribbean.

Sites dating from the time of European arrival have become the focus of many recent excavations. Another factor in Caribbean archaeological research is the degree of international interest this region has received. Researchers from throughout the world now work in the Caribbean. Each researcher brings the tools, techniques and styles of their particular nation, leading to problems of consistency and comparability. Another problem that we have encountered as researchers, is gaining access to these reports often published in a variety of languages and hidden in obscure journals. While it is reassuring that a renewed interest currently lies in Caribbean archaeology, it is difficult and often frustrating to try to access this research once completed.

The history of the Caribbean peoples is both complex and intriguing. To fully understand these peoples, it is necessary to have a thorough comprehension of their origins, as well as the environment in which they lived and flourished. To interpret and understand the archaeological record, researchers must have a thorough knowledge of the climate, vegetation and animal species inhabiting these islands. Research in the Caribbean is currently seeing an increase in attention from professionals focused on understanding the region that was host to the first

Spanish colonization. Without a thorough knowledge of the early colonial history of the Caribbean, a reliable interpretation of the surrounding mainland regions is difficult.

CHAPTER THREE

Methods

Core Collection

During July of 2008, the sediment core named MB08-1 (Meadow Beach, 2008, Core 1) was collected by a team directed by Dr. Peter Siegel of Montclair State University and Dr. John G. Jones of Washington State University. When searching for an appropriate sediment collection locality, there are several environmental aspects to consider in regard to pollen preservation. In particular, it is vital that researchers locate an area that remains permanently saturated for the collection of sediment cores. Although pollen grains can be incredibly durable and can survive for thousands or millions of years unchanged, there are multiple environmental factors that must be met in order to maintain an identifiable level of preservation. A permanently wet environment is preferable for good pollen preservation because periods of wetting and drying can lead to fungal and bacterial degradation that can ultimately cause damage the exterior features of the grains. Each subsequent wet-dry cycle further increases the chances of the grains themselves being unidentifiable, rendering them meaningless for the reconstruction of the paeleoenvironment (Faegri and Iversen 1989). Because of this sensitivity, the local environment greatly affects whether or not appropriate quantities of well-preserved pollen grains are available for collection, analysis and identification, and whether a paleoenvironmental reconstruction is even possible within a particular region.

The proximity to Lake Antoine, as well as the Pearls archaeological site was considered when choosing a coring location in an attempt to provide in-depth environmental data that would be contemporary with both the Lake Antoine core and the habitation of the Pearls site. The coring location, situated in a Red Mangrove (*Rhizophora mangle*) swamp approximately 100 meters inland from the northeastern coast of the island, was selected by Jones based on its undisturbed appearance (Figure 3). Meadow Beach, located on the northeastern coast of Grenada, presented not only an undisturbed area, but a location which had not been subjected to extreme variations in wetting and drying, with the buried sediments remaining wet year-round, a necessary requirement for pollen preservation. The sites' proximity to the coast and its location in a reduced organic accumulating location made it an ideal coring location. The appropriateness of the location was further confirmed by the presence of well preserved fossil pollen grains throughout the column. A modified Livingstone Piston Coring Device, constructed by Dr. Jason Curtis of the University of Florida, was used to extract the core. A series of 1 meter segments, representing a total core length of 493cm was collected from Meadow Beach. After extraction from the ground the segments were sealed and labeled for transport.

Sediments were transported back to the base camp, and the cores were subsampled on the same day that the core was collected. After extrusion, each section of core was split longitudinally for sampling. Sediment samples for pollen were collected in one centimeter thick portions at five centimeter increments along the core length, using a knife, cleaned between each use. Sediments for phytolith and soil analysis were also collected from the remaining portions of the core by Dr. Pat Farrell from the University of Minnesota, Duluth, and Jason Fenton from the University of Missouri. Pollen samples were sealed in whirl paks for transport back to the Washington State University Palynology Lab.

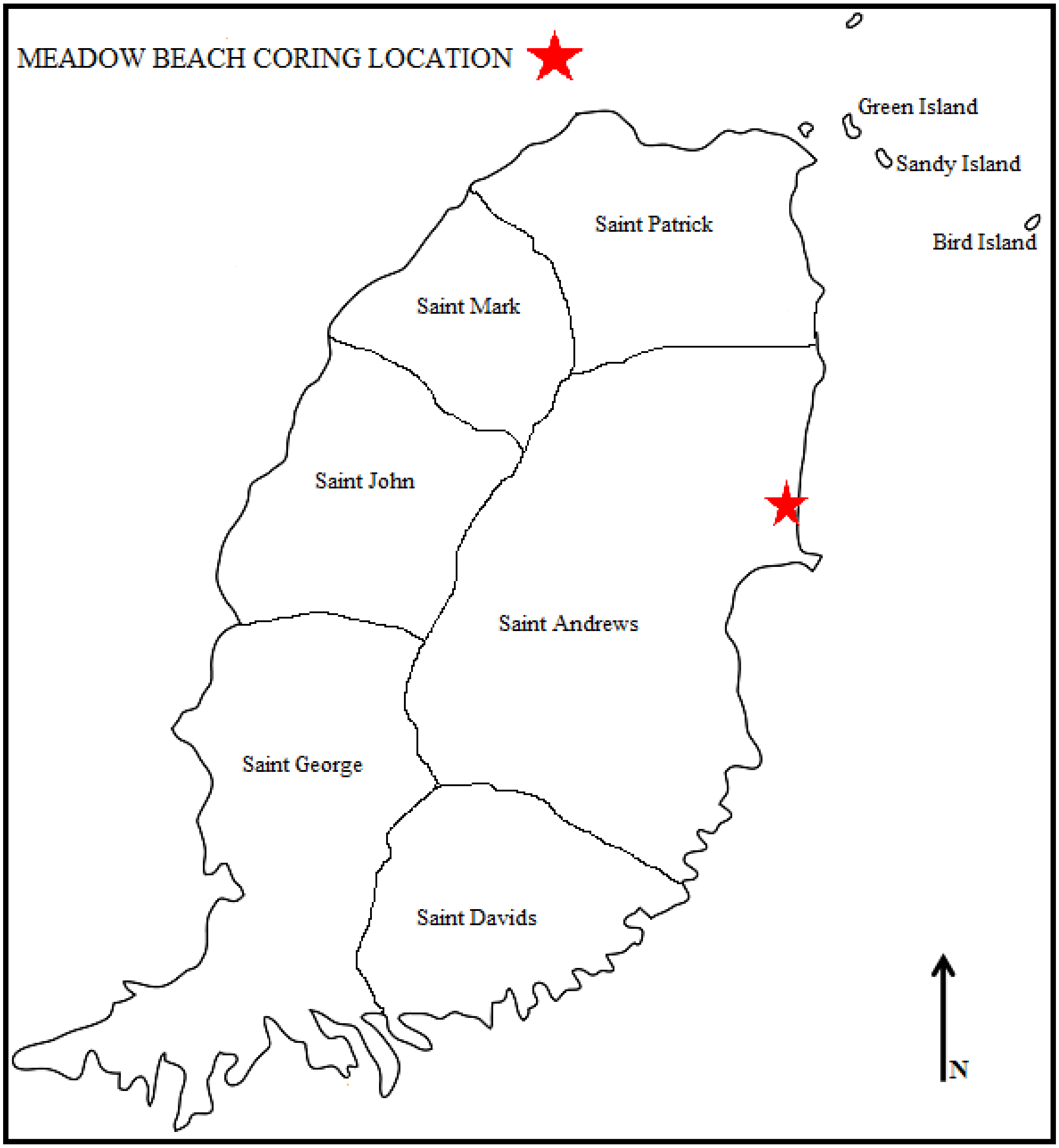

Figure 5. Map of the Island of Grenada featuring MB08-1 coring location in the northeastern corner of the island.

Lab Procedure: Sampling and Processing

The pollen samples were first quantified (1cc.), placed in sterile beakers, and a known quantity of exotic tracer spores was added to each sample. Here, European *Lycopodium* spp. spores were chosen as an exotic, because these spores are unlikely to be found in the actual fossil pollen assemblages from this region. Tracer spores are added to samples for two reasons. First, by adding a known quantity of exotic spores to a known quantity of sediment, fossil pollen concentration values can be calculated. Second, in the event that no fossil pollen is observed in the sediment sample, the presence of *Lycopodium* tracer spores verifies that processor error was not a factor in the pollen loss.

Following the addition of the tracer spores, the samples were washed with concentrated Hydrochloric Acid. This step removed carbonates and dissolved the bonding agent in the tracer spore tablets. The samples were then rinsed in distilled water, sieved through 150 micron mesh screens, and swirled to remove the heavier inorganic particles. Next the samples were consolidated, and 50% Hydrofluoric Acid was added to the residues to remove unwanted silicates. This step deflocculated the residues, effectively removing all colloidal material smaller than two microns. Samples were then washed in 1% KOH to remove any remaining humates.

Next, the samples were dehydrated in Glacial Acetic Acid, and were subjected to an acetolysis treatment (Erdtman 1960) consisting of 9 parts Acetic Anhydride to 1 part concentrated Sulfuric Acid. During this process, the samples were placed in a heating block for a period not exceeding 8 minutes. This step removed most unwanted organic materials, including cellulose, hemi-cellulose, lipids and proteins, and converted these materials to water-soluble humates. The samples were then rinsed in distilled water until a neutral pH was achieved.

Following this treatment, the samples were next subjected to a heavy density separation using Zinc Chloride (Sp.G. 2.00). Here, the lighter organic fraction was isolated from the heavier minerals. After this treatment, the lighter pollen and organic remains were collected. The residues were then dehydrated in absolute alcohol, and transferred to a glycerine medium for curation in glass vials.

Permanent slides were prepared using glycerine as a mounting medium, and identifications were made on a Nikon compound stereomicroscope at 400x magnification. Identifications were confirmed by using the Washington State University Palynology Laboratory's extensive pollen reference collections, and published keys. Minimum 200-grain counts, standard among most palynologists (Barkley 1934), were made for each sample. 200-grain counts are thought to be fairly reflective of past vegetation and paleoenvironmental conditions.

Concentration values were calculated for all samples. Hall (1981) and Bryant and Hall (1993) note that concentration values below 2,500 grains/ml of sediment may not be well reflective of past conditions, and usually record a differentially preserved assemblage. As a result, counts with low concentration values should be viewed with caution. However, In the event that pollen grains are nearly perfectly preserved, but concentration values are low, then rapid sediment (and associated pollen) influx may be evident. In short, concentration values are a potentially valuable source of information in pollen analysis.

Slide Preparation and Pollen Identification

Slides were made for each sample, using glycerine as a mounting medium. Nail polish was used to seal the cover slips preventing movement and dessication. With the help and instruction of Dr. John G. Jones, as well as reference collections and published pollen keys, grains were identified to their highest identifiable taxonomic level (Chavez et al. 1991, Roubik and Moreno 1991). For each sample, a minimum of 200 pollen grains was counted, along with the introduced *Lycopodium* sp. spores encountered during the 200 grain count (Barkley 1934). While each sample produced well preserved and identifiable pollen, several samples required that multiple slides be made due to high quantities of organic detritus in order to reach the prerequisite 200 grain counts.

Charcoal fragments were counted following a standard WSU pollen laboratory protocol. All fragments of charcoal between 8 and 80 microns were counted in scans, along with *Lycopodium* tracer spores, until a minimal of 20 tracer spores were encountered. This allows for the calculation of charcoal concentration values.

CHAPTER FOUR

Results

A total of 44 sediment samples were examined for the core MB08-1. Well preserved pollen was found in all samples and 200 grain counts were achieved for all samples. A minimum of 38 pollen taxons was identified in the assemblage, representing mangrove, non-arboreal, arboreal and unidentified or otherwise unknown categories. Pollen concentration values ranged from 7,942 to 217,971 fossil grains/ml of sediment. These values are considered to be high confirming the generally excellent pollen preservation in the Meadow Beach Core. Pollen taxa identified in the assemblages are shown in Table 2, and pollen counts and percentages are provided in Appendix A.

Radiocarbon Dates

In order to assure that the Meadow Beach core contained intact sediment deposits that were representative of a significant portion of Grenada's paleoenvironmental history, a preliminary $_{14}$C sample was submitted to the University of Arizona AMS lab from the bottom of the core at 493cm. The date recovered demonstrated that the lowest portion of the Meadow Beach core was approximately 6055 years BP, assuring us that the environmental record would include significant events throughout the time period of human occupation of the island. Two additional $_{14}$C samples collected at points of noticeable change along the length of the core were later submitted for radiocarbon dating. The samples from 330 centimeters returned a date of approximately 4421BP, while the samples from 215 centimeters yielded a representative date of approximately 2881BP (Table 2).

All radiocarbon samples were composed of highly organic sediment. These samples were collected from the center of the core where the outer rind of the core had been removed to eliminate any possibility of sediment mixing. Using tweezers, all potentially younger modern day rootlets and organic matter were removed from the sample following the Washington State University Protocol for the palynology lab.

				Isotopic	
Lab #	**Depth**	**Type**	**Calibrated**	**Value**	**Date**
AA84798	215-217cm	Organic Peat	-	D13C: -27.0	2881+/-39BP
AA84799	330-332cm	Organic Peat	-	D13C: -30.4	4421+/-41BP
AA82678	492cm	Organic Peat	Cal5927-6182BP, 2 sigma	D13C: -31.1	5265+/-51BP

Table 2. Radiocarbon dates for Meadow Beach core MB08-1.

Pollen Taxons

There are multiple plant taxa that are significant in the interpretation of the environment of Grenada that must be addressed in order to fully understand the pollen interpretation of this particular core. The analysis of core MB08-1 resulted in the identification of 38 pollen types. Grains were identified according to an analysis of morphological features including surface ornamentation, apertures and only occasionally size. The identification of the various grain types was facilitated with the assistance of Dr. John G. Jones, and grains were identified to the highest taxonomic level. Mangroves have been presented first within the following section as they are discussed often throughout the interpretation of the Meadow Beach sediment core, and therefore should be paid particular attention. Arboreal taxons and Herbs have been separated and alphabetized based on physical properties suggested by each classification.

MANGROVES

Avicennia

Avicennia is a member of the Avicenniaceae or Black Mangrove Family and is generally found in hypersaline coastal environments. *Avicennia* relies on insect vectors for pollen transportation and pollination, and therefore makes use of impressive floral displays to attract the necessary insects. Across the world there is only one known genus of *Avicennia* which includes eight identified species (Smith 2004). Pollen produced by *Avicennia* can occasionally be identified to the species level if preservation is optimal. *Avicennia* pollen is the least common mangrove taxon found within this sediment core, occurring in 50% of all samples analyzed, in percentages never exceeding 10%.

Combretaceae

Pollen from the Combretaceae or White Mangrove Family was well-represented in the Meadow Beach Core. Plants in this family thrive in a saturated but less saline environment. Members of the Combretaceae Family primarily grow in tropical environments, most notably South and Central America, and can be an important species within forest, savanna and mangrove environmental systems (Blake 2008). Combretaceae grains are both wind and insect pollinated, thus they tend to be fairly common in archaeological samples. The pollen produced by the Combretaceae Family is mostly similar in appearance, making it difficult to identify grains to the species level. Major genera included in the Caribbean region include *Laguncularia, Terminalia, Conocarpus* and *Bucida.*

Rhizophora

Rhizophora is a member of the Rhizophoraceae Family, commonly known as Red Mangrove. Red mangroves are common in all tropical and subtropical regions in the world, where they are often seen in coastal areas, swamps, streams and estuaries. Due to its tolerance of salt, it is often the dominant species within the environments in which it grows. Unlike black and white mangroves, red mangroves prefer a more brackish environment rather than a fresh and/or saltwater environment (Gustafsson 2004). *Rhizophora* is the most dominant species identified in the MB08-1 core, with examples identified in 100% of the samples analyzed in percentages as high as 92%.

HERBS

Asteraceae

Asteraceae (Aster of Compositae Family) pollen grains are among the most easily identifiable grains due to their distinctive surface morphologies. Elaborate surface decoration such as that seen on Asteraceae grains often implies that the plant is insect pollinated, relying its ability to attach itself to an insect or animal vector for transportation and pollination. The Asteraceae Family is one of the largest flowering plant families with over 1,500 genera, many of which are found in the neotropics (Pruski and Sancho 2004). This family is most commonly represented in the form of perennial herbs and shrubs, and is often found in disturbed environmental zones or areas with minimal forestation (Pruski and Sancho 2004). Asteraceae grains were infrequently identified in the MB08-1 samples, with higher percentages found in certain zones, possibly representing either human-caused or natural disturbances.

Cheno-Ams

Cheno-Ams are pollen grains from the family Chenopodiaceae and the genus *Amaranthus* in the Amarantheaceae Family. They are commonly found in nearly all New World pollen assemblages. The grains are generally covered by a plethora of evenly spaced pores, and are usually unidentifiable to the genus or species level. Plants in this group generally grow in disturbed areas in the form of herbaceous weeds, and are oten used as an indicator of agriculture or human clearing (Clemants 2004). This grain was only encountered in small numbers in a few samples, and probably represents natural salt-tolerant weeds.

Cucurbitaceae

Cucurbitaceae (Squash Family), is represented by 53 genera in tropical America including 325 species (Nee 2004). Members of the Cucurbitaceae Family are found worldwide with the exclusion of cold-temperate and arctic regions (Nee 2004). Most members of the Cucurbitaceae Family are typically difficult to identify based on pollen grain analysis, and all members of the family are insect pollinated and are rarely encountered in archaeological assemblages. This grain was only encountered twice in the Meadow Beach core.

Euphorbiaceae

Euphorbiaceae, (Spurge Family) has approximately 105 identified genera and 1,800 species growing in tropical America (Webster 2004), and is represented by both herbs and arboreal forms. Euphorbiaceae is most commonly found in seasonal forests and deserts, as well as rainforests within tropical environments (Webster 2004). Within the Meadow Beach Core, Euphorbiaceae pollen grains were only identified in one sample, located at 425cm below surface.

Fabaceae

Fabaceae, most commonly known as the Legume or Bean Family, contains 272 genera and over 6,700 species in the Western Hemisphere alone. Members of this family are generally found in a variety of habitats, and these plants are often the most abundant and conspicuous plants within these environmental zones (Seigler 2004). The Bean Family contains many economic species including peanuts, peas, carob, tamarind, lentils and lima beans, and their seeds frequently contain high protein content (Seigler 2004). Within the Meadow Beach Core, Fabaceae pollen was identified in only six samples with frequencies less than 2%.

Nympheacaea

Nympheaceae represents the Water Lily Family, and is only rarely encountered in archaeological assemblages. Across the world six genera and 55 species have been identified, with 3 genera occurring in tropical America (Padgett and Les 2004). Nympheaceae is commonly found growing in shallow, freshwater pools or slow moving rivers (Padgett and Les 2004). This species was uncommon in the MB08-1 Core, occurring in only eight samples, usually represented by single grain occurrences.

Onagraceae

Onagraceae, also known as the Evening Primrose Family is commonly found in the western hemisphere with 12 identified genera and 240 species (Berry and Hoch 2004). Onagraceae occurs in a variety of habitats and some species are aquatic. All members of this family rely on insect vectors for pollination, and it is often difficult to identify these pollen grains to the generic level. Onagraceae pollen is uncommon in the Meadow Beach Core, with grains identified in only six samples, and with frequencies below 3%.

Poaceae

Poaceae (Grass Family) grains are wind pollinated, thus are commonly found in many archaeological samples. Poaceae pollen grains can rarely be identified below the family level, with the exception of domesticated Old World cereal grains and maize. Over 2,500 species of grass are known from the American neotropics, and grass pollen is one of the most commonly found grains (Kapp et al. 2000). Grasses can be found in every habitat across the world, and are wind pollinated, allowing grains to travel great distances from the source. Their presence often indicated a disturbed area or savannah type environment. Poaceae grains were commonly found in the Meadow Beach Core occurring in fluctuating frequencies throughout the length of the core.

Ranunculaceae

Ranunculaceae is a member of the Crowfoot Family, with 11 genera documented from tropical America containing approximately 100 species (Stevenson 2004). These grains are often difficult to identify, and classification at a species level is rarely possible. Ranunculaceae was not a commonly found grain in the Meadow Beach core, occurring in very low percentages (Less than 3%) in under half of the processed samples.

Sedge

Sedge, a member of the Cyperaceae or Sedge family, has approximately 40 genera and 1,000 species in tropical America (Thomas 2004). Sedges can be found in multiple neotropical habitats including marshes and open wetlands, grasslands and savannas. Sedges are generally wind pollinated, suggesting not only a high level of pollen production as well as a wide distribution area, although some forms produce much more pollen than others. Sedge was commonly found within the MB08-1 core, with grains identified in 50% of the analyzed samples in frequencies up to 10%.

Solanaceae

Solanaceae is the Nightshade Family and consists of over 60 genera in neotropical America. Plants of the Solanaceae Family often include shrubs, vines and herbs or rarely small trees. This family includes multiple species of wild and domesticated edible plants including peppers, potatoes, tomatoes and chilies (Blake 2008). Solanaceae grains often have tricolporate, psilate morphologies, making identification nearly impossible. Solanaceae was encountered in only six samples, and in quantities less than 5%.

Verbenaceae

Verbenaceae is the Vervain Family. This family is represented by 42 genera and 1,100 species in the Western Hemisphere, 700 of these species can be found in tropical America (Atkins 2004). Most members of this family are weedy herbs, but some trees are also represented. The herbacious members of this family are typically found occupying open forest areas as well as forest margins. Shrubs and herbs can also be found around the edges of mangrove lagoons, and in well-drained grasslands (Atkins 2004). Verbenaceae grains were not common in the Meadow Beach Core as only a single grain was identified at 115cm below surface.

ARBOREAL

Arecaceae

Arecaceae, also known as the Palmae or Palm Family. has over 67 genera and 550 species growing in tropical America. Palms are common in tropical climates around the world, as well as some sub-tropical areas including the United States, Africa and Asia (Henderson 2004). Palms are most often found in lowland and montane moist forests, although they also can occur in mangrove swamps and deserts (Henderson 2004). Palms were commonly identified in the MB08-1 Core, although exclusively below 325cm below surface, and in significant amounts up to 10%.

Bursera and *Protium*

Bursera and *Protium* are both members of the Burseraceae Family, *Bursera*, which is comprised of approximately 100 species and *Protium* with 147 species make up a large percentage of the Burseraceae Family. These genera are an important component of swamp forest ecosystems, though they can also be found in some dry forests. Members of the Burseraceae Family are insect pollinated and the presence of significant quantities of grains suggests a number of specimens within a close proximity to the coring location (Daly 2004). *Bursera* was commonly found in small percentages throughout the Meadow Beach Core, and was identified in 39 of the 44 samples analyzed, while *Protium* was rare, with only 3 identified grains.

Celtis

Celtis (hackberry), a member of the Ulmaceae or Elm Family occur throughout North America and the Neo-tropics, and is represented by seven identified genera with 25 identified species (Berg 2004b). This taxa was not commonly found within the Meadow Beach core, identified in only three samples with a total of four grains.

Coccoloba

Coccoloba, a member of the Polygonaceae Family, is widespread in Central America and the Caribbean and is commonly seen growing in saline coastal environments. There are between 120 and 200 species of *Coccoloba* identified in the neotropics, making it the largest genus of the Polygonaceae family (Atha 2004). Sea Grape, is a commonly encountered economic member of this genus. *Coccoloba* was present within the majority of the MB08-1 samples in quantities less than 10%.

Gymnopodium

*Gymnopodium,*is a tree in the Polygonaceae or Knotweed Family (Atha 2004). *Gymnopodium* generally relies on the use of insect vectors for pollination, and can rarely be identified to the species level based on the analysis of pollen grains. Only one grain was identified within the Meadow Beach Core at 425cm below the surface.

Ilex

Ilex (holly) is a member of the Aquifoliaceae Family. This genus is represented by over 500 species and is most commonly encountered in lowland or sub-montane cloud forests. This genus is insect pollinated and is not usually a common component of most pollen assemblages. In South America Loizeau and Spichiger (2004) have identified this plant growing in the Andes up to 4,000m in elevation. One economic member of this genus is *Ilex paraguagensis*, the source of maté tea.

Moraceae

Moraceae, the Mulberry Family, is composed of 19 different genera found throughout the neotropics. This family is often not identifiable to the genus of species level although the grains can usually be divided into morphological categories. Moraceae genera is one of the few tropical trees that is pollinated by wind, thus its pollen is often over-represented in archaeological samples (Berg 2004a). Members of the Moraceae Family have documented economic value, and *Brosimum* (breadnut), has been considered a food source of the Maya. Because these plants favor phosphate-rich soil, they are frequently found growing near archaeological sites (Blake 2008). Moraceae has been identified in 29 of the core samples in percentages that increase towards that bottom of the core, and represent a forested habitat.

Myrtaceae

Myrtaceae (Myrtle Family), is a large family of mostly tropical and subtropical trees and shrubs. These grains are rarely diagnostic below the family level, although they can usually be sub-divided into meaningful categories (Kawasaki 2004). Economic member of this family in the New World include *Psidium* spp. (allspice and Bay Rum) and *Eugenia* spp. Most of the grains noted in the Meadow Beach core compare favorably to *Eugenia* type, although a positive generic identification is not possible.

Quercus

Quercus (oak), is a member of the Fagaceae family and is one of three genera known from tropical America. Oak is wind pollinated, and generally produces enormous amounts of pollen (Blake 2008). Low frequencies of *Quercus* suggest that oak trees were not present within the immediate area. Oak grains were identified in 50% of the analyzed samples, never exceeding 3% of the total sample.

Rubiaceae

Rubiaceae, commonly known as part of the Madder Family, is the fourth largest family of flowering plants known with approximately 650 genera and 13,000 identifiable species across the world (Delprete 2004). Approximately 217 genera and 5,000 species are found in tropical America, and they are found in a variety of tropical habitats. Rubiaceae pollen grains are all insect-pollinated and are thus rare in archaeological pollen assemblages. These rare grains probably represent *Chiococca*, a common shrub in lowland Caribbean environments.

Sapotaceae

Sapotaceae (Sapodilla Family), is often identifiable to the genus level, although most MB08-1 samples were non-diagnostic. Sapotaceae trees are found distributed throughout the tropics, and unlike many species, prefers undisturbed forests (Pennington 2004). The majority of these species rely on zoophilous transport (animal vectors) for pollination. Sapotaceae grains were identified in over 50% of the samples with increasing frequency towards the bottom of the core. Many members of this family are of great economic significance and they are often spared when forests are cleared for settlement or agriculture (Jones 1994).

Spondias

Spondias is a member of the Anacardiaceae Family, and generally thrives in swamp forests and other lowland forests with high moisture levels. This genus relies on insect vectors as their primary tool for pollination (Mitchell 2004). *Spondias* trees are known to provide edible fruit that has been utilized and encouraged by the Maya peoples (Blake 2008). *Spondias* grains were identified in all but eight of the Meadow Beach samples, with increasing frequencies towards the bottom of the core.

Zanthoxylum

Zanthoxylum (prickly ash), is a member of the Rutaceae Family. *Zanthoxylum* is a large genera, with approximately 180 species, 72 of which are documented to occur in the Western Hemisphere. These trees or shrubs are commonly found in moist forests or swamp forests and observations suggest that they rely on insect vectors for pollination (Kallunki 2004, Blake 2008). *Zanthoxylum* is a commonly encountered grain towards the bottom of the Meadow Beach Core, increasing in frequency with greater depth.

OTHER ARBOREAL TAXA

A number of additional probably Arboreal types were encountered in the Meadow Beach Core, although never in significant quantities. These arboreal pollen types include the genera *Aspidosperma* (Mylady), *Haematoxylon* (hogwood), *Hura* (sand box), and *Myrica* (wax myrtle). These genera all represent swamp forest types favoring permanently saturated but freshwater systems. All but *Myrica* are insect pollinated and are thus only rarely encountered. Other rare arboreal pollen types could only be identified to the family level, and include Anacardiaceae (Cashew Family), Rhamnaceae (Buckthorn Family), Sapindaceae (Soapberry Family) and Tiliaceae (Linden Family). These types are known for a variety of habitats including both swamp and lowland forests.

Pollen Types	**Common Name**	**Habitat Class**
Avicennia	Black Mangrove	Mangrove
Combretaceae	White Mangrove Family	Mangrove
Rhizophora	Red Mangrove	Mangrove
Cucurbitaceae	Squash Family	Herb
Asteraceae	Aster Family	Herb
Cheno-Am	Goosefoot/Pigweed	Herb
Euphorbiaceae	Spurge Family	Herb?
Fabaceae	Bean Family	Herb?
Nympheaceae	Water Lily Family	Herb
Onagraceae	Evening Primrose Family	Herb
Poaceae	Grass Family	Herb
Ranunculaceae	Crowfoot Family	Herb
Sedge	Sedge Family	Herb
Solanaceae	Nightshade Family	Herb
Verbenaceae	Vervain Family	Herb?
Anacardiaceae	Cashew Family	Arboreal
Arecaceae	Palm Family	Arboreal
Aspidosperma	Mylady	Arboreal
Bursera	Gumbo Limbo	Arboreal
Celtis	Hackberry	Arboreal
Coccoloba	Sea Grape	Arboreal
Gymnopodium		Arboreal
Haematoxylon	Logwood	Arboreal
Hura	Sandbox	Arboreal
Ilex	Holly	Arboreal
Moraceae	Mulberry Family	Arboreal
Myrica	Wax Myrtle	Arboreal
Myrtaceae	Myrtle Family	Arboreal
Protium	Copal	Arboreal
Quercus	Oak	Arboreal
Rhamnaceae	Buckthorn Family	Arboreal
Rubiaceae	Madder Family	Arboreal
Sapindaceae	Soapberry Family	Arboreal
Sapotaceae	Sapodilla Family	Arboreal
Spondias	Hogplum	Arboreal
Tiliaceae	Linden Family	Arboreal
Zanthoxylum	Prickly Ash	Arboreal

Table 3. Pollen types identified from Meadow Beach sediment core.

Limitations of Paleoenvironmental Reconstructions using Pollen Data

When using pollen data to create a paleoenvironmental reconstruction of a particular region—in this case, an island—there are several factors to consider when interpreting pollen data. Aside from possible complications which may arise from researcher error, there are several qualities of the pollen grains themselves that may lead to difficulties in interpretation. While many species of plants produce pollen grains that both preserve well and are identifiable in the pollen record, other species may produce grains that are not only difficult to identify, but may not preserve well at all, which creates gaps in the paleoenvironmental interpretation (Faegri and Iversen 1989). Limitations must be recognized when interpreting the pollen record in order to ascertain how fully a paleoenvironmental record can be created.

Soil Characteristics of MB08-1

Analysis of the soil morphology from the Meadow Beach Core been completed for a total of 34 sections throughout the core, taking into account sediment changes in color and texture as well as location. Analysis was completed during the 2008 summer field season at the time of extraction by Dr. Pat Farrell of the University of Minnesota, Duluth. Soils recovered consisted primarily of silty-clays and clayey-silts with sections of dense peat and a firm sand layer at the very bottom of the core. Each designated soil change was determined by Dr. Farrell on the basis of changes in texture, color and inclusions. Sediments consisted primarily of silty-clay's and clayey-silts, with segments of peat, and surface and basal samples composed mainly of sand (Table 4).

Depth (cm)	Organic	Color	Texture	Notes
				Peat and sand at surface
5-13	Sapric	10YR 3/2	Silty	
13-30	Sapric	10YR3/1-10YR4/1	Clayey-silt	
30-35	Sapric	2.5Y 4/1	Clayey silt	Intact wood in matrix of sediment
35-40	Sapric	Alternating bands 2.5Y 4/2 - 2.5Y 3/1	Clayey silt	
40-55	Hemic	5Y2.5/2	Silty clay	Some wood; abundant black flecks
55-60	Sapric	2.5Y 2.5/1		Peat
60-70	Sapric	10YR 2/2	Silty	Peat
70-74				Undecomposed wood
74-95	Sapric	5YR 2.5/1		Reddish black peat
95-100	Hemic	5YR 2.5/1		Reddish black peat (bottom of Tube 1)
100-105				Slop; (top of Tube 2)
105-130	Sapric	10YR 2/1		Abundant black flecks
130-165	Sapric	5Y 2.5/1	Silty	Abrupt boundary at 165
165-180	Sapric	2.5Y 3/2; 10YR 2/1 at base	Silty clay	(bottom of Tube 2)
180-200				Slop; (top of Tube 3)
200-209	Sapric	10YR 2/1	Silt	
209-215		2.5Y 3/2	Silty clay	
215-220	Sapric	2.5Y 3/1	Silty clay	
220-244	Sapric	5Y 2.5/1		Peat
244-250	Sapric	2.5Y 3/2	Clayey silt	
250-266	Sapric	10YR 3/1	Clayey silt	
266-280	Sapric	10YR 2/2		Peat (bottom of Tube 3)
280-290				Slop; (top of Tube 4)
290-303	Sapric	2.5Y 3/1	Silty clay	
303-310	Hemic	2.5Y 2.5/1 (some 2.5Y 4/2)		Peat
310-325	Sapric	5Y 2.5/1		Peat
325-343	Sapric	5Y 2.5/1		Peat (bottom of Tube 4)
343-365				Slop; (top of Tube 5)
365-382	Sapric	10YR 2/2	Silty	Peat
385-443	Sapric	10YR 2/2 – 10YR 2/1	Clayey silt (stiff clay)	(bottom of Tube 5)
443-455				Slop (Top of Tube 6)
455-470	Sapric	10YR 3/1	Silty (small amount grit)	
470-488		Gley1 2.5/10Y	Sandy silt (grit increases with depth)	
488-493		Gley1 2.5/5GY	Sand (fine – medium)	Shell layer with sapric peat; (bottom of Tube 6)

Table 4. The soil morphologies determined from an analysis of the MB08-1 core depict a shift from silty clay to sandier sediments, and color and color boundaries.

CHAPTER FIVE

Interpretation and Discussion

Multiple environmental trends were identified during the analysis of the MB08-1 sediment core. The results of a detailed statistical analysis have proven to be particularly informative illuminating the changing environment of the region. A minimum of three zones were apparent in the Meadow Beach Core, outlined in Figure 6.

Pollen Zones in the Meadow Beach Core

The basal zone (Zone 3) of the Meadow Beach Core occurs between 493 and 330cm below the surface. This zone is made up largely of freshwater plants including Poaceae (grasses) Myrtaceae (myrtle family), as well as *Zanthoxylum* (prickly ash), palms and other swamp forest types, along with some mangroves. During sediment coring, we were extremely fortunate to encounter ancient and deeply buried lacustrine sediments at this location, as no traces are visible on the surface. The most apparent feature in this particular zone is the reduced representation of salt-favoring red mangrove pollen in contrast to the upper two zones of the core. The reduction in saltwater elements suggests that sea levels had not yet risen to their modern levels. Towards the top of this zone, there is a rise in both White and Red mangrove, marking what is probably a gradual rise in sea level.

The environment of the Meadow Beach region during the time of sedimentation was clearly different in this basal section than in later periods. Pollen types that are rare or absent from upper sections of the core are common between 493 and 330cm below surface. Many common taxa from this zone are typical of a swamp forest environment. Swamp forests occur in marshy, generally fresh, but sometimes brackish water areas. Trees in this type of forest will tolerate or often prefer having their roots wet throughout most of the year. Common Meadow Beach taxa for this zone characteristic of a swamp forest include *Coccoloba* (Sea Grape), Moraceae (Fig), Myrtaceae, Sapotaceae (Sapodilla Family), *Spondias* (Hogplum) and *Zanthoxylum*. A less saline, perhaps more open environment may also be indicated by increased amounts of pollen from Poaceae, Solanaceae (Nightshade Family) and Nympheaceae (Water Lily Family).

Particularly enigmatic is the abundance of pollen from an unidentified species of Palm (Arecaceae type H). These grains occur exclusively in this basal zone and likely represent an understory palm species. Both pollen and charcoal concentration values are fairly low during this zone. Low pollen concentration values may indicate a more rapid sediment accumulation rate. Low concentrations of charcoal suggest a minimal human presence in the area. Total counts of ferns are high during this zone, possibly suggesting a somewhat open freshwater habitat.

Zone 2, representing sediments from 330-215 cm below surface is significantly different from Zone 3. Here, there is a significant rise in red mangrove pollen, with a corresponding decline in most swamp forest taxa. Within this zone, red mangrove increases to an average of around 75% of each assemblage. *Avicennia* (black mangrove) also increases during this period. The increase in mangrove pollen likely corresponds to an increase and stabilization of sea level at essentially modern levels. Radiocarbon dates bracket this zone between 4,421 and 2,881 BP.

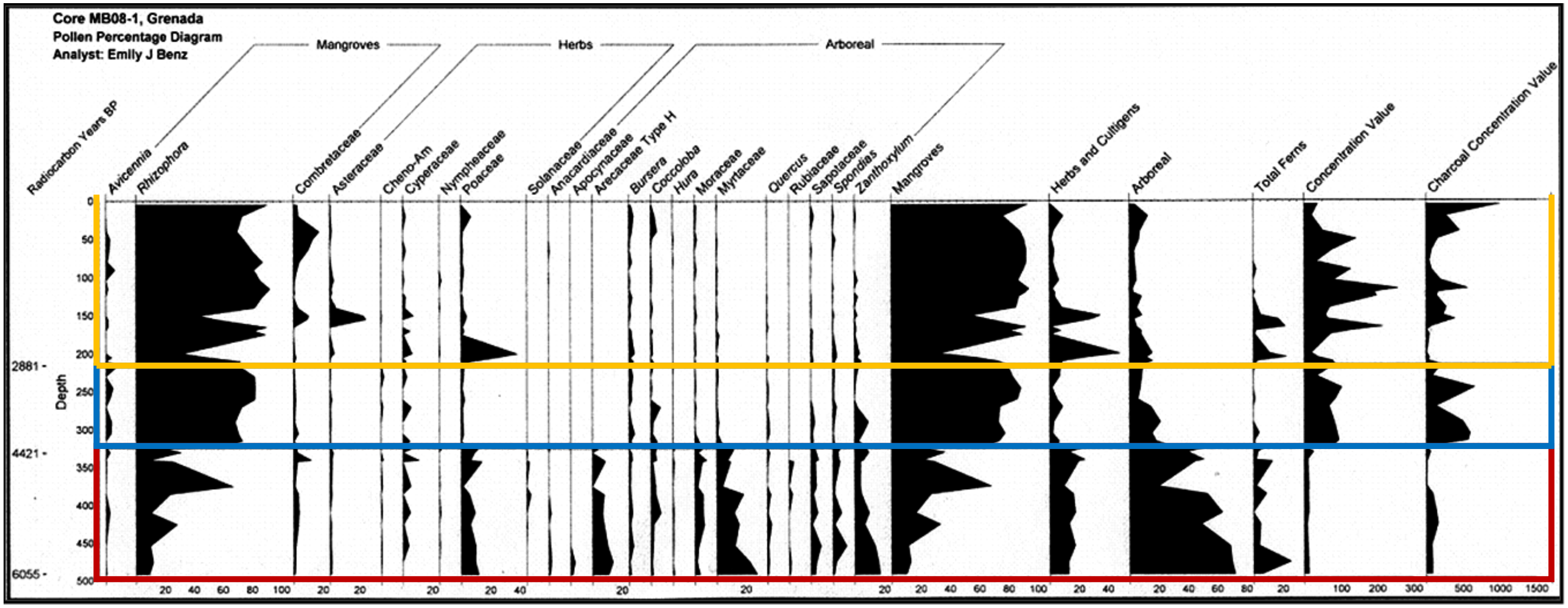

Figure 6: Pollen Percentage Diagram for MB08-1. Zone 1 is highlighted in yellow, Zone 2 has been highlighted in blue, and Zone 3 has been highlighted in red.

Along with the rise in mangrove type pollen, there is a corresponding decrease in arboreal and particularly swamp forest types. Moraceae, Myrtaceae, Rubiaceae (Madder Family) are significantly reduced, and by approximately 275 cm below surface, other swamp forest types are nearly gone from the record including *Coccoloba,* Sapotaceae, *Spondias* and *Zanthoxylum.* Ferns are also nearly eliminated from Zone 2, supporting the assumption that increased salinity during this period. Most ferns, with the exception of *Acrostichum* will not survive in a saline environment. Palms, common in Zone 3, are completely absent from this section of the sequence.

Herbs are noticeably reduced during Zone 2, suggesting for their lower presence in the coring vicinity. However, charcoal concentrations are higher during this period which would suggest human activity nearby, resulting in disturbed earth and an increased presence of herbs and grasses. Two explanations for this apparent contradiction are possible. First, the appreciable quantity of charcoal noted in Zone 2 may represent an increase in the human activity elsewhere in the northeastern Grenada area, but removed from the immediate site area. Alternatively, increased pollen concentration values during Zone 2 may reflect slower sedimentation rates. These slower rates might allow for the buildup of greater quantities of charcoal in the sediment. Both options are likely to have contributed to the increase in charcoal in Zone 2.

Zone 1, located above 215cm below surface, represents the period after 2,881 BP. The environment continues to be dominated by red mangroves, but with periods of abrupt change as reflected by spikes in grasses and composites (Asteraceae). These changes are likely to be anthropogenic in origin due to the corresponding charcoal spikes, but supporting evidence is scarce. Concentration values during this upper zone are highly variable possibly reflecting periodic storm events which would affect pollen distribution as well as sedimentation.

Sedimentation likely proceeded at a fairly slow and more or less constant rate, punctuated by periodic storm events. Charcoal concentrations, although fairly low, show two periods of increased particulate influx; from 150-100cm, possibly representing the time of the nearby Pearls site occupation, and from 50cm to the surface of the core, a period likely representing historic period activity in northeast Grenada. Additional radiocarbon dates are needed to support these ideas.

An interesting episode of fern spikes is apparent at the base of Zone 1 below 150 cm below surface. Although the cause of this is unknown, they occur at the same time that Poaceae and Asteraceae pollen increase and are thus likely to be associated with clearing or disturbance events.

In summary the pollen assemblages from Meadow Beach record a remarkable first glimpse into the paleoenvironment of prehistoric Grenada. The base of the core represents a fresh or brackish water swamp forest environment with minimal evidence of human activity. A palm forest behind the mangroves is recorded at this time at 330cm below surface, radiocarbon dated to around 4,421 BP until 2,881 BP representing Late Archaic times. Although increased charcoal counts strongly suggests human activity in the area, archaeological sites dating to this period are not yet documented from Grenada. This zone documents the stabilization of effectively modern sea level. Above this middle zone, above 215cm, a period of significant environmental fluctuations strongly suggests human activity in the region. Increases in disturbance taxa, including grasses and Asteraceae, along with corresponding increases in fern species signal clearing, possibly associated with human activity. Sustained periods of clearing likely indicate human activity nearby, for example at the nearby Pearls site or Savanne Suazey site. Increases in charcoal above 50cm likely represent historical activity in the Meadow Beach area.

Statistical Testing and Results

Multiple statistical tests were conducted on the pollen data recovered from the Meadow Beach sediment core, with the intention of evaluating the trends observed in the pollen percentage diagram that provide some interesting points for discussion.

One of the most significant trends noticeable within the distribution of pollen grains throughout the Meadow Beach core is the apparent shift from predominately freshwater pollen taxa to primarily saltwater species at approximately 4,421 BP. While this trend is strongly represented in the pollen percentage diagram, it is necessary to examine these changes in more detail to determine their strength. In order to create these figures, all of the data was standardized according to the sample size collected within each sample. This was accomplished by dividing the number of grains counted for each individual taxa by the total number of grains recorded per sample (simple percentage occurrence). This standardization ensures that one particular taxa is not overrepresented as a result of differences in sample sizes of grains identified in each individual sample.

Figure 7 represents the differences between freshwater and saltwater taxa after individual taxa standardization. For this particular test, the focus was directed specifically towards the comparison of the three varieties of mangrove identified, *Rhizophora mangle, Avicennia* and Combretaceae, and the eight most prevalent freshwater (swamp forest) taxa which included Arecaceae, Asteraceae, Moraceae, Myrtaceae, Poaceae, Sapotaceae, *Spondias* and *Zanthoxylum.* These particular taxa were selected because they display a significant degree of change throughout the length of the sediment core. The species not included in this test were excluded either because of insufficient numbers within the various samples, if they were not strongly indicative of a particular environment (salt or freshwater) or because they did not exhibit significant change throughout the length of the core.

By adding up the total percentages of saltwater and freshwater taxa, major trends are evident in the total percentages throughout the length of the core. These trends support the larger changes seen in the pollen percentage diagram, suggesting a substantially significant shift from freshwater to saltwater taxa about 315cm below the surface, or approximately 4,022 BP (Figure 7).

One very noticeable trend observed throughout the pollen record of core MB08-1 is the substantial degree to which mangrove species are represented throughout the entirety of the core. In an effort to more fully illuminate the representation of some of the more important freshwater taxa, an examination of pollen represented exclusive of these three mangrove taxa can be considered.

Similar to the standardization originally conducted on the various salt and freshwater taxa standardization of all of the taxa with the exclusion of all three mangrove species was carried out by dividing taxa occurrence by the total number of grains/assemblage. Here, percentages of freshwater taxa were calculated. Because there are over thirty freshwater taxa identified in the Meadow Beach sediment core, the five most frequently occurring freshwater taxa were selected to determine the degree of change through the sequence. While this figure may appear noisy, clear fluctuation of freshwater plants are readily apparent, and suggest that while there are indeed varying quantities of pollen within each sample, the fluctuations within these five types remain fairly constant, rarely exceeding 30% of any given sample.

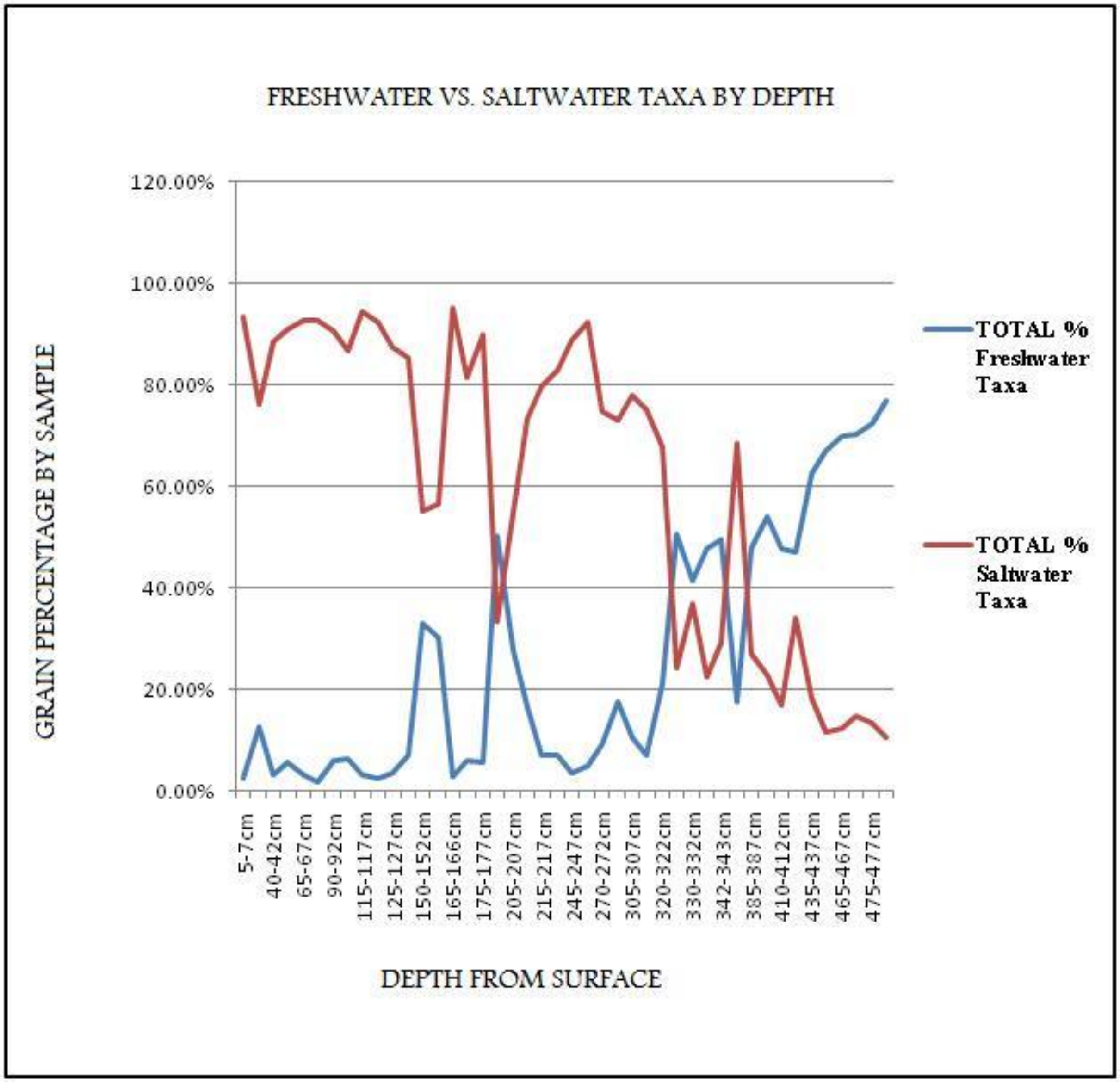

Figure 7: Freshwater vs. Saltwater Taxa organized by Depth. Over time a change occurs showing saltwater taxa becoming much more prevalent within the pollen record. Greater depth from the surface coincides with increased age, surface sample equals present data.

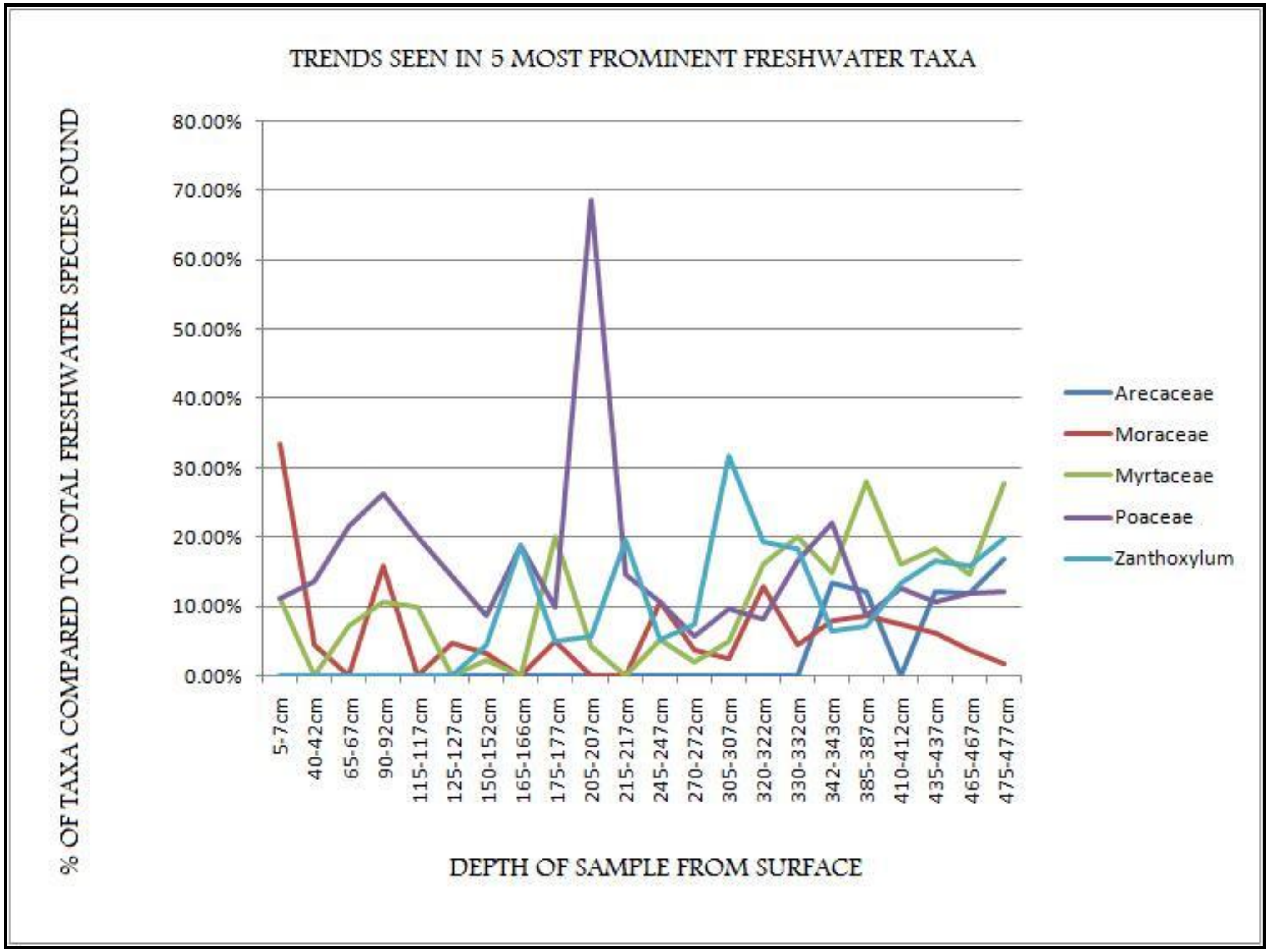

Figure 8. Trends observed in the five most prevalent freshwater pollen taxa from MB08-1. Percentages generally remain below 30%, however never exhibit the huge decreases suggested by the Pollen Percentage Diagram created.

One noticeable trend that is very apparent in Figure 8 is the sharp increase in Poaceae pollen found at 215cm below the surface. This trend, taking place around 2881 BP, suggests a notable, but short-lived change in the local environment, however, because it remains a distinct spike rather than an ongoing trend it is difficult to determine the degree of importance of this particular event. Additional research may be needed to determine if this is simply a unique occurrence in the Meadow Beach core, or whether it reflects a more widespread environmental event.

In addition to examining trends between saltwater and freshwater taxa throughout the length of the core, it is interesting to examine those same trends within the three specified zones that have been discussed based on the pollen percentage diagram. Figures (9,10,11) were created from standardized pollen counts for each separate zone show some interesting trends. Both of the uppermost zones (Zone 2 and Zone 3), show a similar trends which include fluctuating, but strong percentages of mangrove compared to much lower levels of freshwater taxons. These particular figures are representative of all identifiable taxons throughout the length of the core. Unidentified and indeterminate grains were omitted because they were not classified as either fresh or saltwater taxa and may have skewed the remainder of the data. While Zone 3 shows some major fluctuations near the uppermost portion of the designated Zone, Zone 2 shows a sharp and defined trend as the segment begins to transition into the lower Zone 1 (Figure 9 and Figure 10). Specifically, Figure 9 shows the predominance of mangrove species within the area compared to freshwater species with a slight overlap during a period of increased Poaceae production with may be the result of human activity (most likely clearing)

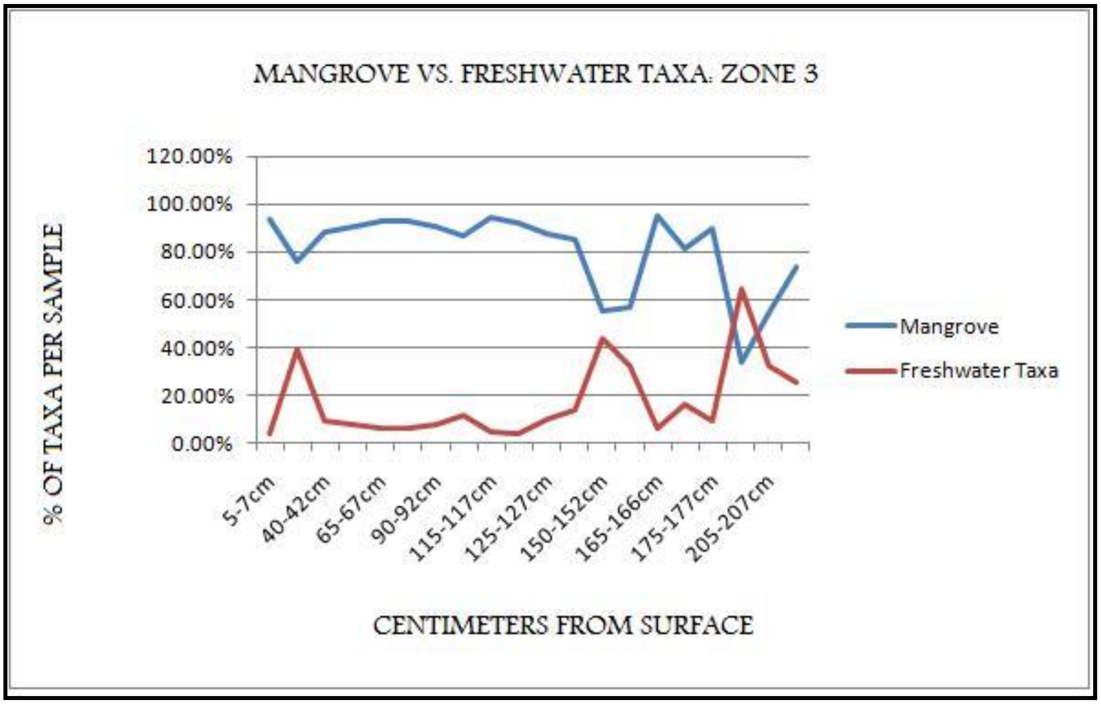

Figure 9. Mangrove vs. Freshwater plant taxa from Zone 3. Mangrove remains the dominant type with fluctuations occurring around the designated zone cutoff.

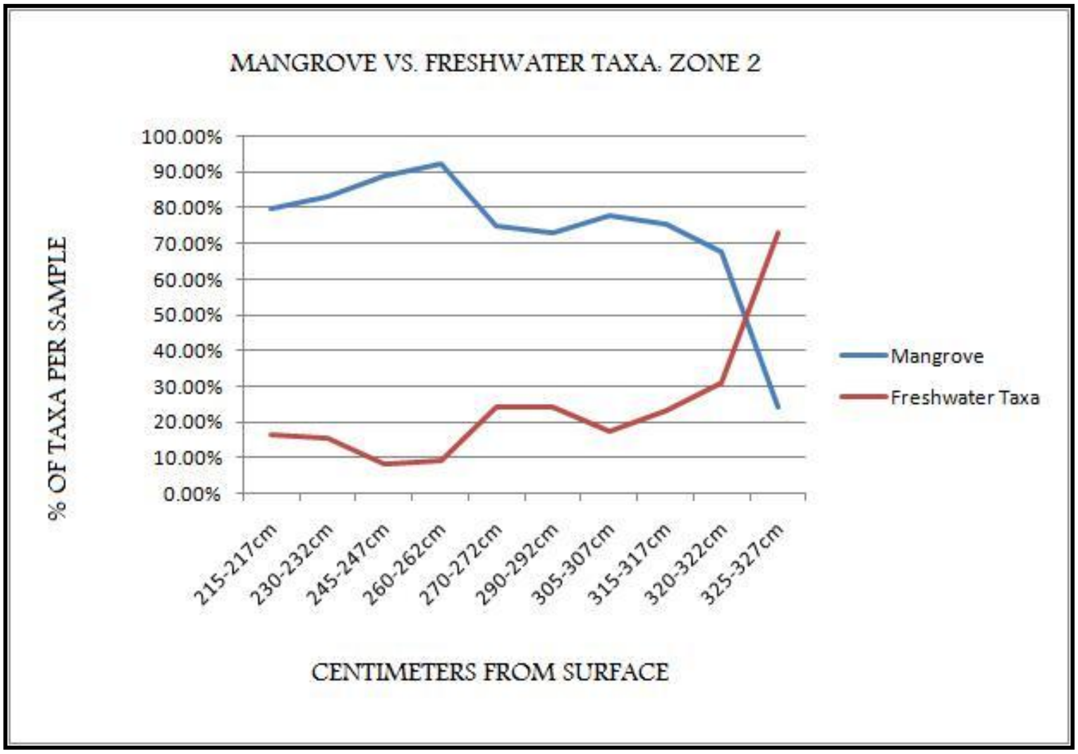

Figure 10. Mangrove vs. Freshwater plant taxa from Zone 2. Sharp delineations between Mangrove types and freshwater become reversed at the point of a new Zone (Zone 1).

within the area. Figure 10, similarly shows a stable period of mangrove dominance that abruptly ends with an increase in freshwater taxa towards the bottom of the zone.

Zone 1 presents perhaps the most interesting shift in that it demonstrates the dramatic change from predominately saltwater taxa, to a region primarily dominated by freshwater plant species. An examination of this Zone suggests that freshwater plant taxa are the primary pollen producers during this particular time period, and are interrupted only by a brief, albeit dramatic, spike in mangrove pollen within one particular sample. When compared to the other two Zones, 2 and 3, it is interesting to notice that while the two uppermost Zones depict a switch of dominant plant taxa at the bottom of the Zone, Zone 1's behavior may be interpreted as the exact opposite (Figure 8).

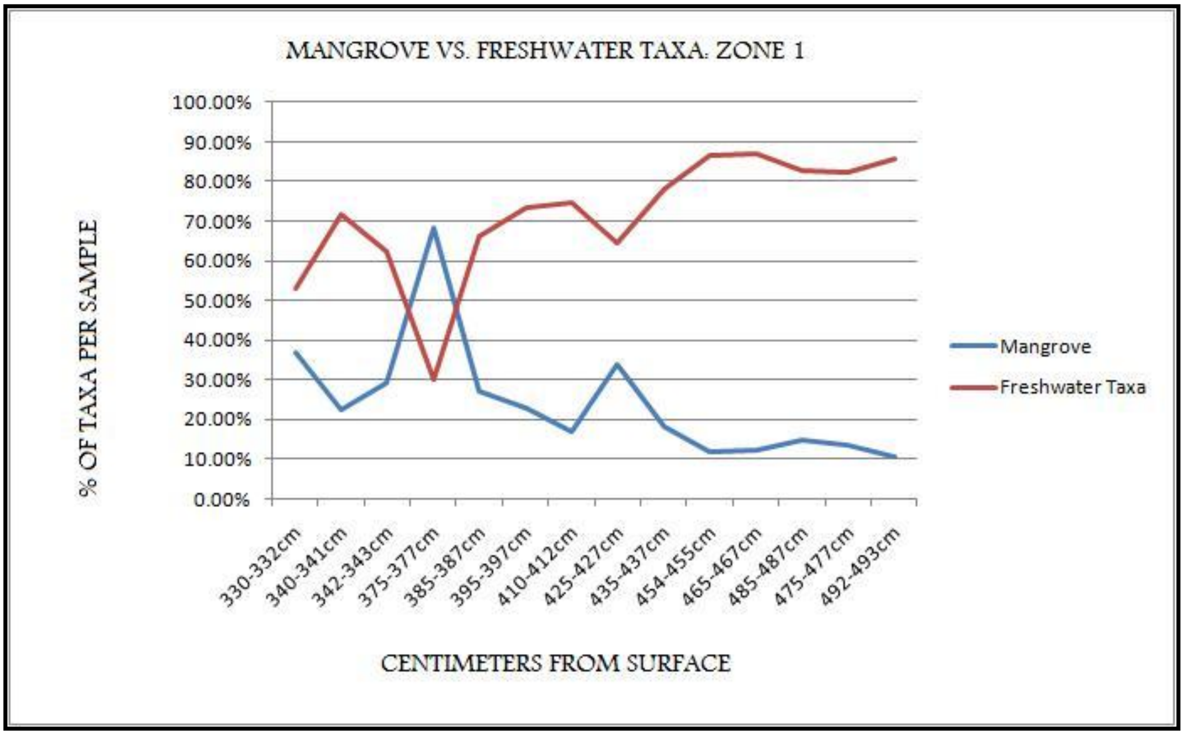

Figure 11. Mangrove vs. Freshwater plant taxa for Zone 1. Trend shows the shift from predominately freshwater plant species to mangrove taxa.

By creating visual representations of each individual zone, the displayed trends become more apparent when compared to one another. Several fluctuations can be seen within Zone 1 and Zone 3, however these can be attributed to single sample trends that may suggest isolated incidences within the paleoenvironmental record. An examination of the trends discussed by manipulating and focusing on specific data sets allows for an increased level of confidence when interpreting the pollen record based off of a collection of individual samples tested throughout the length of the Meadow Beach core. These trends support the original interpretation and observations based on the pollen percentage diagram.

Charcoal Values and Interpretation

One aspect of the Meadow Beach core that has provided an interesting basis for discussion lies in the variation of charcoal found in the individual samples. Charcoal counts within a sediment core can be used to compare fluctuations within the pollen assemblage to charcoal to help explain major changes within the paleoenvironmental record (Faegri and Iversen 1989).

Charcoal values were determined by Dr. John G. Jones of Washington State University. While values overall were fairly low, the fluctuations in concentration values of charcoal are thought to be reflective of actual burning on the local and regional scale, possibly as a result of human occupation within the area.

Three sustained burning periods are reflected in the core (See Figure 6). The first, from 330-215cm below surface, dating to the period between 4,421 and 2,881 BP reflects the time period of Archaic or pre-ceramic human activities in the region. This period corresponds to when sea levels reach their current levels. Archaeological sites of this age have not been documented on the island of Grenada. The second period of burning represented in the Meadow Beach core is undated, and is found in samples occurring from 150-100cm below surface and likely corresponds to human activity at the nearby Savanne Suazey site or Pearls site. Finally, charcoal concentration values increase from 50cm below surface to the surface, surely representing historical activity on the island.

Both pollen counts and charcoal concentration values from a continuous sediment sequence serve as an effective survey tool in areas that are otherwise difficult to survey, although early sites are undoubtedly deeply buried if located in the lowlands adjacent to the coast. Pollen evidence suggests this area had stabilized making favorable conditions for human settlement, and sustained increases in charcoal indicate that humans had settled in this area. Future survey in northeast Grenada needs to target this region to identify sites associated with this important time period.

Concentration Values Represented in Core MB08-1:

The importance of concentration values determined within the pollen analysis of a sediment core lies in the ability to accurately identify pollen grains within a given sample, and to effectively process each individual sample to allow for the maximum preservation of the grains while removing unwanted materials. The standard rule for dealing with concentration values within a sediment sample is that a sample must have a concentration value of at least 2,500 grains cc. in order to be deemed reliable for analysis (Faegri and Iversen 1989, Bryant and Hall 1993). The values found in the Meadow Beach core all exceeded the 2,500 per cc. minimum with the lowest found value being 7,942 grains per cc., and the highest exceeding 250,000 grains per cc. (Table 5).

DEPTH	**CV**	**DEPTH**	**CV**	**DEPTH**	**CV**	**DEPTH**	**CV**
5-7cm	37,029	**140-142cm**	70,904	**245-247cm**	103,024	**375-377cm**	12,604
20-22cm	21,501	**150-152cm**	59,683	**260-262cm**	85,795	**385-387cm**	11,501
40-42cm	51,549	**155-157cm**	65,532	**270-272cm**	68,216	**395-397cm**	10,780
50-52cm	143,934	**165-166cm**	217,971	**290-292cm**	82,124	**410-412cm**	12,461
65-67cm	75,959	**170-172cm**	133,259	**305-307cm**	90,538	**425-427cm**	7,942
80-82cm	33,755	**175-177cm**	73,486	**315-317cm**	95,226	**435-437cm**	8,669
90-92cm	129,879	**200-202cm**	19,813	**320-322cm**	85,456	**454-455cm**	10,547
105-105cm	80,551	**205-207cm**	36,847	**325-327cm**	10,345	**465-467cm**	9,581
115-117cm	259,201	**210-212cm**	78,673	**330-332cm**	25,932	**485-487cm**	10,043
120-122cm	193,294	**215-217cm**	85,085	**340-341cm**	9,690	**475-477cm**	11,542
125-127cm	199,743	**230-232cm**	34,531	**342-343cm**	10,400	**492-493cm**	12,357

Table 5. Concentration Values from core MB08-1.

Figure 12 provides the variation in concentration that occurred over time according to the depth of the specific sample analyzed (Figure 12). This figure shows how while concentration values fluctuate quite dramatically, they are relatively high throughout the core. Values noticeably lessen towards the bottom of the core, which may be attributed to the fact that sedimentation rates were somewhat accelerated during this period, or that pollen preservation was not quite as high as in the uppermost samples tested.

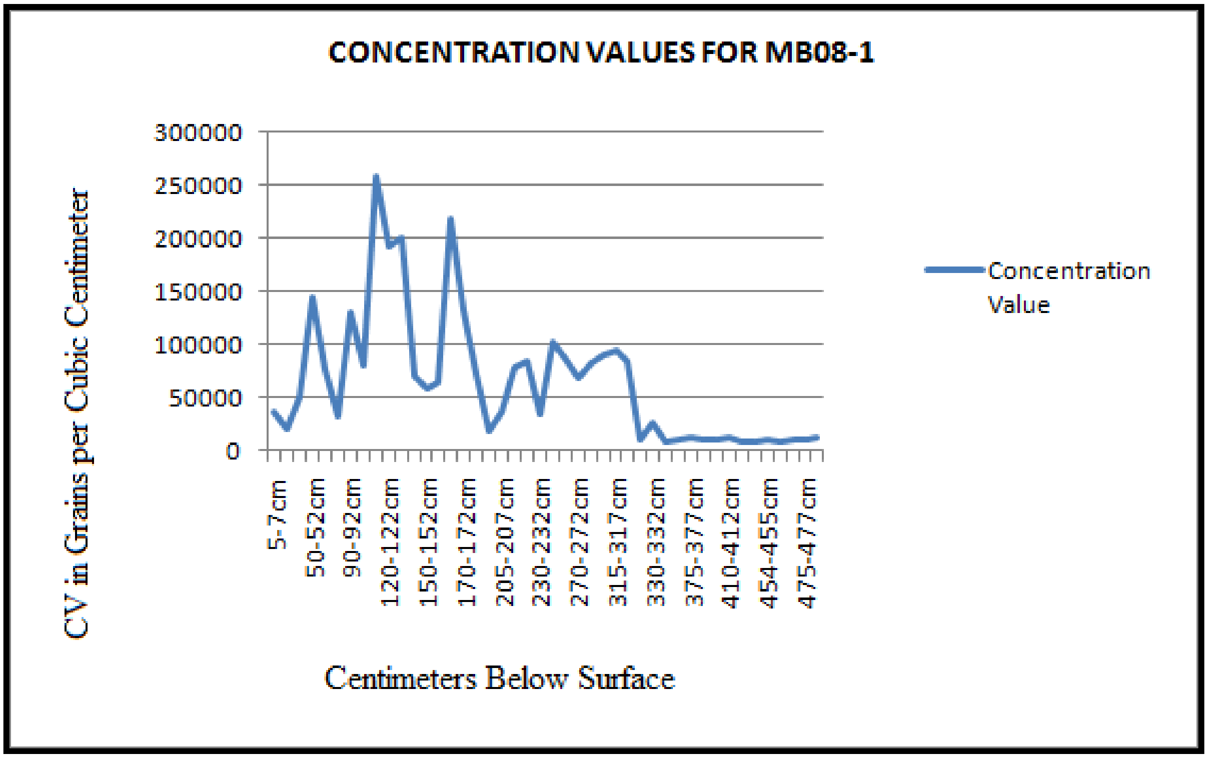

Figure 12. Concentration Values for the Meadow Beach Pollen Core over time. Concentration values remained high throughout the sample analysis, but were noticeably lower within the older samples from the core.

By reorganizing the pollen data to show the various trends observed within the pollen percentage diagram, it becomes fairly obvious that these trends are not merely a result of the organization of the percentage diagram, but they are actually an accurate reflection of the changing environment of Grenada over several thousand years.

CHAPTER SIX

Conclusions

The archaeology of the Caribbean is fascinating as well as important to our understanding of the original inhabitants of the islands, including the arrival of Europeans in the late 15th century. Despite the current interest in Caribbean archaeology, there is a significant lack of available literature detailing the archaeology of the Caribbean and Grenada, the focus of this study. The use of fossil pollen to reconstruct past environmental shifts and fluctuations during periods of human occupation can greatly add to the interpretation of the archaeological record. In this thesis I have detailed the analyses and various methods that were used in order to create a paleoenvironmental reconstruction of the island of Grenada prior to and during the time of human occupation. Specifically, this project has been conducted with the purpose of creating a set of strong baseline environmental data that can then be used to strengthen archaeological research done in the Caribbean, and on the island of Grenada.

The pollen analysis conducted on the Meadow Beach sediment core will ultimately contribute to a more extensive study which will include phytolith, soil and chemical analyses of the series of cores collected from the Lesser Antilles, that can then be placed within a greater archaeological context. The Meadow Beach core not only allows for a greater understanding of the environmental changes occurring in Grenada during the time of human occupation, it also allows for a strong setting in which archaeological data can be placed. Due to the undisturbed nature of the sediment stratigraphy, extensive sampling was completed allowing for the creation of a detailed environmental record of the past 6,000 years of human occupation and vegetation changes within the region.

Three distinct zones were identified through changes in pollen taxa within the Meadow Beach Core. These zones depict the environment changing from a predominately freshwater swamp forest, to a strongly saline environment rich with mangrove swamps, and contain strong evidence of associated human activity reflected by the charcoal present within the record. Zone 3, located at the bottom of the core from 493-330 cm presents pollen data that depicts a swamp forest environment with significant percentages of arboreal, insect pollinated plant taxons. Zone 2, occurring between 330-215cm, initiates a significant shift to a more saline environment. Zone 1, located above 215cm depicts a strongly saline environment, with large percentages of mangrove taxa and a trend towards the saline-swamp environment currently located at Meadow Beach. Charcoal data corresponding to these changes suggests periods of human occupation in the nearby area, associated with periods of increased burning.

Analysis of the Meadow Beach Core and its corresponding charcoal and environmental zones suggests that there is a much lengthier period of human occupation than had previously been established.

The pollen analysis of the Meadow Beach Core has multiple implications. First, from a palynological perspective, the Meadow Beach Core provides details from a closely sampled and radiometrically dated pollen core for a 6,000 year period for the island of Grenada. This data may be of great utility to other Caribbean researchers including paleoecologists, paleoclimatologists, paleobotanists and archaeologists. This core provides invaluable data as to the settlement of Caribbean populations that will ultimately aid researchers in their understanding of the population and occupation Grenada, as well as the Lesser Antilles in general.

Implications for Future Research on Grenada

The implications for the Meadow Beach Core are far reaching and may apply to multiple avenues of research. One of the most important implications is the knowledge that people did, in fact, inhabit the island for a significant portion of time; indeed much longer than has currently been suggested by the established archaeological record. Based on the information from this study, archaeologists should conduct a search for older undiscovered Pre-Ceramic sites in the area. Additional C14 dates for the MB08-1 core should be secured, particularly from 150-100cm below surface, bracketing a period of probably human settlement. Corresponding archaeological research on the island will help to determine and define a stronger and more detailed cultural chronology of this interesting island.

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APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**25**	**13**	**1**	**26**	**14**	**2**
Depth	**5-7cm**	**20-22cm**	**40-42cm**	**50-52cm**	**65-67cm**	**80-82cm**
Lycopodium	147	245	109	42	71	162
Anacardeaceae	0	0	0	0	2	0
Arecaceae	0	0	0	0	0	0
Aspidosperma	0	0	0	0	0	0
Asteraceae	0	1	3	1	0	1
Avicennia	0	0	1	7	5	2
Bursera	3	7	5	2	1	5
Celtis	0	0	0	0	0	0
Cheno-Am	0	0	0	0	0	0
Coccaloba	1	6	10	2	0	1
Combretaceae	6	7	40	32	21	9
Cucurbitaceae	0	0	0	0	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	0	0	0	0	0	0
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	1	0	0	0	0
Hura Crepitans	0	0	0	1	0	1
Ilex	0	0	0	0	0	0
Moraceae	3	2	1	4	0	1
Myrica	0	0	0	0	0	0
Myrtaceae	1	0	0	2	1	0
Nympheaceae	0	0	0	0	0	0
Onagraceae	0	0	0	0	0	0
Poaceae	1	15	3	2	3	2
Protium	0	0	0	0	0	0
Quercus	0	0	0	0	0	0
Ranunculaceae	0	0	0	0	0	2
Rhamnaceae	0	0	0	0	0	0
Rhizophora mangle	197	154	157	180	173	191
Rubiaceae	0	0	0	0	0	0
Sapindaceae	0	2	0	0	0	0
Sapotaceae	0	5	0	0	2	0
Sedge	0	4	0	0	4	0
Solanaceae	0	0	0	0	0	0
Spondias	0	2	0	5	1	0
Verbenaceae	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Zanthoxylum	0	2	0	0	0	0
Unknown G	0	0	0	0	0	0
Unknown I	0	1	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	4	1	4	3	2	3
TOTAL	**217**	**211**	**224**	**241**	**215**	**218**
Concentration Value	**37029**	**21501**	**51549**	**143934**	**75959**	**33755**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**27**	**15**	**3**	**28**	**37**	**16**
Depth	**90-92cm**	**105-105cm**	**115-117cm**	**120-122cm**	**125-127cm**	**140-142cm**
Lycopodium	45	71	22	34	27	75
Anacardeaceae	0	1	0	0	0	0
Arecaceae	0	0	0	0	0	0
Aspidosperma	0	0	0	0	0	0
Asteraceae	3	6	2	4	1	9
Avicennia	15	0	3	2	0	0
Bursera	0	2	1	3	5	2
Celtis	0	0	0	0	0	0
Cheno-Am	0	0	0	0	0	0
Coccaloba	2	2	1	0	0	3
Combretaceae	6	2	1	3	0	7
Cucurbitaceae	0	0	0	1	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	2	0	0	0	0	0
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	0	0	0	0	0
Hura Crepitans	0	0	0	0	0	0
Ilex	0	0	0	0	0	0
Moraceae	3	0	0	0	1	1
Myrica	0	0	0	0	2	0
Myrtaceae	2	1	1	2	0	1
Nympheaceae	0	3	0	0	0	1
Onagraceae	0	0	0	0	0	0
Poaceae	5	3	2	0	3	3
Protium	0	0	0	1	0	0
Quercus	0	0	0	0	1	0
Ranunculaceae	1	1	0	0	0	2
Rhamnaceae	0	0	0	0	0	0
Rhizophora mangle	190	196	201	237	188	174
Rubiaceae	0	0	0	0	0	0
Sapindaceae	0	0	0	0	2	3
Sapotaceae	1	0	0	0	1	1
Sedge	0	2	0	0	4	3
Solanaceae	0	0	0	0	0	0
Spondias	0	0	2	0	1	0
Verbenaceae	0	0	1	0	0	0
Tiliaceae	0	0	0	0	0	0
Zanthoxylum	0	5	0	0	0	0
Unknown G	0	3	0	0	0	1
Unknown I	0	0	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	3	0	2	4	1	1
TOTAL	**233**	**228**	**217**	**262**	**215**	**212**
Concentration Value	**129879**	**80551**	**259201**	**193294**	**199743**	**70904**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**38**	**4**	**29**	**39**	**17**	**40**
Depth	**150-152cm**	**155-157cm**	**165-166cm**	**170-172cm**	**175-177cm**	**200-202cm**
Lycopodium	87	80	29	48	71	257
Anacardeaceae	0	0	0	0	0	0
Arecaceae	0	0	0	0	0	0
Aspidosperma	0	0	0	0	0	0
Asteraceae	48	52	0	0	0	6
Avicennia	0	3	4	0	0	0
Bursera	3	1	0	5	4	8
Celtis	0	0	0	0	0	0
Cheno-Am	1	1	0	0	0	0
Coccaloba	1	0	0	4	1	3
Combretaceae	22	0	1	0	0	2
Cucurbitaceae	0	1	0	0	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	0	0	0	0	0	0
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	0	0	0	0	0
Hura Crepitans	0	0	0	0	0	0
Ilex	0	0	0	0	0	0
Moraceae	3	2	0	0	1	2
Myrica	0	0	0	0	0	0
Myrtaceae	2	1	0	1	4	0
Nympheaceae	0	0	0	0	0	1
Onagraceae	0	0	0	0	0	0
Poaceae	8	7	3	6	2	79
Protium	0	2	0	0	0	0
Quercus	1	0	2	1	0	0
Ranunculaceae	1	0	0	1	0	0
Rhamnaceae	0	0	0	0	0	0
Rhizophora mangle	92	116	235	208	187	66
Rubiaceae	0	0	0	0	0	0
Sapindaceae	1	0	7	1	2	4
Sapotaceae	1	0	0	4	3	2
Sedge	15	0	0	13	1	13
Solanaceae	0	0	0	0	0	0
Spondias	2	1	1	1	1	6
Verbenaceae	0	0	0	0	0	0
Tiliaceae	0	0	0	1	0	0
Zanthoxylum	4	0	3	3	1	7
Unknown G	0	0	0	4	0	2
Unknown I	0	0	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	2	3	3	1	1	2
TOTAL	**207**	**210**	**252**	**255**	**208**	**203**
Concentration Value	**59683**	**65532**	**217971**	**133259**	**73486**	**19813**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**5**	**41**	**30**	**18**	**6**	**31**
Depth	**205-207cm**	**210-212cm**	**215-217cm**	**230-232cm**	**245-247cm**	**260-262cm**
Lycopodium	145	66	74	154	56	69
Anacardeaceae	0	0	0	0	0	0
Arecaceae	0	0	0	0	0	0
Aspidosperma	0	0	0	0	0	0
Asteraceae	1	0	1	1	0	3
Avicennia	8	0	22	0	11	6
Bursera	2	7	3	6	4	5
Celtis	0	0	0	0	0	0
Cheno-Am	0	0	0	4	0	0
Coccaloba	0	4	5	0	0	0
Combretaceae	4	2	1	2	3	4
Cucurbitaceae	0	0	0	0	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	0	0	0	0	0	0
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	0	0	0	0	0
Hura Crepitans	0	0	1	0	0	0
Ilex	0	0	0	0	0	0
Moraceae	0	1	0	1	2	0
Myrica	1	0	0	0	0	0
Myrtaceae	3	2	0	3	1	1
Nympheaceae	0	0	0	0	0	0
Onagraceae	0	0	0	0	1	0
Poaceae	48	14	6	4	2	6
Protium	0	0	0	0	0	0
Quercus	3	1	1	0	2	2
Ranunculaceae	3	0	12	0	1	2
Rhamnaceae	0	0	0	0	0	2
Rhizophora mangle	105	150	177	174	190	194
Rubiaceae	0	0	0	0	0	0
Sapindaceae	2	1	1	2	3	2
Sapotaceae	3	4	0	0	0	0
Sedge	0	5	0	6	0	0
Solanaceae	0	0	0	0	0	0
Spondias	0	3	3	3	2	2
Verbenaceae	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Zanthoxylum	4	10	8	3	1	0
Unknown G	0	0	0	0	0	0
Unknown I	0	0	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	11	3	9	3	5	4
TOTAL	**214**	**207**	**251**	**212**	**230**	**236**
Concentration Value	**36847**	**78673**	**85085**	**34531**	**103024**	**85795**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**19**	**7**	**32**	**42**	**20**	**44**
Depth	**270-272cm**	**290-292cm**	**305-307cm**	**315-317cm**	**320-322cm**	**325-327cm**
Lycopodium	82	73	64	54	59	531
Anacardeaceae	0	0	0	0	0	2
Arecaceae	0	0	0	0	0	9
Aspidosperma	0	0	0	0	0	0
Asteraceae	1	2	1	1	1	2
Avicennia	0	9	8	3	0	2
Bursera	0	4	9	0	5	0
Celtis	1	0	0	0	0	2
Cheno-Am	3	0	0	9	0	0
Coccaloba	15	4	3	1	8	8
Combretaceae	3	2	8	0	4	5
Cucurbitaceae	0	0	0	0	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	0	0	0	0	0	5
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	0	0	0	0	0
Hura Crepitans	0	0	0	0	0	2
Ilex	0	0	0	6	0	2
Moraceae	2	0	1	0	8	12
Myrica	0	0	0	6	0	4
Myrtaceae	1	4	2	0	10	26
Nympheaceae	0	0	0	0	0	3
Onagraceae	0	1	0	0	0	0
Poaceae	3	3	4	1	5	26
Protium	0	0	0	0	0	0
Quercus	0	4	4	0	1	1
Ranunculaceae	0	1	0	1	1	0
Rhamnaceae	0	0	0	0	0	0
Rhizophora mangle	163	164	164	151	132	46
Rubiaceae	0	0	0	0	0	0
Sapindaceae	1	2	0	1	0	7
Sapotaceae	3	7	3	4	3	6
Sedge	13	0	0	10	5	13
Solanaceae	0	0	0	0	0	0
Spondias	6	3	1	2	3	12
Verbenaceae	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Zanthoxylum	4	23	13	6	12	18
Unknown G	0	1	1	2	0	3
Unknown I	0	0	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	3	5	9	1	2	3
TOTAL	**222**	**239**	**231**	**205**	**201**	**219**
Concentration Value	**68216**	**82124**	**90538**	**95226**	**85456**	**10345**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**8**	**43**	**33**	**21**	**9**	**34**
Depth	**330-332cm**	**340-341cm**	**342-343cm**	**375-377cm**	**385-387cm**	**395-397cm**
Lycopodium	207	541	521	404	458	470
Anacardeaceae	0	0	0	0	0	0
Arecaceae	0	17	19	0	17	7
Aspidosperma	0	0	0	0	0	0
Asteraceae	5	3	4	2	3	1
Avicennia	6	0	1	0	0	0
Bursera	4	5	3	2	3	2
Celtis	0	0	0	0	0	0
Cheno-Am	0	3	0	2	0	0
Coccaloba	7	8	3	7	7	12
Combretaceae	6	26	6	2	7	9
Cucurbitaceae	0	0	0	0	0	0
Euphorbiaceae	0	0	0	0	0	0
Fabaceae	0	0	0	1	0	1
Gymnopodium	0	0	0	0	0	0
Hematoxylum	0	0	0	0	0	0
Hura Crepitans	0	1	2	0	0	0
Ilex	0	0	0	0	0	0
Moraceae	5	17	11	4	12	14
Myrica	0	0	0	1	0	1
Myrtaceae	23	16	21	8	39	36
Nympheaceae	0	0	0	1	0	0
Onagraceae	0	0	3	0	4	0
Poaceae	19	14	31	3	12	19
Protium	0	0	0	0	0	0
Quercus	4	2	1	0	5	2
Ranunculaceae	2	0	1	0	2	0
Rhamnaceae	0	0	0	0	0	0
Rhizophora mangle	67	21	56	137	50	37
Rubiaceae	0	0	7	0	5	0
Sapindaceae	6	8	4	0	7	11
Sapotaceae	8	11	7	8	4	9
Sedge	0	23	0	11	0	8
Solanaceae	2	0	4	0	6	2
Spondias	8	9	11	3	3	5
Verbenaceae	0	0	0	0	0	0
Tiliaceae	0	0	0	0	0	0
Zanthoxylum	21	13	9	8	10	18
Unknown G	0	0	0	1	0	0
Unknown I	0	0	0	0	0	0
Unknown Z	0	0	0	0	0	0
Indeterminate	27	2	12	2	7	8
TOTAL	**214**	**209**	**216**	**203**	**210**	**202**
Concentration Value	**25932**	**9690**	**10400**	**12604**	**11501**	**10780**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**22**	**10**	**35**	**23**
Depth	**410-412cm**	**425-427cm**	**435-437cm**	**454-455cm**
Lycopodium	467	638	651	547
Anacardeaceae	4	0	0	3
Arecaceae	0	16	22	24
Aspidosperma	0	0	0	0
Asteraceae	0	2	3	2
Avicennia	6	3	3	0
Bursera	6	3	6	7
Celtis	0	0	0	1
Cheno-Am	2	0	0	1
Coccaloba	16	5	4	4
Combretaceae	9	7	8	4
Cucurbitaceae	0	0	0	0
Euphorbiaceae	0	6	0	0
Fabaceae	3	0	0	2
Gymnopodium	0	1	0	0
Hematoxylum	0	0	0	0
Hura Crepitans	2	1	2	1
Ilex	3	0	0	1
Moraceae	13	13	11	6
Myrica	2	0	1	2
Myrtaceae	28	31	33	29
Nympheaceae	2	0	0	1
Onagraceae	0	3	0	0
Poaceae	22	13	19	23
Protium	0	0	0	0
Quercus	1	6	3	2
Ranunculaceae	0	1	2	2
Rhamnaceae	0	0	0	0
Rhizophora mangle	24	58	30	23
Rubiaceae	0	0	0	0
Sapindaceae	9	7	9	9
Sapotaceae	11	2	11	16
Sedge	12	1	7	9
Solanaceae	0	1	1	0
Spondias	14	3	16	22
Verbenaceae	0	0	0	0
Tiliaceae	0	0	0	0
Zanthoxylum	23	14	30	32
Unknown G	2	0	0	2
Unknown I	0	0	0	0
Unknown Z	0	0	0	0
Indeterminate	4	6	4	2
TOTAL	**232**	**201**	**225**	**230**
Concentration Value	**12461**	**7942**	**8669**	**10547**

APPENDIX A: POLLEN COUNTS AND CONCENTRATION VALUES FOR EACH SAMPLE

Sample #	**11**	**24**	**36**	**12**
Depth	**465-467cm**	**485-487cm**	**475-477cm**	**492-493cm**
Lycopodium	555	502	439	408
Anacardeaceae	2	3	4	2
Arecaceae	22	29	28	22
Aspidosperma	0	2	6	3
Asteraceae	2	2	3	2
Avicennia	0	0	0	1
Bursera	4	5	1	3
Celtis	1	0	0	0
Cheno-Am	1	1	1	0
Coccaloba	5	4	2	3
Combretaceae	4	4	3	2
Cucurbitaceae	0	0	0	0
Euphorbiaceae	0	0	0	0
Fabaceae	1	0	0	0
Gymnopodium	0	0	0	0
Hematoxylum	0	0	0	0
Hura Crepitans	1	1	0	2
Ilex	0	1	0	0
Moraceae	7	3	3	7
Myrica	1	2	0	0
Myrtaceae	27	34	46	56
Nympheaceae	1	0	0	0
Onagraceae	0	0	0	0
Poaceae	22	19	20	24
Protium	0	0	0	0
Quercus	1	2	3	2
Ranunculaceae	2	0	0	0
Rhamnaceae	0	0	0	0
Rhizophora mangle	22	26	24	18
Rubiaceae	0	0	3	2
Sapindaceae	7	4	0	0
Sapotaceae	14	9	8	6
Sedge	9	0	0	0
Solanaceae	0	0	0	0
Spondias	25	11	5	2
Verbenaceae	0	0	0	0
Tiliaceae	0	0	0	0
Zanthoxylum	29	34	33	35
Unknown G	1	0	0	0
Unknown I	0	0	0	0
Unknown Z	0	0	0	0
Indeterminate	1	5	7	8
TOTAL	**212**	**201**	**202**	**200**
Concentration Value	**9581**	**10043**	**11542**	**12357**