

ABSTRACT

STONE, JESSICA HALI. Paleodiet and Nutrition at Grand Bay, Carriacou, West Indies. (Under the direction of Dr. Scott Fitzpatrick).

The overall aims of this research were to conduct a preliminary examination of paleodiet on the island of Carriacou as inferred from multiple lines of evidence, including stable isotope, zooarchaeological, and paleobotanical analyses; and then evaluate health and nutrition based on frequencies of linear enamel hypoplasia (LEH), a nonspecific physiological stress indicator. It was hypothesized that diet at Grand Bay would follow the same basic patterns of exploiting mixed marine protein and terrestrial horticultural crops that are seen throughout the Caribbean. Furthermore, it was expected that the diverse dietary components would fulfill nutrient requirements and as a result, LEH frequencies would be low. The results demonstrate that the inhabitants at Grand Bay were exploiting both marine and terrestrial resources, the majority of which includes small sized reef fish and species of shellfish, as well as plants that follow a C⁴ photosynthetic pathway, such as amaranth, maize, and other grasses. LEH occurred in about 47% of the skeletal sample, most of which occurred between the ages of 2 and 4, suggesting that a dietary switch associated with weaning could have been a factor in physiological childhood stress. This analysis is the first to investigate paleodiet from multiple lines of evidence on Carriacou and will continue to shed light on past subsistence patterns as future research continues.

Paleodiet and Nutrition at Grand Bay, Carriacou, West Indies.

by
Jessica Stone

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APPROVED BY:

Dr. Scott Fitzpatrick
Committee Chair

Dr. D. Troy Case

Dr. David Eggleston

Dr. Scott Burnett

DEDICATION

For Little Bit, whose antics kept my spirits up even during the most stressful points of this entire process.

BIOGRAPHY

Jessica Stone spent the better part of her childhood moving between Massachusetts, South Carolina, Tennessee, Arizona, and finally Saint Petersburg, Florida where she completed her Bachelor of Arts in Anthropology and Environmental Studies at Eckerd College. After taking an Introduction to Archaeology class and deciding that was a career path she definitely did not want to take, a summer field school on Carriacou completely changed her mind. She returned to her final year at Eckerd, and with the help of Dr. Scott Burnett, narrowed down her interests to bioarchaeology and attended North Carolina State University, where analyzing teeth, sorting shells, and a near death experience involving a suspension bridge in Peru has gotten her to today; where she is currently a candidate for the degree of Master's of Arts in Anthropology under the direction of Dr. Scott Fitzpatrick.

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I. INTRODUCTION

An abundance of archaeological and paleoanthropological evidence worldwide demonstrates the important role of the environment in shaping the cultural and biological evolution of humans (Newsom and Wing 2004, Reitz 2008, Siegel et al. 2005, Tuross 1994). Environmental conditions influence the types of resources available for food, the kinds of materials used for shelter and transport, and ritual uses of plants and objects, among many others. It is important to note that cultural processes may vary over time as a result of differences in resource availability and associated environmental change. Temporal variation in cultural processes can be elucidated through a variety of means, including paleoenvironmental evidence (e.g, paleobotanical remains, stable isotope data, faunal analysis) and other methods to reconstruct the environment and human use of various resources in a given area (deFrance et al. 2008, Tuross 1994). Not only can this help inform us of what the climate was like at various points in time, but also the types of plants and animals available, those that were potentially exploited, and how this ultimately affected various aspects of human health.

Researchers for example, have increasingly recognized the utility of combining paleobotanical and zooarchaeological evidence with stable isotope analysis to reconstruct subsistence as studies in Ecuador and Florida demonstrate (Reitz 2008, Tuross 1994). The Caribbean in particular, is ideal for conducting this type of study given the region's complex history of multiple waves of human migration that led to the introduction of numerous exotic plant and animal species from surrounding mainlands (Fitzpatrick and Keegan 2007, Keegan 2000).

Until recently, however, few studies were dedicated to examining paleodiet and subsistence strategies in many parts of the Caribbean using different lines of environmental evidence, including stable isotope analysis and paleobotany. One island that is particularly well suited to analyzing paleodiet in relation to subsistence and environmental questions is Carriacou, located in the Grenadines island chain in the southern West Indies. Over the course of five field seasons, the Carriacou Archaeological Field Project (CAFP) directed by Scott Fitzpatrick (NCSU), Quetta Kaye (formerly UCL), and Michiel Kappers (QLC, BU, The Netherlands) has yielded a tremendous amount of faunal and artifactual data that provide a strong framework for answering many of these questions including, what kinds of resources were prehistoric Carriacouans consuming for food, and which ecosystems were they primarily exploiting. Skeletal remains from nearly 20 burials excavated at the Grand Bay site, along with other lines of evidence, provide critical data on the health and diet of island inhabitants, suggesting that early Amerindian groups were exploiting both marine and terrestrial resources, although it is still relatively unclear how this may have changed over time (Fitzpatrick et al. 2009, Lefebvre 2007). This research will be the first to examine prehistoric subsistence strategies using multiple data sets on Carriacou. An examination of past subsistence strategies using stable isotopic data, faunal analysis, and preliminary insights gathered from paleobotanical remains prove to be a useful addition to the growing wealth of information now shedding light on the island's prehistory. This research will complement existing studies of paleodiet in the Caribbean (DeFrance et al. 2008, Newsom and Wing 2004, Pestle 2010) to enhance our understanding of subsistence strategies throughout the region and variations of such strategies on different islands.

The overall goal of this research is to investigate paleodiet on Carriacou as inferred from multiple lines of evidence, including paleobotanical and faunal remains, as well as stable carbon and nitrogen isotopic signatures. Data from osteological analyses on human remains from Carriacou will then be used to evaluate the quality of health and nutrition over time as a result of changes in environmental resource availability and diet through an in depth examination of linear enamel hypoplasia (LEH) as an indicator of physiological and nutritional stress. Because of the diversity of different terrestrial and marine ecosystems available for exploitation, I hypothesize that paleodiet at Grand Bay will consist of a wide variety of resources, including tropical crops and marine proteins. This is not uncommon throughout the Caribbean, so I expect Carriacou to follow the same general regional pattern (DeFrance et al. 2008, Pestle 2010). As a result of a diverse and likely nutrient-rich diet, I also hypothesize that frequencies of linear enamel hypoplasias will be low. As my research indicates, the inhabitants at Grand Bay were utilizing a variety of different resources from multiple available ecosystems; however, unexpected patterns related to frequencies of LEH have suggested some nutritional stress may be related to environmental and age-related incidents. Furthermore, the stable isotope analysis data illustrates some differences compared to other Caribbean islands and stresses the need for continued paleobotanical analysis. Overall, the results have led to a multitude of new questions related to the diet of prehistoric inhabitants on Carriacou.

II. ENVIRONMENTAL AND CULTURAL CONTEXT

The Caribbean

Geologically, the Caribbean region was formed during the Cretaceous period as a result of the formation of the Caribbean tectonic plate and its subsequent movement eastward against the North and South American plates. The subduction zone created by the North American plate slipping under the Caribbean plate has resulted in the formation of a series of underwater volcanoes in the region (Dincauze 2000, Donovan et al. 2003, Hedges 2001, Jackson et al. 2008). The combined effects of tectonic activity, volcanism and the resulting deposits on the surface, and supported coral reefs that were exposed during periods of lower sea level led to the formation of the Antillean island chain by the late Cretaceous period, between 100 to 70 million years ago. Geographically, the region is typically divided into three major areas: the Greater Antilles, Lesser Antilles, and the Bahamas, as well as several smaller islands or island groups, including the Caymans, Trinidad and Tobago, and the islands of Aruba, Bonaire, and Curacao along the coast of South America (Figure 1). The Greater Antilles, comprised of the islands of Cuba, Jamaica, Hispaniola, and Puerto Rico, are the largest and geologically oldest islands. The Lesser Antilles are made up of smaller islands in two arcs — an older limestone group of islands and a younger group consisting of numerous historically active volcanoes. The Bahamas are the most recently formed group of islands and are a series of low-lying limestone islands (Newsom and Wing 2004). Today, the Caribbean region consists of a combination of volcanic and limestone islands located within the world's second largest sea and the seventh largest body of water which includes a diverse

array of different terrestrial and aquatic ecosystems (Fitzpatrick and Ross 2010, Hedges 2001).



Figure 1. Map of Caribbean (drafted by Scott Fitzpatrick).

Climate in the Caribbean has fluctuated over time and primarily affected precipitation levels. Oxygen isotopes taken from lake sediment cores reflect higher moisture levels during the earlier Holocene, followed by drier conditions in the middle Holocene, and intermittent periods of drought (Higuera-Gundy et. al 1999, Newsom and Wing 2004). Though many of these changes occurred prior to human occupation of the islands, fluctuating climate

throughout the Holocene shifted the distributions of plant and animal biota. Additionally, frequencies of tropical storm activity were altered as a result of changes in precipitation levels, pressure systems, and atmospheric circulation. Therefore, storms were significantly less frequent about 500 years ago (Callaghan 2003).

It has been argued that periodic volcanic uplift may have created a temporary land bridge connecting islands that allowed for colonization and dispersal of now endemic animal species from the Americas; however, this has yet to be unequivocally demonstrated. It is also likely that a number of plants and animals were transported to islands via wind or ocean current dispersal from the mainland (Hedges 2001, Newsom and Wing 2004). Due to inter-island variations in geology, topography, and precipitation, there are a variety of different ecosystems and endemic plant and animal species in the region.

The current climate is generally warm, humid, and dominated by weather patterns controlled by tradewinds that consistently blow in from the Atlantic Ocean. When the winds carry moisture towards islands with higher elevations, the islands act as an obstruction and create clouds and periodic precipitation. Distinct wet seasons as a result of shifts in the Intertropical Convergence Zone (ITCZ) that occur from around June to November also contribute to overall rainfall in the region (Dincauze 2000, Newsom and Wing 2004). Additional rainfall comes from periodic hurricanes and tropical storms that occur during the summer months.

The diversity of plant and animal taxa from different terrestrial and aquatic ecosystems have made the Caribbean home to 2.3 percent of the world's endemic plant species and 2.9 percent of endemic vertebrate species, as well as over 1,500 fish, 25 coral,

and over 600 mollusk species (Fitzpatrick and Keegan 2007). Additionally, a variety of different bird, crustacean, sea mammal, and reptile species in marine, freshwater, and estuarine environments have been recorded. However, due to modern human impacts, including pollution, global climate change, tourism-related development, and overfishing, the region is under dire threat and is designated as one of 25 “Diversity Hotspots” that have been targeted for conservation of their high levels of endemic species by Conservation International (Fitzpatrick and Keegan 2007). Not only are these threats leaving the future of numerous plant and animal taxa in peril, but such destructive processes are also impacting multiple ecosystems, including mangrove swamps, coral reefs, and seagrass beds. Additionally, agricultural land use and coastal development are contributing to amplified rates of coastal erosion, resulting in the loss of coastal areas and potential archaeological sites (Fitzpatrick et al. 2006:258).

Prehistoric Settlement

The basic cultural chronology for the settlement and occupation of the Caribbean before European contact is based largely on the presence of stylistically distinct artifacts classified into regional and local styles that change over time. Initial archaeological work in the Caribbean was limited to refining cultural chronologies and debating potential migration patterns which contributed to a basic understanding of the settlement process in the region (Petersen et al. 2004, Rouse 1992). Early work in the late nineteenth and early twentieth centuries established a three-period chronological sequence that has developed into the basis for settlement patterns that are used as a general framework for archaeologists today (Rouse 1992). This relative chronology sequence of “cave-dwellers, the agriculturalists, and the

Carib” (Fewkes 1922:56) later developed into a more complex sequence that included some regionally and locally distinct ceramic styles (Wilson 2007:19). Based on these ideas, Rouse’s (1992) work involved formulating defined series based on characteristic styles separated by time and space. As such, ceramics are traditionally grouped into basic series that are named after the site at which they were first identified. These series are distinguished by an –oid suffix. More localized styles are grouped into subseries (distinguished by an –an suffix) (Keegan 2000).

Initial colonization of the islands took place in what is known as the Lithic period. The earliest evidence of colonization of the West Indies dates to 7000-6000 years ago and consists of at least two waves of migration that settled in Cuba and Hispaniola and Trinidad and Tobago (Keegan 2000). The earliest evidence for their occupation of the Greater Antilles dates to 3500-4000 BC in the form of flaked stone tools (Wilson 1997). Based on Rouse’s (1992) classification system, these blades have been placed into the Casimiroid Series and the Casimiran, Courian, and Redondan subseries, ranging from ca. 4000 BC to 400 BC. There is no evidence of these Casimiroid groups practicing agriculture or producing ceramics. The stone tools found thus far consist of chipped blades and flake tools in more recent assemblages. Unifacial tools are the most commonly found, though occasional biface tools have been recovered as well (Callaghan 2003). During the later Casimiroid period, ground stone tools appear in assemblages, consisting of bowls, beads, and axes, some of which show incised designs. Examination of these tools reveal large blades and cores manufactured from local flint that are the most stylistically similar to macroblade tools found from sites located in the Yucatan peninsula and northern South America, implying that the

groups' origins lay somewhere in these regions (Allaire 1997, Wilson et. al 1998, Wilson 2007).

This hypothesis has been further supported through drift voyage simulations from various locations on the American mainland. Using wind and current information for the Caribbean, as well as paleoclimatic data and performance data for Orinoco and Maya style canoes, Callaghan (2003) simulated computer voyages from northern Central America, northern South America, and southern Florida to determine the most likely origin for Lithic peoples in the Greater Antilles. Based on a multitude of simulations and testing chance discovery of the islands and planned voyages using existing knowledge of the islands' locations, the results found that south Florida, the Yucatan Peninsula, and Venezuela are all likely potential areas of origin. Planned voyages from all three locations have a chance of successful landfall in the Greater Antilles; however, departures from Venezuela require the least navigational skill (Callaghan 2003). In order to reach the islands from the Yucatan without prior knowledge, there is a very limited departure area from which successful landings could be achieved. However, given knowledge of the Greater Antilles' locations, the islands could be reached from the Yucatan fairly easily. Trips from south Florida would involve the highest amount of risk given current patterns and the directional flow of the Gulf Stream which moves in a strong easterly direction toward the Atlantic (Callaghan 2003).

Additionally, the Banwari Trace and St. John sites on Trinidad reflect evidence of occupation by people from the South American mainland around 7000 BC. Like the Lithic peoples in the Greater Antilles, these groups consisted of preceramic hunter-gatherer-foraging groups who were utilizing access to marine environments near the shore (Fitzpatrick

and Ross 2010, Wilson 2007). Stone tools found in these assemblages are related to fishing, gathering, canoe building, and grinding stones. The use of canoes and associated tools demonstrate similarities to groups found in northern South America, including those found near the Orinoco and Guyanas river systems, further supporting the claim that these sites were inhabited by groups from northern South America. Therefore, the initial colonization of the Caribbean appears to have been by people from the Yucatan Peninsula or northern South America who produced stone tools and practiced a foraging subsistence pattern. However, nearly all of the Archaic sites are located in the Greater Antilles on Cuba, Hispaniola, and Puerto Rico, the northern Lesser Antilles, including Antigua, Saba, Nevis, Anguilla, and Barbuda. There is currently only a single radiocarbon date from the southern Lesser Antilles at the Heywoods site on Barbados with an Archaic age (Drewett 1991). For those 1000-2000 years, the movement throughout the Greater Antilles resulted in small settlements on Cuba, Hispaniola, and Puerto Rico, where over this period regionally distinct styles began to emerge and stone tool styles shifted towards flake tools and subsistence focused on hunting large animals, such as seals, manatee, sea turtles, and large sloths (Wilson 2007).

Colonization and occupation of the remainder of the region does not appear to have occurred until a second wave of migration during the Archaic period around 3000 years ago from South America into the Antilles. The majority of Archaic period sites scattered throughout the Lesser Antilles are reflective of small exploratory settlements consisting of flaked and ground stone tools, as well as tools made of chert that appears to have originated on Antigua, implying the island played an important role as a production or distribution center for tools and raw materials (Fitzpatrick et. al 2010, Keegan 2000, Wilson 2007). This

was followed by what appears to be another separate migration consisting of ceramic-making horticulturalists commonly referred to as Saladoid, who settled Puerto Rico, the Virgin Islands, and nearly all the islands in the Lesser Antilles by as early as 500 BC (Fitzpatrick and Ross 2010, Wilson 1997, 2007).

Though the general sequence associated with this chronology is accepted, more recent research investigating the timing and organization of Saladoid migration has created a dispute resulting in several possible explanations for the exact settlement process of the region (Keegan 2000, Wing 2001). The first is that Saladoid migration originated from along the South American littoral and gradually moved northward through the islands in a stepping-stone fashion. However, more recent studies suggest that people may have migrated directly to the northern islands and then worked their way southward (Callaghan 2001, Fitzpatrick et al. 2010). Traditionally, archaeologists believed that the Saladoid migrated out of the Orinoco river basin in northern Venezuela and gradually worked their way north through the Antillean chain and eventually reached Puerto Rico around 500 BC (Rouse 1992). Initially, this appears reasonable because of the close distances between islands and the fact that during clear weather they are visible from one to another or at a point midway between islands. Additionally, early Saladoid pottery has been recovered from islands throughout the Lesser Antilles and Puerto Rico, implying that the chain was occupied relatively quickly (Fitzpatrick et al. 2010, Keegan 2000, Wilson 1997). Recent studies based on seafaring simulations, an increased volume of ceramic artifacts with diagnostic styles, and radiocarbon dates (Fitzpatrick 2006), however, suggest that the northward stepping-stone migration pattern may not be the most likely scenario. One alternative hypothesis that is

becoming more widely accepted is that Saladoid peoples migrated directly to Puerto Rico and other islands in the northern Lesser Antilles and only then migrated southward. This is supported by computer simulations which show that current and wind patterns were more advantageous to this route. Additionally, the distribution of early Saladoid sites is concentrated both in the north and to a certain degree on the northern coasts of islands, which implies a southward-looking focus (Callaghan 2003, Fitzpatrick 2006, Fitzpatrick et. al 2010, Keegan 2000).

Regardless of the pattern of migrations, Saladoid occupation of the Caribbean is characterized by the presence of ceramic artifacts and agricultural development that appears around 500 BC. Saladoid pottery typically shows either white-on-red (WOR) painted vessels or zone-incised-crosshatching (ZIC) decoration. Within the Saladoid ceramic series, Rouse (1992) defined two pottery subseries for the early Saladoid period – the Huecan and Cedrosan subseries (Haviser 1997, Keegan 2000). Some sites reflect a combination of the two subseries which is evidence that the two groups were interacting and contemporaneous. The Huecan Saladoid group is characterized by ZIC decoration and a lack of painted pottery. Lapidary objects include beads and zoomorphic pendants in the shape of exotic animals made of nonlocal stone, as well as ceramic inhaling bowls, all of which are reflective of South American origins. Cedrosan Saladoid pottery is characterized by well-made vessels decorated with red, black and white paint (polychrome) as well as WOR decoration, incision, strap and loop handles, and zoomorphic adornos (Haviser 1997, Keegan 2000, Wilson 2008).

Saladoid sites are located in both the Lesser and Greater Antilles — settlements have been found in both inland areas along river drainages for agricultural use and on coasts to

take advantage of intertidal and shallow marine habitats. Despite the existence of some sites at inland locations, it should be noted that the earliest Saladoid sites are always found on the coast. Villages were fairly large and consisted of houses occupied by extended families located around a central plaza. Although very few actual remnants of these structures have been recovered, they are typically visible as soil stains in the subsoil showing that the structures were circular or oval in shape and reminiscent of communal houses used in lowland South America (Keegan 2000, Righter 1997, Wilson 2008). Non-ceramic artifacts include stone tools similar to those found during the Archaic and Lithic periods, as well as similar axes and adzes made of *Strombus* shell, and stone chert tools. Gourd containers, woven baskets, and wood canoes were also likely used. There is evidence of lapidary work utilizing exotic materials from other islands and the mainland (Keegan 2000, Righter 1997).

Following the Saladoid, distinct styles emerge throughout the Greater and Lesser Antilles. In the Lesser Antilles, the Troumassoid period named for the Troumassee site on St. Lucia, which is broken down into the Troumassan Troumassoid and Suazan Troumassoid ceramic subseries, spans from ca AD 600-1000. Troumassoid pottery is characterized by a decrease in overall quality of the vessels, the use of red, black and white painting, and curvilinear incised lines. The Windward Islands, including Grenada, show evidence of the Suazan Troumassoid subseries which spans from ca AD 1000-1450 and is characterized by ceramic remains that are thick with scratched surfaces and a departure away from more sophisticated pieces that appear in earlier periods (Petersen et al. 2004). In the Greater Antilles, the Ostionoid is seen as a continuation of Saladoid culture with some stylistic changes in pottery (Keegan 2000). Ostionoid subseries include the Ostionan, Meillacan, and

Chican. In the Bahamas, shell-tempered Palmetto ware became visible by AD 800 (Keegan 2000, Rouse 1992). Straight-sided bowls, as well as similarities to later Saladoid ceramics, including polychrome and red painting, characterize the Ostionan subseries. Meillacan Ostionoid pottery share a similar shape to Ostionan pottery, but with a rougher surface and more rectilinear incision. Chican pottery is the least similar to the previous Saladoid pottery, and is decorated with modeled incision. Effigy vessels are also characteristic of this subseries. Distinct local styles began to emerge and settlements expanded along the coast and towards interior areas (Petersen et al. 2004). Finger-indented rims and the use of footed griddles for cooking manioc are also characteristic of this period. Occasionally, vessels will have flat human head adorns, but are typically left undecorated. Throughout the Caribbean there was an overall decline in the use of pottery following the Saladoid period, as well as a devolution in manufacturing and stylistic details (Keegan 2000). With the development of Taíno society in the Greater Antilles and their spreading influence into the Lesser Antilles, ceremonial ceramic objects, including effigy figures, as well as three-pointed stone cemis, emerged.

Overall, the period between AD 600-1200 is characterized by population growth and development of social and political organization into the more complex Taíno groups that were encountered by Europeans at Contact. During this time, villages became aligned into polity groups of larger populations consisting of socially ranked individuals. Social complexity continues to expand in the Greater Antilles almost to an archaic state level, while the groups in the Lesser Antilles appear to have remained at the tribal or early chiefdom level. Archaeological evidence for growing social complexity in the Greater Antilles include

the development of central plazas around which villages were located in the Saladoid into central ceremonial plazas, ball courts, and become the location around which the elite chiefs lived (Keegan 2000, Wilson 2008). Ceremonial centers organized around central plazas and aligned very similarly to cosmological arrangements become more common, particularly in Puerto Rico. The location of such villages and ceremonial centers were still located along coasts; however, there is also some movement inland and along rivers (Cooper 2010).

Although a general chronology for the Caribbean has been developed using these stylistic changes in ceramic styles and various waves of migration, it is important to remember that the region consists of a variety of different groups, differentiated by regional stylistic variety in artifacts and an extensive trade network both between islands and with the mainland. Just prior to European contact, it appears that many Caribbean settlements were rapidly depopulated. This has been further substantiated by historic accounts in which small numbers of Amerindians were present, though the decrease in population size does not necessarily appear related to the arrival of Europeans (Fitzpatrick and Giovas, in review).

Carriacou

The island of Carriacou is located in the southern Grenadines about 200 km north of Venezuela and 30 km north of Grenada (Figure 2). Carriacou is the largest island in the Grenadines chain of the southeastern Caribbean and measures about 32 square kilometers in area. Geologically, Carriacou is divided into two zones – outcrops of Miocene limestone on the eastern third of the island and volcanic areas that are the product of past lava flows on the remainder of the island. The island is the exposed summit of an underwater volcano, with elevations reaching up to 290 meters above sea level at its peaks (Fitzpatrick et al. 2009,

Fitzpatrick and Ross 2010, Kaye 2003). Many different types of habitat including mangrove swamps, beaches, and forested areas, and coastal scrubland are present, as well as coral reefs offshore.

Known as the “Island of Many Reefs,” by indigenous Amerindians, little archaeological work had been done on Carriacou until recently. Initial attempts were made by Fewkes (1907), Bullen and Bullen (1972), and Suttly (1990) to document early occupation of the island. Fewkes visited Grenada and Carriacou in 1904 and the specimens he collected were described as “among the finest West Indian ware that has yet come to the Smithsonian Institution” (Fewkes 1907:189-190). Bullen and Bullen (1972) spent a few days in 1969 examining the sites of Grand Bay, Sabazan, and Dover on the eastern and southern coasts. Surface scatter at all three sites revealed dense concentrations of archaeological material from a period spanning the Terminal Saladoid to the late Suazoid. At Sabazan, they excavated a “single foot thick slice” of the coastal profile and radiocarbon dated recovered charcoal to 940 ± 100 years B.P. (cal. AD 1010), as well as a wide range of ceramic artifacts ranging from Saladoid to Suazoid era styles (Bullen and Bullen 1972:14). Suttly (1990) who attempted to survey sites across Carriacou and note associated artifacts, identified Grand Bay as the most important due to its large size and variety of ceramic styles (Kaye 2003).

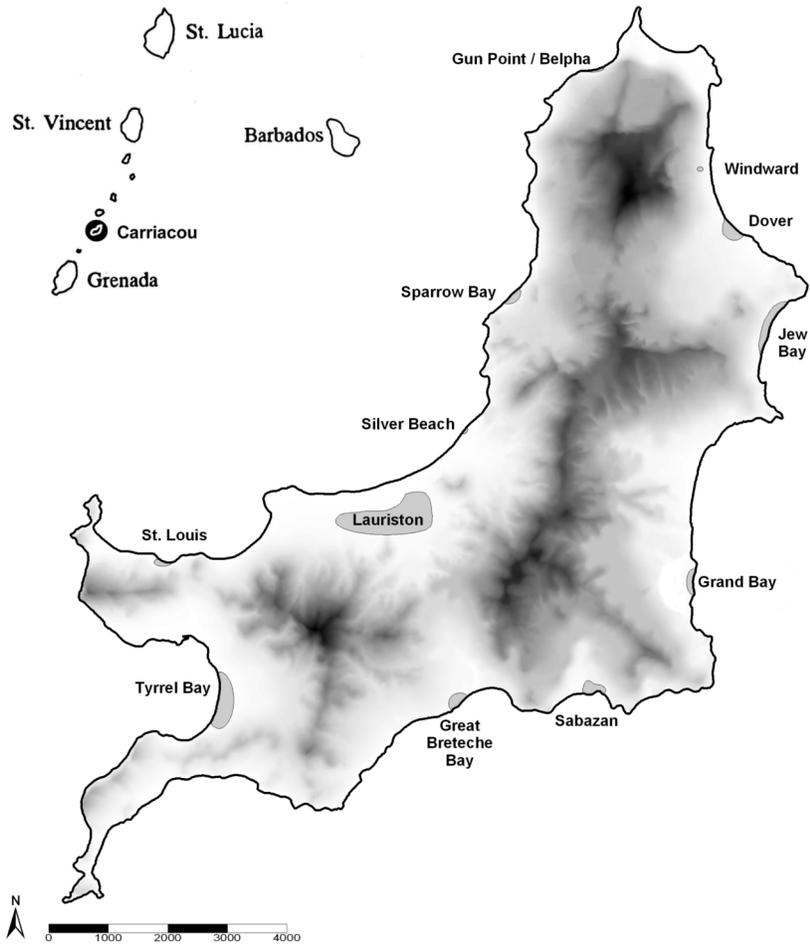


Figure 2. Map of Carriacou showing site locations (drafted by Michiel Kappers).

Until a 2003 island-wide survey by Quetta Kaye (University College London), Michiel Kappers (In Terris Site Technics), and Scott Fitzpatrick (North Carolina State University), no intensive archaeological work had been undertaken on Carriacou. Their research revealed evidence of six major and several minor Pre-Columbian sites (Figure 2).

Based on results of the survey and areas most at risk for erosion-caused site destruction, Grand Bay and Sabazan were selected for intensive archaeological investigation (Kaye 2003). Most of the work has concentrated at the Grand Bay site, located on the east coast of the island and contains the remnants of a large Amerindian village, dating between ca. AD 400-1300 (Fitzpatrick et al. 2004, Fitzpatrick et al. 2009). Work at Sabazan, a site on the southeast coast began in 2007 under the direction of Christina Giovas, a Ph.D. candidate at the University of Washington (Fitzpatrick et al. 2009).

Grand Bay

The Grand Bay site is located directly on the southeastern coast of Carriacou and covers an area of about 6000 m² (Kaye et al. 2004). The area is currently used as grazing land for donkeys, goats, and cows and is characterized by scrub habitat, including plants like Manchineel (*Hippomane manicella*) trees and cacti. The site is comprised of the remnants of a large village and dense archaeological midden located along the coastal profile, about 4 m above the water at its highest point. The exposed coastal profile and the intersection of eroded gulleys of land have revealed a humic topsoil, dense layers of stratified midden deposits, and an orange-yellow subsoil into which numerous archaeological features have been cut, including postholes and over 20 burials (Figure 3) (Fitzpatrick et al. 2006, 2009, Kaye et al. 2004, 2005).



Figure 3. Image of coast at Grand Bay facing south (Photograph by Scott Fitzpatrick).

Currently, the coastal profile is eroding at an average of about one meter per year, primarily due to a combination of natural erosion and sand mining. Removal of beach sand is undercutting the profile and increasing natural erosion caused by wave action and storms. In a typical, undisturbed coastal environment, the tide runs parallel to the shoreline; however, removal of the existing sediment through mining activities has altered tidal influx and direction and increased rates of erosion (Dincauze 2000, Kaye et al. 2005). Locals mine

beach sand as an ingredient for cement in building construction (Fitzpatrick et al. 2006). Ironically, if the sand is not rinsed thoroughly before use, the remaining salt causes corrosion from the inside out and reduces the structural strength of the building. Additionally, recent hurricanes (Ivan in 2004 and Emily in 2005) have intensified coastal erosion through heavy rain, strong winds, and wave action (Fitzpatrick et al. 2006). Due to trade wind patterns and easterly currents, the environment on the east coast near Grand Bay is particularly dynamic. Coral reefs about 1.5 km offshore provides some buffering, but not nearly enough to prevent much erosion (Fitzpatrick et al. 2006, Kaye et al. 2005, Lefevbre 2007). As a result, excavation has been focused at this site in order to document as much of the site as possible.

As part of archaeological excavation, the site has been organized into an arbitrary grid system with a series of 5×5 meter trenches that are further subdivided into 25 1×1 m excavation squares (Figure 4). To date, six 5×5 m trenches have been excavated using 10 cm arbitrary stratigraphic levels in combination with natural stratigraphic layers. Archaeological material from each square is collected by hand or trowel, with the exception of four squares within each unit (square numbers 7, 9, 17, and 19) that are designated as environmental sample squares. Three quarters of the material from these squares are wet screened through 6 mm (1/4 inch) mesh. The remaining material is designated as a column sample and wet screened through nested 6 mm and 1.5 mm (1/16 inch) mesh for recovery of smaller site constituents (Giovas et al. 2010, Fitzpatrick et al. 2009). All material is then processed through the ArcheoLINK database system, which utilizes a barcode label system to identify finds by provenience.

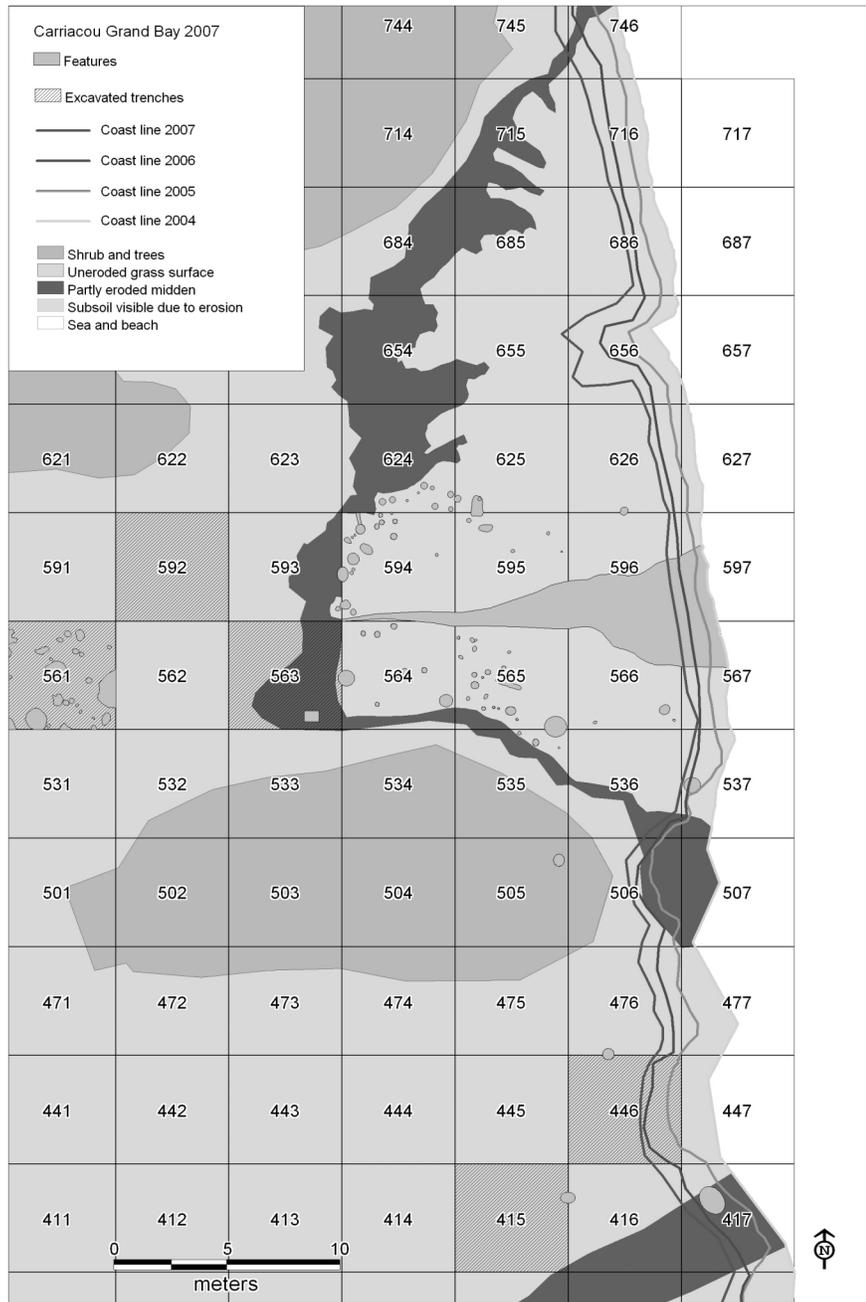


Figure 4. Map of Grand Bay site showing grid system and excavated trenches (indicated by hatch marks), coastal erosion rates, and locations of archaeological features (drafted by Michiel Kappers).

A suite of radiocarbon dates from a variety of charcoal, marine shell, and human bone samples at Grand Bay indicate that the site was settled by people during the Ceramic Age sometime between cal. AD 380-500, or the Terminal Saladoid period. Additional dates span cal. AD 500-1250, with the majority of dates corresponding to the Troumassoid period and Troumassan Troumassoid ceramic subseries (Table 1) (Fitzpatrick et al. 2009). Additional luminescence dates from stylistically distinct potsherds that range from cal. AD 900 to AD 1200, correlate well with the radiocarbon dates and further support an intensive Troumassoid period occupancy of the site. Luminescence dates from inhaling bowl fragments found at Grand Bay were, however, much older (ca. 390 ± 190 BC), suggesting they may have been heirlooms transported from another location, possibly Puerto Rico (Fitzpatrick et al. 2008, 2009). This occupation is earlier than what has been found at larger islands nearby. Though Carriacou is smaller in land surface area than other nearby islands (such as Grenada or St. Vincent), the extent of productive marine ecosystems close to shore may have been attractive to settlers (Keegan et al. 2008).

Findings thus far include a variety of ceramic, shell, bone and coral artifacts, vertebrate and invertebrate faunal remains, and human burials. Similar to most Ceramic Age sites in the Caribbean, the most abundant artifact recovered at Grand Bay was pottery. Macroscopic analysis on about 25% of the sherds collected have been examined according to a method developed by Mary Hill Harris that compares different characteristics with provenience of pieces to determine trends in stylistic traits over time (Fitzpatrick et al. 2009). Harris utilizes non-metric and metric descriptions of sherd thickness, color, temper, shape, curvature, size, and other diagnostic characteristics to categorize samples into spatial and

temporal sequences (Drewett 1991). Common finds include sherds that are slipped with a pale brown or reddish-brown color and pieces that are covered with a smooth surface and scratched. Some pieces showing characteristic Saladoid traits such as zone incised cross-hatching and white on red color have been recovered, but are far less common. Other ceramic objects include spindle whorls, body stamps, and adornos, or zoomorphic appliqués attached to pot rims (Figure 5) (Fitzpatrick et al. 2009).



Figure 5. Ceramic artifacts recovered from Grand Bay, including a human adorno (A) and a clay body stamp (B). (Photographs by Quetta Kaye).

Table 1. Calibrated radiocarbon dates for Carriacou (CALIB 6.0.2).

Site	Lab No.	Type	species	Unit	Layer	cmbs	¹³ C/ ¹² C ratio	measured ¹⁴ C age	cal. (2 sigma)
CARRIACOU									
Grand Bay	AA-62278	shell	<i>C. pica</i>	447	XV	145	2.53	1917±37	AD 390-590
Grand Bay	AA-62279	charcoal	---	447	VI	110	-25.13	1243±36	AD 680-880
Grand Bay	AA-62280	shell	<i>Venus</i> sp.	447	VI	127	3.39	1789±38	AD 530-690
Grand Bay	AA-62280	shell	<i>Venus</i> sp.	447	VI	127	3.36	1822±41	AD 470-670
Grand Bay	AA-62281	charcoal	---	447	VI	93	-23.96	1339±36	AD 640-770
Grand Bay	AA-62282	charcoal	---	F016	---	---	-25.97	1227±36	AD 690-890
Grand Bay	AA-62283	bone	human (child - rt. fibula)	F006	---	---	-14.21	1062±44	AD 1050-1250
Grand Bay	Beta-206685	shell	<i>E. gigas</i> (juvenile)	N. profile	---	108	2.1	1870±70	AD 380-670
Grand Bay	Beta-233647	shell	<i>C. pica</i>	415	V	---	1.8	870±40	AD 1400-1530
Harvey Vale	AA-62284	bone	human (rt. ulna)	---	---	---	-12.55	1027±46	AD 1060-1280
Sabazan	RL-29	charcoal	---	midden	---	~60-80	---	940±100	AD 900-1270
Sabazan	GX-30423	shell	<i>C. pica</i>	profile	VI	160	2.4	1400±60	AD 870-1160
Sabazan	GX-30424	shell	<i>E. gigas</i>	profile	X	200	0.2	1570±60	AD 690-970
Sabazan	GX-30425	shell	<i>C. pica</i>	profile	XI	230	2.5	1460±60	AD 790-1060
Sabazan	OS-41358	charcoal	---	profile	X	215	-23.94	1030±30	AD 900-1120
Sabazan	AA67529	charcoal	---	profile	XI	53-108	-25.6	988±42	AD 980-1160
Sabazan	AA67530	charcoal	---	profile	XI	53-108	-25.6	1039±35	AD 900-1120
Sabazan	AA67531	charcoal	---	profile	XIII	108-115	-24.6	1133±38	AD 780-990
Sabazan	AA67532	charcoal	---	profile	XIII	108-115	(-25)	1073±38	AD 890-1020
Sabazan	AA67533	charcoal	---	profile	XIV	115-154	(-25)	1172±36	AD 770-970
Sabazan	AA67534	charcoal	---	profile	XIV	115-154	-24.6	1333±57	AD 600-860
Sabazan	AA67535	charcoal	---	profile	XV	149-164	-24.8	1588±36	AD 400- 550
Sabazan	AA67536	charcoal	---	profile	XV	149-164	-25.8	1584±36	AD 410- 560
Sabazan	AA81054	charcoal	---	Tr 1: sq 1	2	3-13	-23.8	657±44	AD 1275-1400
Sabazan	OS-71407	charred seed	---	Tr 1: sq 1	4	30-34	-23.55	960±15	AD 1020-1150
Sabazan	OS-71408	charcoal	---	Tr 1: sq 1	5	43-53	-25.99	970±15	AD 1020-1150
Sabazan	AA81056	charred seed	---	Tr 1: sq 1	6	57-67	-25.5	994±45	AD 910-1160
Sabazan	OS-71409	charcoal	---	Tr 1: sq 1	6	73.5	-24.73	925±15	AD 1040-1160
Sabazan	OS-71410	charcoal	---	Tr 2: sq 1	2	2-11	-26.05	> modern	modern
Sabazan	OS-71462	charred seed	---	Tr 2: sq 1	3	19-29	-24.5	975±20	AD 1020-1150
Sabazan	AA81055	charcoal	---	Tr 2: sq 1	3A	40-50	-25.1	1158±45	AD 730-990
Sabazan	OS-71463	charcoal	---	Tr 2: sq 1	3A	75.5	-23.62	1140±15	AD 870-970
Sabazan	OS-71464	charred seed	---	Tr 2: sq 1	8	89-91	-24.03	1100±20	AD 890-990
Sabazan	OS-71465	charcoal	---	Tr 2: sq 1	9	115	-24.04	1080±15	AD 900-1010
Sabazan	OS-71466	charcoal	---	Tr 3: sq 1	2	8-19	-24.77	680±15	AD 1280-1380
Sabazan	OS-71467	charcoal	---	Tr 3: sq 1	3A	84	-25.67	1220±20	AD 710-880

Non-ceramic artifacts found at Grand Bay are primarily made from stone, shell, and bone. Shell tools (*Strombus gigas*) are the most common and are typically scrapers and adzes made from conch (Figure 6). Stone tools and lapidary objects made from crystal quartz or green stone, as well as ritualistic objects, including three-pointed stone *cemis* and vomit spatulas made from turtle bone, have also been recovered. Cemi stones are associated with Taíno cosmology in the Greater Antilles and are fairly rare in the southern Caribbean (Kaye et al. 2007). European records state that the stones were used by indigenous groups as a symbol for magic powers and as spiritual aids for good luck and prosperity (Olazagasti 1997). Vomit spatulas are associated with the *cohoba* ritual, which uses a psychoactive plant known as piptademia as a ritual purification method. Such finds imply that Carriacou and other islands in the area were a part of a larger regional network of religious belief systems (Hofman et al. 2008, Fitzpatrick et al. 2009).



Figure 6. Shell adzes recovered from Grand Bay (Photograph by Scott Fitzpatrick).

Vertebrate remains consist of a vast array of marine fishes, sea turtle, and terrestrial mammals. Invertebrate remains consist of marine and land mollusks, many of which inhabit rocky outcroppings along the shore or shallow water habitats (Giovas, personal communication, Lefebvre 2007). Use of so many marine taxa is not particularly surprising due to Grand Bay's close proximity to the shore and differing coastal and marine habitats.

Terrestrial fauna is less abundant, but indicates the presence and exploitation of mammals, birds, and reptiles at the site (Lefevbre 2007).

Over 20 human burials have been recovered thus far. The majority of the burials were discovered eroding out of the coastal profile or were exposed on the surface; therefore many of the burials are fragmented. Of the remains that were well-preserved enough for analysis of sex and age, it appears that male and female adults were represented equally, with an additional four subadult individuals (Table 2) (Fitzpatrick et al. 2009). Many were interred as primary burials in pre-existing postholes and positioned with flexion at the knees and pelvis. No grave goods have been recovered, implying that if any items were placed with individuals, they were perishable. Preliminary osteological analysis was conducted by Reeves (2006) as part of his MA Thesis at the University of Montana and included identification of trauma, pathology, and examination of the dentition on seven individuals recovered from Grand Bay and a construction site at Tyrell Bay. Five of the individuals display evidence of trauma, including fractures of the femur, clavicle, humerus, fibula, ulna, and radius. Additionally, evidence of active periostitis was found on the medial surface of the ribs of two juveniles, implying that a respiratory infection could have been a factor in their death (Reeves 2006). Further analysis on burials recovered after Dr. Scott Burnett (Eckerd College) was the team bioarchaeologist for the 2007 and 2008 field seasons and conducted all osteological analyses on burials recovered after 2005, as well as an in-depth examination of dental pathology.

Table 2. Burials recovered from Grand Bay (Fitzpatrick et al. 2009).

Find No.	Feature No.	Age	Sex	Orientation (burial) ²	Orientation (face)	Posture
03CAR000095	0001	adult	unknown	N-S	unknown	on back, flexed
03CAR000096	0010	adult	unknown	NE-SW	unknown	on back, flexed
03CAR000097	?	adult	unknown	S-N	NE	on back, flexed
04CGB000025	0001	adult	female	N-S	unknown	on back, flexed
04CGB000022	0003	10-14 years	male?	W-E	Unknown	sitting upright, flexed
04CGB000113	0006	6 years	child	SE-NW	Unknown	on back, flexed
04CGB000388	0083	adult	male	S-N	unknown	sitting upright, flexed
04CGB000390	0084	20-25 years	female	S-N	W	on back, flexed
05CGB001024	0088	25-35 years	male	W-E	E	sitting upright, flexed
06CGB001121	0123	adult	male	unknown	?	?
06CGB001145	0124	adult	female	unknown	?	?
07CGB001230	0131	10-15 years	?	unknown	unknown	on back
07CGB001249	0125	not excavated	not excavated	not excavated	not excavated	on R side?, flexed?
07CGB001307	0130	mid adult	female	NE-SW	NE	sitting upright, flexed
07CGB001342	0126	adult	male	N-S?	N	sitting upright?
07CGB001375	0093	14-15 years	male	SW-NE	SW?	sitting upright, flexed
07CGB001379	0129	?	?	limited excavation	limited excavation	on side?, flexed?
07CGB001419	0128	adult?	female?	unknown	unknown	?
07CGB001444	0132	adult	female	NE-SW	SW	on back, flexed

Sabazan

The Sabazan site is located on the southeast coast of Carriacou and was chosen as a site for excavation due to the results of an island-wide survey in 2003 and its high risk of material loss due to coastal erosion (Fitzpatrick et al. 2004). Excavations were conducted by Christina Giovas (University of Washington) during the 2007 and 2008 field seasons following results from a column sample collected in 2005. Three units have been opened for excavation – two 1×1 m trenches and one 2×1 m trench. The units are located further inland

than the Grand Bay site and are located in a forested area about 50 m from the coastal profile. All three were excavated using 10 cm arbitrary levels and all material was wet-screened through nested 6 mm and 1.5 mm mesh recover smaller site constituents.

Radiocarbon dates for Sabazan indicate that the site was occupied from around AD 400-1400, with more intense occupation between AD 700-1130, contemporaneous with Grand Bay (Fitzpatrick et al. 2004). The excavated material to date is associated with dates as far back as AD 800-900. However, not all of the trenches have been excavated down to sterile subsoil, so it is likely that further excavation would reveal finds that date to earlier periods of occupation (Giovas, personal communication). Biological remains recovered thus far are similar to those found at Grand Bay and include marine fishes and invertebrates, as well as terrestrial fauna.

As can be seen, Grand Bay and Sabazan possess a rich archaeological record that is quickly disappearing, and lacks more detailed analysis of paleoenvironmental remains and detailed skeletal analysis to help to fill in many of the gaps we have about the diet of local inhabitants, changing environmental conditions, and their general nutritional health. As I discuss in the following chapters using LEH and a combination of paleoenvironmental lines of evidence, sites located on Carriacou contain a wealth of information that can shed light paleodiet among prehistoric Caribbean peoples.

III. BACKGROUND

Bioarchaeological examinations of physiological stress commonly include skeletal stress indicators such as cribra orbitalia, porotic hyperostosis, short long bone length, and linear enamel hypoplasia (LEH) (Larsen 1997). Both cribra orbitalia and porotic hyperostosis are indicators of iron deficiency anemia. Cribra orbitalia manifests itself in the eye orbits, while porotic hyperostosis is characterized by lesions on the cranial vault. Both pathologies are the result of the body's attempt to produce more red blood cells in bone marrow to compensate for having less iron. Short long bone length is occurs as a result of nutritional stress during childhood (Larsen 1997). Due to the lack of sufficient nutrients, an individual's full growth potential is not reached and body size is smaller. LEH is a nonspecific stress indicator representing arrested enamel development. Each indicator has its share of benefits and drawbacks; however, primarily due to poor preservation of cranial and postcranial remains, LEH was chosen as a stress indicator to evaluate health in the Grand Bay skeletal sample.

Linear Enamel Hypoplasia

Linear enamel hypoplasia (LEH) is a non-specific stress indicator found in tooth enamel. LEH results from cessation of enamel formation during dental development due to physiological stress. Because the dentition begins forming in utero and continues through most of childhood, as well as the fact that enamel does not remodel over the life course, LEH is a useful indicator of childhood stress regardless of the age at which an individual died (Hillson 2006, Larsen 1997). Tooth enamel also preserves well in archaeological contexts, so

in conditions of poor preservation of skeletal remains, the dentition and LEH in particular can provide important information about nutrition and physiological stress.

Development of the Dentition

Tooth formation begins about six weeks after fertilization with the development of two layers of tissue known as epithelium—which form the tooth germ and mesenchyme—and that eventually develop into connective tissue. The epithelium forms a band around an arch-shaped zone of mesenchyme in the developing jaw and divides into lobes known as “vestibular” and “dental lamina”. Swollen areas form around the dental lamina and become the developmental organs for tooth enamel around the tenth week (Hillson 2006). The enamel organs create a bud shape that gradually shifts into a cap. During the cap phase, the enamel separates into an internal layer of epithelial tissue that will later form the basic enamel matrix. The overall cap continues to grow into a bell shape with an interior hollow that will take on a pattern of folds and creases that eventually form the tooth crown’s shape. Within the interior hollowed area, mesenchymal tissue known as dental papilla begins to formulate into odontoblasts, which are dentine-secreting cells. The internal epithelial tissue will divide into ameloblasts which are enamel-secreting cells (Alt et. al, 1998, Hillson 2006) (Figure 7).

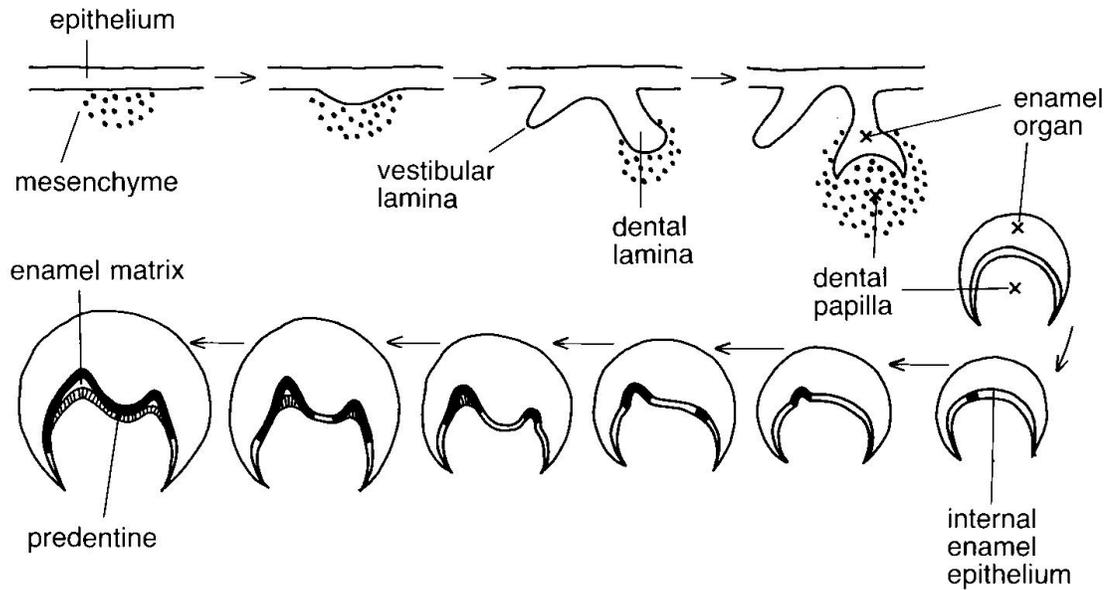


Figure 7. Development of tooth germ (Hillson 2006).

Enamel forms in two basic stages: first, ameloblasts form from the internal epithelium and secrete an initial enamel matrix containing both organic and mineral components (Hillson 2006, Larsen 1997). In the second stage, the ameloblasts transform and break down the organic compounds, leaving a mineralized material, or enamel, to cover the dentition within the hollowed area (Hillson 2006). Enamel continues to be deposited in a series of layers known as “perikymata” from the cusp of the tooth down to the cemento-enamel junction (CEJ). The perikymata forms a pattern of ridges and grooves along the tooth crown in the permanent dentition.

Tooth formation at the stage of enamel and dentine deposition begins with the deciduous incisors between 14 and 16 weeks after fertilization. Formation of the canines

begins a week later and the molars subsequently follow 3-4 weeks later. By birth, tooth crowns of the deciduous dentition have begun forming and cusps of the permanent first molars have commenced development (Hillson 2006, Schour and Massler 1940). Formation of the complete dentition ends around 17-20 years of age with completion of the permanent third molars (Figure 8) (Ritzman et al. 2008).

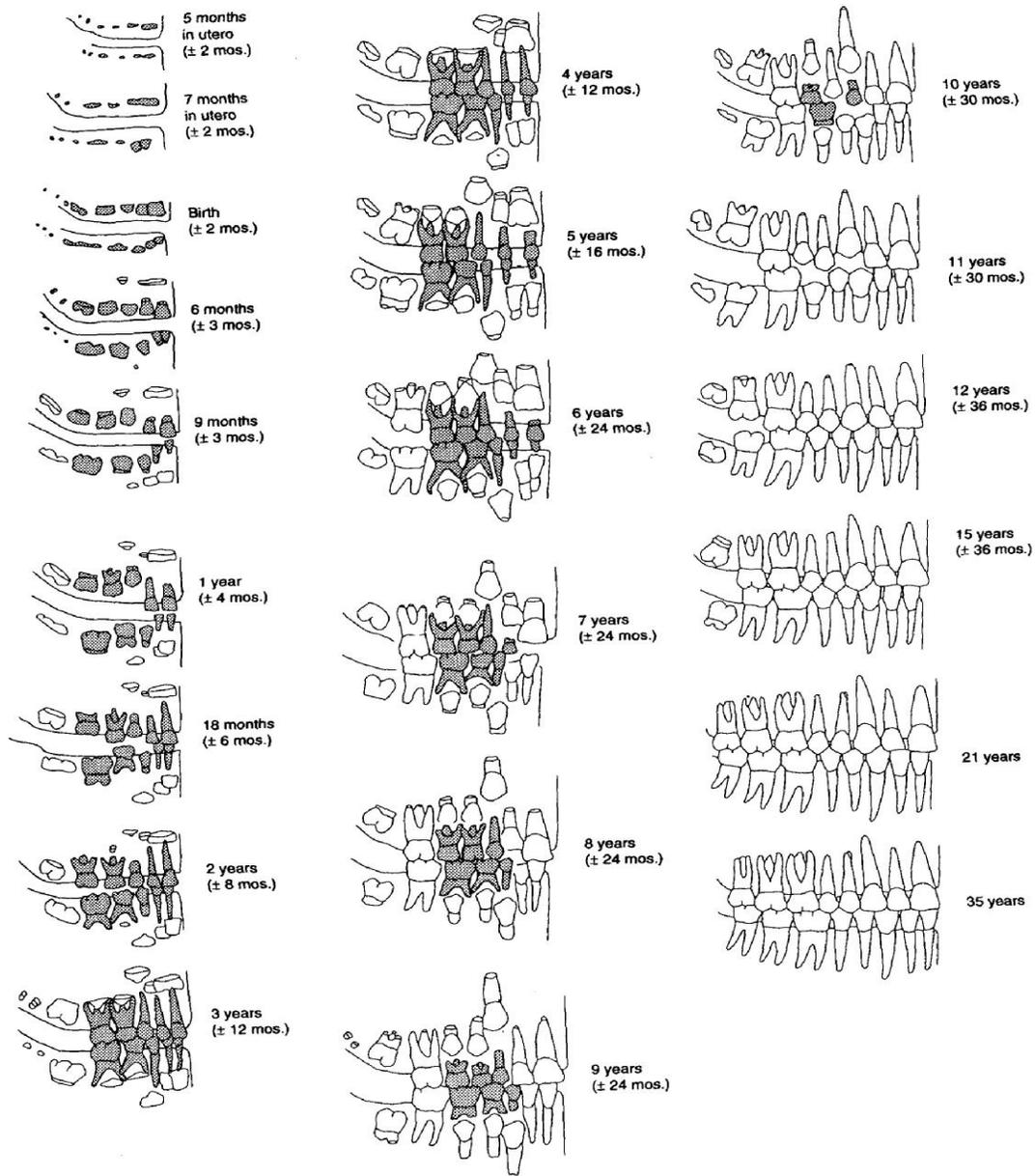


Figure 8. Diagram of dental development (Buikstra and Ubelaker 1994).

Enamel Hypoplasias

If an individual experiences some degree of physiological stress during the growth stages, production of enamel is disrupted. Hypoplasias are defects defined as a deficiency of enamel thickness due to physiological stress and are characterized by their disruption of the contour of the tooth surface. There are three forms of hypoplastic defects: furrows, pits, and planes. Furrows, more frequently referred to as linear enamel hypoplasias (LEH) appear as exaggerations of natural perikymata lines that wrap around the tooth surface. Each perikymata represents a growth layer on the tooth crown and an LEH is a groove in the enamel that is caused by the cessation of enamel secretion within a perikymata layer earlier than expected. LEH events are the result of a band of ameloblasts ceasing enamel production. Pits can vary in size and are the result of individual ameloblast interruption. Plane defects expose larger areas of the tooth surface and are less common (Hillson 1992). It is also possible to have LEH events in the form of rows of pits.

Hypoplasias are commonly found in the anterior teeth. Because tooth enamel is never remodeled, a hypoplasia remains as evidence of a stressful event, as well as a reflection of the duration and severity of the incidence. If the distance between a hypoplasia and the CEJ is measured, it can then be correlated with the timing of dental development to identify the age at which a stressful event occurred if tooth wear is minimal. This can be compared among individuals of a population to determine if the stress is related to a specific event or cultural differences that affected certain portions of the population (Larsen 1997).

Traditionally the hypoplasia is measured in distance from the CEJ and matched with charts that illustrate dental development. Based on the location of the hypoplasia on the

tooth, the age at which the hypoplasia occurred can be ascertained. This can be further refined using regression formulaes (Ritzman et al 2008). However this method assumes that enamel develops at a constant rate and does not include the formation of the tooth cusp. As such, it has been argued that this method underestimates the ages at which hypoplasias developed. However, there is no way to assess the accuracy of these results. Other methods that have been used include time for cusp development. As a result, these measurements correlate with an older age range (Martin et al 2008). It has been argued that the differences between the methods range from a few months up to about a year and therefore should not have a significant effect on findings (Martin et al. 2008).

A review of studies of LEH frequency from around the globe find that there is no single ecosystem or environment in which populations are particularly susceptible to enamel defects (Larsen 1997). Instead, ecological and social factors, such as dietary resource availability or a lack thereof as a result of famine, drought, or natural disaster, have more of an effect. Individuals born in the People's Republic of China during the starvation famine of 1959-1961 have higher frequencies of LEH in comparison to those born before or after the event (Larsen 1997). Social structure and rank also plays a role. A study of African American slaves from Maryland and Virginia show elevated rates of LEH in comparison to their owners (Blakey et al 1994). At the Tutu site on St. Thomas, individuals appeared to be undergoing minimal stress, with LEH frequencies at less than 30% (Larsen et al. 2002). However, further examination of age at which the defect occurred or social class and access to resources to explain the reason for infrequent LEH has yet to be conducted (Larsen et al. 2002).

Paleobotany

Over the millennia peoples who inhabited the Caribbean islands required plants for food, fuelwood, and medicine in order to survive and adapt to insular environments that were biologically impoverished. During the course of human occupation, these islands provided habitats for both endemic and introduced animal taxa from the mainland, and played a critical role in supplying raw materials for domestic structures, weapons, textiles, tools, inter-island transportation, and a host of other ritualistic and routine purposes. Because the region is composed of numerous islands with different kinds of ecosystems, regional vegetation is extremely diverse and variable. Little paleoethnobotanical research was undertaken in the Caribbean until the last 30 years, and generally relied on ethnohistorical accounts related to indigenous plant use and historical records from European contact. However, recent work has focused on increasing archaeobotanical data and comparative collections in order to shed light on many of the more common plant species found in the region (Newsom and Pearsall 2003, Newsom 2010).

Little is known about Lithic groups' plant use due to a paucity of sites and botanical data from such assemblages. Sites of fishing and foraging groups from the Archaic age in the Greater Antilles have revealed evidence of a multitude of edible plants, including guáyiga (*Zamia debilis*)—a starchy plant with edible underground stems, mastic-bully (*Sideroxylon*) and cockspur (*Celtis* sp.) which are native fruits, and non-native plants including avocado (*Persea Americana*) and yellow sapote (*Lucuma salicifolia*) that were both common plants used in home gardens on the mainland (Newsom and Pearsall 2003). These identifications are especially important because the two species are native to Mexico and Central America

which would indicate an Archaic origin in that geographic area. The Saladoid migration signifies the initial movement of tropical root-crop horticulture from the northern Amazon region to the Caribbean islands, including manioc (*Manihot esculenta*), sweet potato (*Ipomoea batata*), maraca (*Marantaceae*), and maraca amarillo (*Canna* sp.) that were all common taxa (Newsom and Peasall 2003, Newsom 2010).

In the Lesser Antilles common finds from Archaic and Saladoid sites include edible tree fruits such as soursop, spiny palm, West Indian Locust, and calabash trees for gourd containers, as well as microbotanical remains of what appear to be tubers. Though exact identifications have yet to be determined, the evidence suggests that the remains are likely manioc. There has yet to be evidence within these earlier assemblages of other imported taxa or domesticated species. Wood assemblages between the Archaic and Ceramic ages are relatively similar and reflect coastal and dry forest ecosystems, indicating that wood was collected for fuel, structural materials, and canoe building, from local areas (Newsom and Pearsall 2003, Newsom and Wing 2004).

Newsom's (2009) research at Tibes, Puerto Rico, for example, has identified many of the common crops and botanical resources used by Ceramic Age peoples. Concentrations of carbonized wood and associated cultural artifacts are evidence of the presence of hearths that could have been used for a variety of activities, including food processing and religious rituals. The distribution of carbonized wood throughout different levels reveals periods of intensification of wood use, and are a proxy for an increase in human activity. It appears that buttonwood mangroves (*Conocarpus erectus*) and sea grapes (*Coccoloba uvifera*), both local coastal species, were commonly used for fuelwood (Newsom 2009). Many of the other wood

species identified in the area were also found to be used for posts, furniture, construction, cordage, and a variety of other items (deFrance and Newsom 2005). In later deposits in the Greater Antilles, phytoliths identified as maize (*Zea mays*) have been found in sediment cores from Puerto Rico, the Dominican Republic, and Haiti. However, links between radiocarbon dates and the presence of the phytoliths are not absolute. Definitive samples have been recovered and dated to between AD 1000-1500, which is much earlier than expected, but dates from Central America, Mexico, and the northern Amazon indicate that the crop would have been available to groups migrating to the Caribbean at this time. Maize macroremains have been recovered from En Bas Saline, Haiti and Tutu, St. Thomas, as well as phytoliths from the Three Dog site in the Bahamas — all date to around AD 1000-1350, which is well within the time period at which maize was known to be present throughout the Americas, including the southeastern United States (Berman and Pearsall 2000, Higuera-Gundy 1991, Newsom and Deagan 1994)

Many crops were recorded as being grown at the time of contact, including manioc (*Manihot esculenta*), sweet potatoes (*Ipomoea batata*), squash (*Curcubita*), and assorted other crops such as chili peppers (*Capsicum*) and tobacco (*Nicotiana*). Many of these crops originated, or are also found, on the mainland throughout Central and South America, so it can be inferred that early inhabitants emphasized horticultural production that focused on root crops (such as manioc and sweet potatoes) introduced from the mainland (deFrance and Newsom 2005). Their subsistence system also seemed to include fruit trees such as papaya (*Carica papaya*), avocado (*Persea americana*), guava (*Psidium guajava*), and mastic-bully (*Sideroxylon*). Other trees that were likely maintained for other uses are higuera for gourd-

like fruits to be used as containers and for medicinal purposes, achiote (*Bixa orellana*) for red dye, and cohoba (*Anadenanthera*). As previously mentioned, many of these plants have been found to have origins on mainland Latin America, and it is possible that the plants were introduced by Saladoid people upon migrating to the Caribbean (Siegel 2005). Most of these crops have also been found on other islands, including Grenada, Nevis, and St. Martin (Newsom and Wing 2004).

Caribbean Faunal Remains

Examinations of faunal assemblages throughout the Caribbean have provided critical information on the availability of marine and terrestrial species for subsistence resources. A combination of marine and terrestrial species is common at sites across the Caribbean, with an emphasis placed on marine fish and invertebrates. Common fish taxa include groupers (*Serranidae*), jack fishes (*Carangidae*), parrotfish (*Scaridae*), surgeon fish (*Acanthuridae*), and trigger fish (*Balistidae*) (Lefevbre 2007, Wing and Wing 2001). Overall, changes throughout the history of occupation reflect some shifts among terrestrial and marine focus of resources as a result of overexploitation and introduction of new taxa (Wing 2001).

Archaic period assemblages reflect a fishing and foraging subsistence pattern, with the majority of the faunal remains indicating that people focused heavily on exploiting marine ecosystems. The most abundant vertebrates at Archaic sites on Antigua and Nevis show high quantities of reef fish and marine mollusks from rocky and intertidal zones. There is no evidence of domesticated or managed terrestrial species, although there is evidence for the consumption of endemic rice rat species (Newsom and Wing 2004). The Ceramic Age shows a slight shift in marine exploitation, primarily through movement offshore to capture

pelagic fish species in addition to shallow water reef fishes. Rocky intertidal zone invertebrates such as West Indian Top Shell (*Cittarium pica*) and various nerite species (*Nerita* sp.) are usually abundant, comprising large portions of faunal assemblages throughout the Caribbean. The initial introduction of terrestrial mammals such as agouti (*Dasyprocta* sp.) and guinea pig (*Cavia porcellus*), as well as domesticated dogs, are seen at the Pearls site on Grenada and the Trants site on Montserrat. The Saladoid and post-Saladoid faunal assemblages are most notably characterized by a shift in invertebrate assemblages from one dominated by land crab early on to marine mollusks at the end of the Saladoid (Newsom and Wing 2004).

Analysis of faunal remains from Saladoid and post-Saladoid sites on Puerto Rico, Nevis, St. Martin, St. Thomas, and Saba were studied by Wing and Wing (2001) to determine the changes in fisheries exploitation over time. Results indicated a gradual decrease in the contribution of reef fish species to the faunal assemblage while pelagic fish species reflected a gradual increase. This is indicative of a fisheries shift to resources that predominate more offshore habitats and could be a result of overexploitation. Marine invertebrates are also common, as many of them occupy intertidal or shoreline habitats and can be easily collected. Taxa that are typical of prehistoric Caribbean assemblages include conch (*Strombidae*), nerites (*Neritidae*), West Indian Top Shell (*Cittarium pica*), chiton (*Chitonidae*), and various crab species. Larger marine species, including sea turtles (*Chelonidae*), are likely significant food resources as well; however, due to their size it should be noted that fewer individuals contribute to the assemblage, but contribute larger amounts of meat to overall yields (Fitzpatrick et al. 2009, Giovas, personal communication). Terrestrial mammals, birds, and

reptiles were also exploited, but they are much less abundant than fish. Mammals include agouti (*Dasyprocta sp.*), opossum (*Didelphis sp.*), rice rat (*Oryzomys sp.*), guinea pig (*Cavia porcellus*), peccary (*Pecari/Tayassu sp.*), and armadillo (*Dasypus sp.*). Considered native to South America, the presence of these species within Caribbean faunal assemblages provide evidence for human translocation of the animals for subsistence needs (Giovas et al. 2010). Therefore, a combination of native fish species and invertebrates gathered from nearby intertidal areas and offshore reef systems and introduced terrestrial mammals appear to have provided the majority of the faunal species exploited for subsistence.

Carriacou Faunal Remains

A variety of faunal samples, including both vertebrate and invertebrate remains from Grand Bay and Sabazan, have been analyzed by PhD students Christina Giovas (University of Washington) and Michelle Lefebvre (University of Florida). Common methods of collecting smaller faunal material involve the use of wet or dry sieves. As mentioned previously, collection of faunal material at Grand Bay is by a combination of trowel collection during excavation and wet-screening designated sample squares at each arbitrary level. At Sabazan, all excavated material was wet screened for nearly complete recovery of faunal remains and smaller artifacts and then subsampled. For the 1/4-in. fauna, a quarter of the sample was selected based on the weight of the original material. Because the volume of excavated material is smaller at Sabazan compared to Grand Bay, and the screened material from Grand Bay was already subdivided into samples during excavation, the samples of faunal remains available at both sites for analysis are roughly the same size. 100 g of material from the 1/16-in. screened fauna were analyzed from each level. Additionally, three 1/4 –in.

samples and one square from Trench 2 were analyzed as complete column samples (Giovas, personal communication).

Common methods of analysis include identification of taxa to the lowest taxonomic level possible using comparative collections, as well as recording the number of identified specimens (NISP), weight, minimum number of individuals (MNI), and biomass. NISP and specimen weight provide information related to the relative frequencies of individual taxa (Grayson 1984, Reitz and Wing 2008). Based on this information, changes in frequencies over time can be examined and how they relate to potential changes in the environment or cultural preferences. However, NISP is a measurement that is vulnerable to biases related to preservation and fragmentation. Multiple fragments of the same individual element can skew results toward a higher frequency than what actually exists. Calculating MNI accounts for some fragmentation by measuring the smallest number of individuals necessary to account for the elements present (Reitz and Wing 2008). This can be accounted for using a variety of methods, including counting numbers of non-repetitive elements, evidence of sex, size, and age, or consideration of the percentage of fragments required to make up a complete element. However, each method introduces some biases related to observational and theoretical errors (Giovas 2009, Reitz and Wing 2008). Based on initial frequencies using MNI and NISP, dietary contributions based on species availability can be calculated without introducing potential bias from assuming which animal parts were preferred (LeFebvre 2007).

Additional analyses include calculations of biomass, diversity, equitability, and estimations of body size and meat weight contributions. Using these methods in addition to initial descriptive analyses that use MNI, NISP, and weight allow for interpretation of faunal

remains in terms of potential dietary contributions and the ecological implications of animal exploitation for dietary purposes (Grayson 1984, Reitz and Wing 2008). Estimation of biomass and body size can be made using allometric regressions, indices, and comparisons with modern samples. Changes in body size are important to note because they can be indicative of overexploitation. As demand for animal resources increase, populations of taxa may not have enough time to replenish. Optimal foraging theory postulates that larger individuals will be preferred because they will yield more meat per calories expended to capture, thus leaving smaller individuals to reproduce and create the next generation (Grayson 1984, Keegan et al. 2008). Also, as populations dwindle, individuals are exploited at younger ages. Therefore, decreases in size over time act as a good indicator of resource exploitation at more intensive levels. Diversity and equitability measures are indicators of the taxa that make up the total assemblage and each taxon's relative contribution and how it changes over time (Grayson 1984). Diversity scores reflect the abundance of overall taxa represented, while equitability scores reflect whether a sample is dominated by one or more species. Shifts in exploited taxa can be ascertained based on diversity and equitability scores and used in conjunction with other zooarchaeological analyses such as body size to interpret incidences of environmental change or resource shifting as a result of overexploitation.

For the Grand Bay faunal analysis conducted by Christina Giovas and Michelle Lefebvre, identification of vertebrate taxa was made to the lowest taxonomic level possible using the comparative collections at the Florida Museum of Natural History in Gainesville, Florida and the Vertebrate Paleontology and Mammalogy Departments of the Royal Ontario Museum in Toronto, Canada. Initial analysis included determination of NISP, weight, and

records of any natural or cultural taphonomic processes. Secondary analysis involved biomass estimates to determine relative meat weight contributions of identified taxa by habitat as well as allometric scaling of fish vertebrate measurements to evaluate fish weight and determine potential capture methods (Lefevbre 2007). Fish vertebrae were chosen because the Grand Bay assemblage reflects high numbers of marine species, especially finfish taxa. Allometric regression formulae are useful for body size estimation in animals that have indeterminate growth patterns like fish because they use reference measurements to compare and predict standard body length based on the width of the centrum of vertebrae (Reitz and Wing 2008). Because fish vertebrae size usually correlate well with body size, the widths of all complete precaudal and thoracic vertebrae were measured. Finally, the MNI counts were used to calculate species diversity and equitability values using the Shannon-Weaver Index which allows for interpretation of human selection of taxa during the site's occupation and reflects the evenness of species abundance within a sample (Lefevbre 2007). The Shannon-Weaver Index is a common diversity index in which samples with even abundance distributions will be indicative of high diversity (Reitz and Wing 2008).

By combining these results with stable isotope data, some of the general consumption patterns of the inhabitants of Grand Bay, as well as their potential relative contribution to overall diet in terms of marine and terrestrial species, can be determined. Though it already appears likely that marine animals were a primary contribution to diet at Grand Bay, the faunal analysis will clarify which individual taxa were exploited and can be coupled with the paleobotanical and stable isotope analysis to more thoroughly investigate the health and diet of ancient Carriacouans.

Stable Isotope Analysis

Stable isotope analysis of carbon and nitrogen is based on isotopes being stored in the cells of animals and plants. Different types of plants exhibit varying levels of carbon as a result of discrepancies among photosynthetic processes and terrestrial resources exhibit different levels of nitrogen when compared to marine resources (Larsen 1997). Therefore, all living things have a distinct isotopic signature with values of carbon and nitrogen. When a food is consumed, such isotopic concentrations are transferred up the trophic pyramid. In the case of humans (and other animals), the concentrations of carbon and nitrogen isotopes present in their bodies reflect the isotopic signatures of the foods they consumed in life (Figure 9).

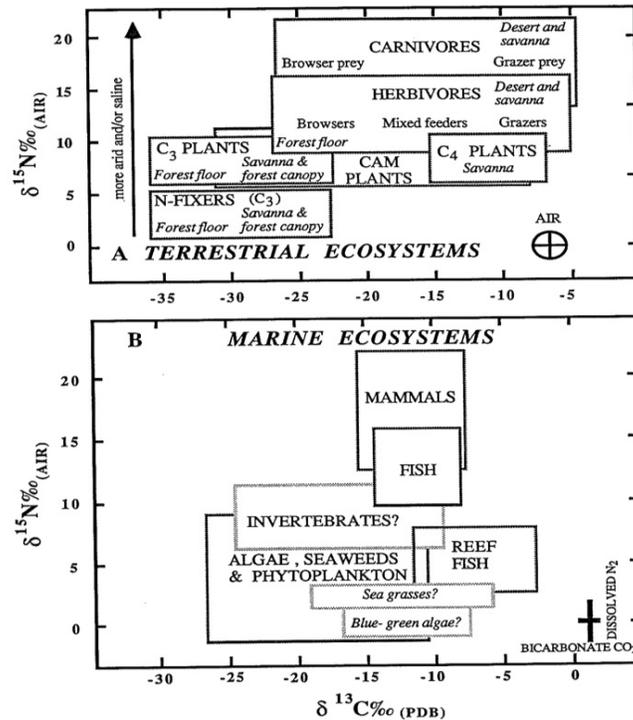


Figure 9. Distribution of common dietary items based on isotopic signature (deFrance 2008:299)

Carbon has two stable isotopes— ^{12}C and ^{13}C —that are expressed in delta (δ) levels of concentrations in parts per thousand (‰). The difference between the two isotopes lies in their atomic weight, which results in different rates of chemical reactions. Carbon isotopes are expressed in relation to a standard level, which is the Pee Dee marine fossil—referred to as PDB—that has a level of carbon higher than food resources, so that carbon isotope ratios will be expressed as negative δ values (Pearsall 2000). Carbon isotope ratios vary in plants based on the type of photosynthetic pathway they use. Plants photosynthesize in three different ways that are distinguished by the number of carbon molecules they produce throughout the photosynthetic process. C_3 plants are named for the resulting three molecules of carbon that are produced—these plants tend to grow in temperate climates and include grasses, trees, shrubs, and tubers (Larsen 1997). C_4 plants are adapted to relatively hot and arid environments and have further elaborated their photosynthetic pathways as a result. These plants include tropical grasses, maize, sugar cane, and millet. They have a less negative δ level than C_3 plants (Larsen 1997). CAM plants have yet another different photosynthetic pathway and are adapted for arid climates. These plants include succulents, cacti, and bromeliads. Their δ level is typically between that of a C_3 and C_4 , but varies depending on the time of day they uptake carbon (Pearsall 2000). Marine plants fall somewhere near the range of CAM plants due to an additional uptake of carbon from bicarbonate found in the ocean. Carbon fixation in reef and seagrass environments result in even higher carbon values in those particular ecosystems as well. Typically, $\delta^{13}\text{C}$ values for C_3 plants range between -38‰ and -22‰; C_4 plants ranges from -9‰ to -21‰; and CAM plants tend to have a range between C_3 and C_4 plants (Larsen 1997). Carbon isotope levels

can be tested and compared with the type of plant that level is associated with; further tests can be done for a specific plant species that more closely matches a particular level as well. Common plant resources used in prehistoric Caribbean contexts include a variety of C₃ plants, namely manioc and flowering fruit trees (Stokes 1998).

Nitrogen isotope analysis is similar to that of carbon. The element contains two isotopes—¹⁴N and ¹⁵N—that are also expressed in delta levels that are relative to the level of atmospheric nitrogen. Fluctuations between levels of nitrogen reflect differences between terrestrial and marine food sources. Nitrogen is higher in marine contexts because marine resources get additional nitrogen from nitrogen-fixing bacteria and algae, while terrestrial sources gather nitrogen directly from the air or soil. As a result, the nitrogen levels for terrestrial resources are lower than those of marine sources (Larsen 1997). However, coral reef and seagrass communities tend to have low nitrogen levels and higher carbon levels than other marine areas due to nitrogen fixation and carbon enrichment in shallow corals that reflect in higher trophic levels within the ecosystem as well (Keegan and DeNiro 1988).

To date, there have only been a few stable isotope studies on prehistoric skeletal remains undertaken in the Caribbean (see Keegan 1985, Keegan and DeNiro 1988, Pestle 2010, and Schoeninger et al. 1983), the majority of which are from the Greater Antilles or the Bahamas. Earlier studies relied on bone collagen samples and a linear mixing model which assumed that organic material and its associated isotopes are transferred to the body's tissues equally. More recent research has found that bone collagen primarily contains the protein aspect of the diet, while bone apatite reflects the whole diet. Therefore, some of the early studies contain methodological flaws that render their results less relevant (Pestle 2010).

However, some of this research has highlighted the discrepancies between marine, coral reef, and seagrass isotopic levels in relation to averages in other environments.

Schoeninger et al. (1983) and Keegan and DeNiro (1988) found that Taíno populations in the Bahamas exhibited lower ^{13}C and ^{15}N levels than other coastal populations that consume large quantities of marine foods. This has been attributed to nitrogen fixation in coral reefs and enrichment of carbon by seagrasses and reef-building corals. Samples from indigenous terrestrial and marine animals have also been taken for comparisons in such environments (Keegan and DeNiro 1988). Archaeological evidence reflects a shift over time from focusing on terrestrial resources to moving towards marine-based diets in the Bahamas, and Keegan and DeNiro (1988) attempted to match these data with stable isotope evidence. Their study found that discrete photosynthetic pathways, as well as carbon pathways in certain marine mollusk species and phytoplankton, are enough to distinguish between tropical marine and terrestrial resources using carbon isotopes. Nitrogen isotopic evidence reflected distinct pathways that tend to overlap in such environmental contexts; however, when used in combination with carbon isotopes, are useful for distinguishing between marine mollusks and pelagic fishes in the Taíno diet (Keegan and DeNiro 1988).

More recent studies using bone apatite have been undertaken in Puerto Rico where samples from four sites located in different ecological zones and covering different cultural and chronological periods were examined (Pestle 2010). At Tibes, a ceremonial site located somewhat inland along a river, nitrogen values were found to be similar to those of high trophic level marine fishes. However the results of lower carbon values imply that samples from Tibes were likely gaining protein resources in the form of freshwater faunal species,

terrestrial mammals, and birds (Pestle 2010). Stable isotope analysis using samples from Carriacou represents one of the few undertaken in the Caribbean and one of the first to examine paleodiet in the Lesser Antilles where freshwater resources are less available and rivers are less common (or in the case of the smaller Grenadines, nonexistent). The Grand Bay site's proximity to the coast as well as the lack of riverine resources, make it appear likely that a higher marine signature is to be expected. These results have been compared with the marine faunal remains recovered and analyzed through previous zooarchaeological research in order to identify more specific dietary resources which will be discussed in later sections.

IV. MATERIALS AND METHODS

Linear Enamel Hypoplasia

A collection of teeth from 15 different individuals and proveniences at Grand Bay are currently located at Eckerd College in Saint Petersburg, Florida and are currently undergoing analysis by Dr. Scott Burnett. For my research, I examined teeth from Grand Bay to determine the frequency and presence of linear enamel hypoplasia among different individuals in relation to age and sex. This analysis can provide some insight into physiological stress in the Grand Bay population that could be a result of environmental or subsistence changes. Evidence of a population-wide event (i.e., weaning) can be matched to the timing of the hypoplasia, which in turn can be correlated with to specific changes related to diet or the local environment. I chose to examine the frequencies of LEH with regards to sex and age of the individuals in the sample in order to determine if there are differences between demographic groups. The data I collected will be assessed alongside other lines of skeletal evidence already analyzed in order to provide a more complete picture of potential stresses related to paleodiet and nutritional health.

For my analysis, each set of teeth was examined and recorded by individual. Sex and age of the individual was also recorded based on initial analysis of the remains as cited in Fitzpatrick et al. (2009) and Reeves (2006). Although hypoplasias are most commonly found on the anterior teeth, I chose to examine all of the teeth in the dentition for multiple reasons. First, because there are so few individuals in the collection, I wanted to maximize my sample size by expanding the study to include all teeth. This also expanded the time span of dental development to include older ages when later developing teeth are forming, and allows for a

broader sample in which to analyze nutrition. Second, although different teeth have overlapping development times, this does not necessarily mean that an event causing a hypoplasia on one tooth will result in a defect on all of the other teeth developing at the same time (Goodman and Armelagos 1985). Therefore, examination of the full dentition allows for a greater chance of identifying a hypoplastic event.

Each tooth was initially examined with no magnification under light for evidence of hypoplastic defects. The teeth were then further examined with a three lens folding pocket magnifier (5-20× power) for evidence of LEH defects. Only linear furrows or rows of pits were recorded because these are the most likely type of hypoplasia when the defect is a result of longer-term physiological stress as opposed to localized traumatic events (which are more likely to be seen on a single tooth) (Goodman and Armelagos 1985). Presence or absence was recorded using the scoring system from Buikstra and Ubelaker's *Standards for Data Collection from Human Skeletal Remains*. When evidence of a hypoplastic event was observed, measurements were taken with a thin-tipped caliper to the nearest 0.01mm to record the distance from the CEJ to the occlusal surface of the defect and the distance from the occlusal surface of the defect to the occlusal surface of the tooth crown. In order to assess intraobserver error, the first five individuals examined were re-evaluated with a blind test to ensure accurate identification of hypoplastic defects. All of the defects initially identified were also observed during the second examination and no new defects were found. Due to the small sample size, there was time to measure all the identified defects a second time with a blind test to minimize intraobserver error with measurements as well.

The measurements collected were then used to determine the age at which each hypoplasia occurred using the chart method proposed by Reid and Dean (2006). Until recently, many LEH studies incorporated the use of regression formulas developed by Schour and colleagues (Massler et al. 1941, Sarnat and Schour 1941 in Ritzman et al. 2008) and charts based on these formulas that divide the tooth into monthly intervals (Goodman and Rose 1990, 1991, in Ritzman et al. 2008, Swärdstedt 1966). However, recent refinements of these techniques have identified a number of limitations, including the assumption that enamel grows at a linear, constant rate as well as no account for additional enamel growth during cuspal development. Though the extent to which nonlinear growth affects age estimates is unknown, revisions have been made to the chart method to include cuspal development as proposed by Reid and Dean (2006). This method requires taking the total tooth crown height and dividing it into ten equal sections, referred to as “deciles,” that have been correlated to age estimates based on the time it takes for cuspal development and the number of days to form a complete tooth crown. Based on this aging method, matching hypoplasias on different teeth to a single event is also possible. Because the development times of different teeth overlap to some degree, an individual undergoing stress can form multiple hypoplasias on different teeth during the same period and as a result of the same stressful event. Therefore different hypoplasias can be matched to an event to determine how many different stress events an individual underwent during the course of dental development (Hillson 2006, Larsen 1997).

Paleobotany

To examine the paleobotanical record on Carriacou, a variety of soil samples, charcoal, and charred seeds from numerous contexts at both Sabazan and Grand Bay were sent to the Environmental Archaeology Lab at Pennsylvania State University for analysis. In mid-March 2010, I worked with Dr. Lee Newsom, a specialist in the analysis of the micro- and macro-botanical remains in the Caribbean, and Meagan Clark, an undergraduate student at NC State, to begin identifying charcoal and pollen taxa from these samples.

Common methods for recovery of macroremains include use of a dry-sieve or flotation and collection of *in situ* samples (Newsom and Wing 2004, Pearsall 2000). *In situ* collection of materials involves direct collection during excavation and provides data on the spatial distribution of the botanical remains and their association with other archaeological material. However, this method introduces biases based on visibility and size of the samples. The flotation method is based on the notion that the botanical material is lighter than other remains and will therefore float when a sample is placed into a liquid (typically water). With many Caribbean samples, this method tends to break up larger fragments; therefore, either the larger fragments need to be removed before flotation or the sample must be dry-sieved (Newsom and Wing 2004).

The Carriacou samples consist of column soil samples collected from the coastal profile of Grand Bay in 2005 using a hand auger; and macrobotanical remains that were hand-picked or collected by trowel *in situ*. The augered soil samples were dry-sieved through United States Geological Survey standard nested screens measuring 2, 1, and 0.5 mm. The remains collected with each size screen were scanned individually using standard dissecting

microscopes with magnifications of 50× and 60× for macrobotanical remains. The samples taken from the 0.5 mm screen were examined twice to ensure any micro-seed coats were collected, as well as smaller pieces that may have been initially overlooked. Any faunal material found was also collected separately and the weight recorded. Botanical remains collected from the samples were sorted into charcoal and seeds and counted, weighed, and bagged for further analysis and identification. Because optimal preservation involves keeping wet samples wet for as long as possible, any soil samples that contained some moisture were wet-sieved. Volume was measured using displacement in a 200 ml cylinder and then wet-sieved through the same nested screens. The samples were then set out to dry and sorted via microscope in the same way as the dry-sieved samples (Figure 10).



Figure 10. Image of sorted paleobotanical remains from Carriacou sample (photograph by Megan Clark).

The *in situ* samples consisted of pieces of charcoal and large seed coats. Each sample was given an individual lab number. Charcoal was set aside for later examination and the large seed coats were identified using a comparative collection. Individual samples were then further subdivided into sub-samples based on completeness (Table 5). Categories of sub-samples consisted of complete seeds, portions of seed cases containing a hilum, or scar on the seed coat resulting from attachment of the seed during its formation, portion of seed case not containing a hilum, and interior seeds (Figure 11). NISP and MNI were calculated and the complete seeds were measured for length and diameter. Any remaining residue from the samples was scanned under the microscope for additional microbotanical remains or small pieces that may have been overlooked. Each sub-sample was bagged individually and then placed in a larger bag containing the entire sorted sample.

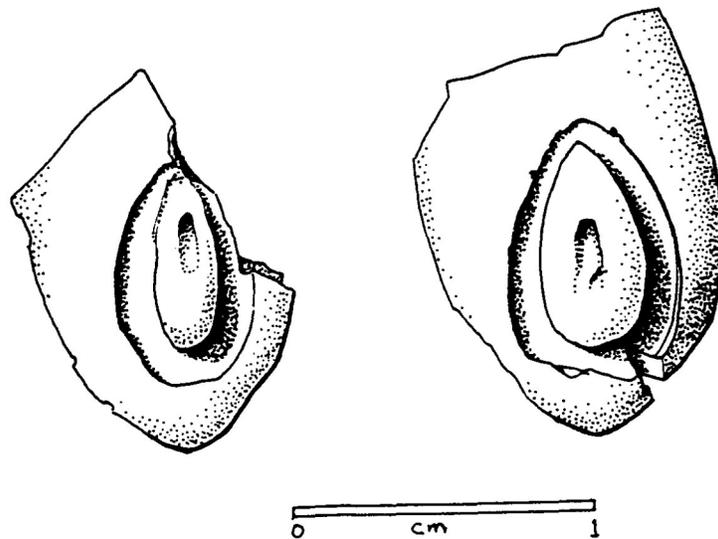


Figure 11. Anatomical structure of Sapotaceae seed coat containing intact hilum (Newsom and Wing 2004).

Table 3. List of paleobotanical samples analyzed.

Sample No.	Find No.	Site	Sample Type	Trench	Planum	Feature #
1	04CGB000025	Grand Bay	SOIL	625	N/A	1
10	05CGB000916SASOIL	Grand Bay	SOIL	N/A	N/A	N/A
11	05CGB000917SASOIL	Grand Bay	SOIL	N/A	N/A	N/A
46	05CGB001059SEC	Grand Bay	CHARCOAL	446	6	L005
54	07CGB001229CHA	Grand Bay	CHARCOAL	446	7	L003
56	05CGB001074CHA	Grand Bay	CHARCOAL	446	6	L003
66	05CGB000690SACH	Grand Bay	CHARCOAL	561	3	L002
68	08CGB001546CHA	Grand Bay	CHARCOAL	562	2	F0163
72	04CGB000310SACH	Grand Bay	CHARCOAL	564	1	F47
78	04CGB000342SACH	Grand Bay	CHARCOAL	594	1	F57

Analysis of botanical remains typically involves identification of samples to the species level using comparative collections and identification guides. Samples are then measured in terms of ubiquity and density, as well as the number of identified species. Ubiquity is the “frequency of a taxon among the total set of proveniences examined and is expressed as a percentage” (Newsom and Wing 2004:44). Density is expressed in terms of the weight or number of plant remains within a sample. The total number of identified species is a measure typically used for wood samples (Newsom and Wing 2004). With these identifications and measurements, the general environment of the Grand Bay and Sabazan sites can be reconstructed and some of the major botanical resources used for subsistence, building and fire materials, and medicinal and ritual use identified. The large amount of charred seedpods found near what appears to have been a hearth suggests that the seeds were

burned for some sort of processing, which could have been related to subsistence (Fitzpatrick et al. 2009).

Stable Isotope Analysis

In stable isotope analysis, prepared samples are converted into a gaseous matter and analyzed with a mass spectrometer. Results are expressed as a ratio of the heavier to lighter isotope being examined. Delta values are determined using formulas that express the isotope ratios relative to the relative standards. Corrections for fractionation, or the discrepancy between isotopic ratios between trophic levels, also need to be calculated and applied (Pestle 2010). Samples from 15 individuals at Grand Bay were analyzed at the University of Florida by Dr. John Krigbaum, Kara Casto (University of South Florida), and Jamie Bankaitis (formerly of NCSU) for stable isotope levels in 2008. A diet high in marine resources, which is consistent with that of an individual living in a coastal environment, would be reflected in a less negative ^{13}C level, as well as a lower nitrogen level. However, coral reefs contain more nitrogen-fixing organisms than other areas of the ocean, which results in different levels than other fish (Siegel 2005). A comparison of isotope levels in human remains will reflect the contributions of marine and terrestrial resources to their diet. By combining these data with the results of paleobotanical and faunal analysis, I can estimate the contributions of different resources to the inhabitants' diets, as well as specific faunal and botanical taxa that make up their isotopic signatures.

V. RESULTS

Linear Enamel Hypoplasia

Of the 15 individuals examined, seven individuals (47%) exhibited evidence of LEH. Evidence of hypoplasias were found on all tooth types, with the most common locations for hypoplastic defects being the maxillary incisors and canines (Tables 6 and 7). The frequency of hypoplastic defects being the maxillary incisors and canines (Tables 6 and 7). The frequency of LEH ranged from one to 14 defects per individual; however, the individual that possesses 14 defects (03CAR000171) was recovered from the Harvey Vale site at Tyrell Bay, which is located on the southwest coast of the island (Figure 12). This individual was included in order to maximize the sample size. When this individual is removed, the frequency ranges from one to six defects.

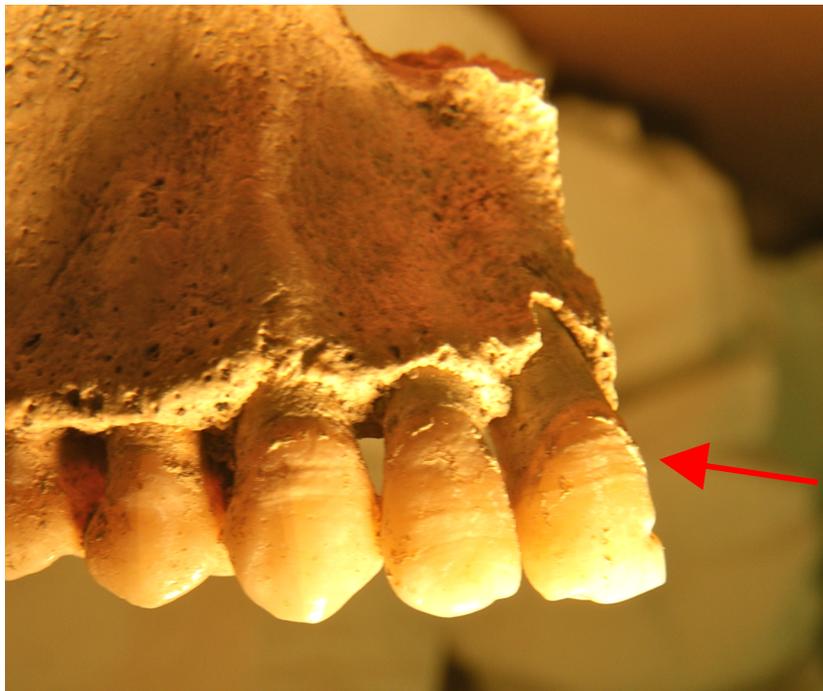


Figure 12. Anterior teeth from right maxilla of 03CAR000171 (Harvey Vale), an individual that possessed 14 enamel defects. The arrow indicates the presence of LEH on the central incisor.

Determination of sex and age were based on observations by Dr. Burnett (as noted in Fitzpatrick et al. 2009) and Reeves (2006). Some of the remains were too fragmentary to determine sex and age. Six individuals were too fragmentary to determine sex. Sex was ascertained for nine individuals and the sample consisted of three males and six females. One of the three males and four of the six females exhibited LEH (Table 8). A Fisher's Exact Test was used to determine if the discrepancies between the sexes was statistically significant. A difference would mean that females and males are experiencing different levels of stress. If that stress is related to diet, it would further suggest that there is a sexual differentiation of resource allocation. No significant differences in the number of hypoplastic events were identified between males and females ($p=0.524$). The post-hoc statistical power associated with this test indicates that there is a 17.35% chance of identifying a statistically significant difference if one was present. When statistical power is low, it is usually a result of small sample sizes.

Table 4. Distribution of LEH by sex.

	No LEH	LEH present	Totals
Males	2	1	3
Females	3	3	6
Unknown	3	3	6
Totals	7	8	15

Table 5. Dental Inventory and LEH frequency by tooth type: Maxillary Dentition (Code: no hypoplasia [0], LEH [1], row of pits [3], tooth absent/unscorable [6]).

	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3	Dec. teeth
03CAR000097	0	6	0	3	6	0	6	6	3(2)	6	0	0	6	0	6	6	
03CAR000171(1)	6	3	0	0	1	1(2)	1	1	1	1	1	0	0	6	1	0	
03CAR000171(2)	6	6	6	6	6	0	6	6	6	6	6	0	0	6	6	6	
04CGB000025	0	6	6	6	6	6	0	6	6	6	0	0	0	6	0	0	
04CGB000113	6	0	0	0	0	6	6	6	1	1	1(2)	0	0	0	0	6	RM1(0), LM1(6), both M2s(0)
04CGB000390	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
05CGB001024	6	6	0	6	0	0	6	0	1	0	1(2)	6	0	0	6	6	
06CGB001145	6	6	6	0	0	0	0	6	0	6	0	6	0	6	6	6	
07CGB001444	6	6	0	0	6	3	3	3	0	0	0	0	0	6	6	6	
07CGB001342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
07CGB001307	6	6	6	0	6	0	0	0	0	0	0	6	6	0	0	6	
07CGB001375	6	6	6	6	6	6	6	6	6	6	6	6	0	0	0	0	
07CGB001419	6	0	6	6	6	6	6	6	0	0	6	6	6	6	6	6	
08CGB001616	6	0	0	6	6	6	6	6	6	6	6	6	6	0	0	6	
08CGB001660	0	6	6	0	0	0	0	0	0	0	6	0	0	6	0	0	
LEH Frequency	1	1	0	1	1	2	2	2	4	2	3	0	0	0	1	0	20

Table 6. Dental Inventory and LEH frequency by tooth type: Mandibular Dentition (Code: no hypoplasia [0], LEH [1], row of pits [3], tooth absent/unscorable [6]).

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3	Deciduous Teeth
03CAR000097	6	6	6	6	1	6	0	0	0	0	6	0	0	6	0	6	
03CAR000171(1)	1	6	6	0	0	1	0	0	0	0	6	1	0	1	0	0	
07CGB000171(2)	0	6	0	0	6	6	6	6	6	6	6	6	6	6	6	6	
04CGB000025	0	6	0	6	6	6	6	6	0	6	0	0	0	0	0	0	
04CGB000113	6	0	0	0	0	0	6	0	0	0	1(2)	0	0	0	0	6	RC(0), LC(6), RM1(0), LM1(6), M2s(0)
04CGB000390	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
05CGB001024	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
06CGB001145	6	6	0	0	0	6	0	0	0	0	0	6	0	6	0	6	
07CGB001444	6	0	6	0	0	0	0	0	0	0	0	0	0	0	1	6	
07CGB001342	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
07CGB001307	6	6	6	0	0	0	0	0	0	0	0	0	0	6	6	6	
07CGB001375	6	6	6	6	6	6	6	6	0	0	0	0	6	0	0	0	
07CGB001419	6	1	6	0	6	6	6	6	6	6	6	6	6	6	6	6	
08CGB001616	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	
08CGB001660	6	6	6	0	0	0	0	0	0	0	0	0	0	6	6	6	
LEH Frequency	1	1	0	0	1	1	1	0	0	0	1	1	0	1	2	0	10

Because the majority of the sample was not aged to specific intervals, examination of LEH in relation to age was limited to discrepancies between juveniles and adults (Table 9). Adults were defined as being older than 18-20 years of age, when adolescence ends and the third molars have erupted. Again, due to the fragmentary nature of some of the remains, age could only be determined for 11 of the 15 total individuals. The juvenile sample consisted of two individuals—a six year old that exhibited LEH and a 14-15 year old that had no evidence of LEH. The adult sample consisted of nine individuals, four of which exhibited LEH. A Fisher’s Exact Test was also used to determine statistical significance for discrepancies based on age. Fisher’s Exact revealed no statistically significant differences between juveniles and adults ($p=1$). Statistical power was once again low, and states that the chance of identifying a statistically significant difference when there is one present is 5.92%. Again, this is due to a small sample size used for analysis.

Table 7. Distribution of LEH by age.

	No LEH	LEH present	Totals
Juveniles	1	1	2
Adults	5	4	9
Unknown	3	1	4
Totals	7	8	15

Most of the LEH events occurred between two and a half and four years of age (Figure 13), with all events occurring between the ages of 1.5 and 10 years of age. In individuals who exhibit multiple defects, it appears likely that some of them were the product of a single

stressful event. This is the case in many of the individuals who were stressed around the 2.5-4 year old age mark (individuals 07CGB001444, 03CAR000171, and 04CGB000113, for example). Because this is the age at which most individuals are experiencing stress, regardless of age at death or sex, it appears that some sort of event, likely weaning, is the cause of most LEH events. There is some additional evidence of LEH in various individuals at other ages, including two individuals who experienced stress between the ages of nine and 10 (03CAR000171 and 04CGB000390), as well as four individuals who experienced stress around four and a half to five years of age (Table 10). 03CAR000171 is an anomalous case due to the overall high numbers of LEH and the fact that this individual is from a different site. Due to the small sample size, it is not possible to infer any larger patterns that would cause hypoplastic events later in childhood. Therefore, LEH events at these other ages could possibly be the result of individual stressful events, such as disease or trauma that resulted in nutritional deficiency.

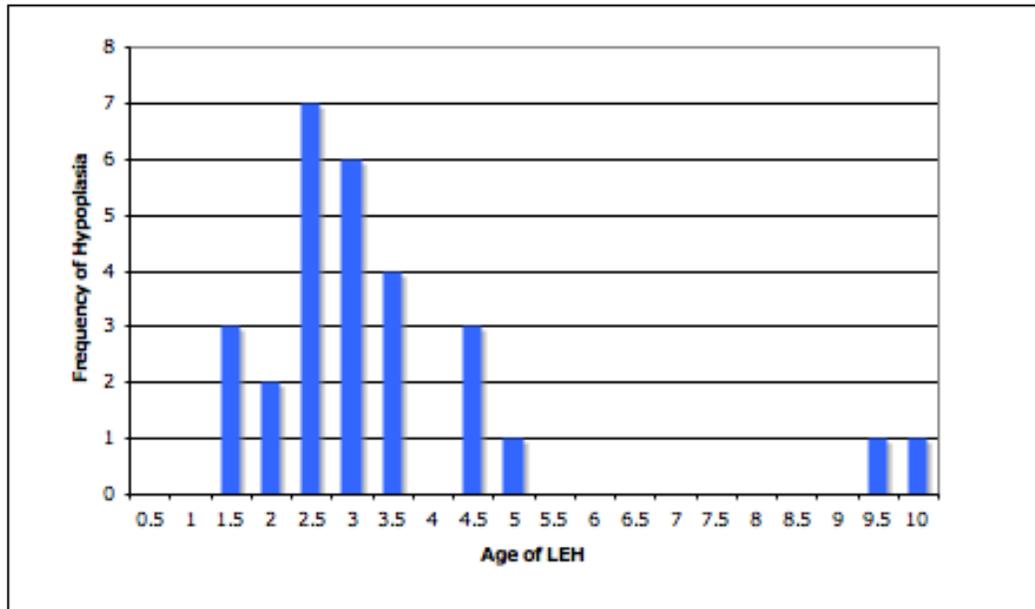


Figure 13. Frequency of LEH distributed by age.

Table 8. Summary of LEH by Individual.

Individual	Age	Sex	# of Defects	Mean Age of Defects	Age at 1st Defect	Age at Last Defect
03CAR000097	Adult	Unknown	4	3.6	3.5	3.7
03CAR000171(1)	Unknown	Unknown	14	3.4	1.5	9.8
03CAR000171(2)	Unknown	Unknown	0	N/A	N/A	N/A
04CGB000025	Adult	Female	0	N/A	N/A	N/A
04CGB000113	~6 years	Unknown	6	3.2	2.4	3.8
04CGB000390	20-25	Female	2	7.5	4.95	10.1
05CGB001024	25-35	Male	3	2.4	1.8	2.9
06CGB001145	Adult	Female	0	N/A	N/A	N/A
07CGB001444	Adult	Female	4	3.7	3.2	4.9
07CGB001342	Adult	Male	0	N/A	N/A	N/A
07CGB001307	Mid Adult	Female	0	N/A	N/A	N/A
07CGB001375	14-15	Male	0	N/A	N/A	N/A
07CGB001419	Adult?	Female?	1	5.2	5	5.4
08CGB001616			0	N/A	N/A	N/A
08CGB001660			0	N/A	N/A	N/A

Paleobotany

To date, approximately 10 of the soil samples selected for paleobotanical analysis from Grand Bay have been through the preliminary stages of sorting, including samples collected from close association with a burial, and some of the augered core samples collected in 2005 (Table 5). The samples selected for analysis were chosen based on the obvious presence of large quantities of macrobotanical remains and those that would provide the most direct evidence for paleodiet (i.e., those recovered from close associations with burials) because of the short-term time constraints placed on the project. Currently, the samples have been returned to the Archaeology Lab at NCSU where the initial sorting is being continued on the remaining samples in order to make later analysis more efficient.

Based on visual assessment and the macrobotanical comparative collection housed at the Environmental Archaeology Lab at Pennsylvania State University and maintained by Dr. Lee Newsom, a single large seed taxon has been identified as belonging to the Sapotaceae (sapodilla) family (Figure 8). Three complete seeds were recovered—because of the fragility and rarity of complete samples such as this; preliminary measurements were taken with caution to determine general seed size for the Sapotaceae samples found (Table 11). Fragmentary Sapotaceae remains that had been classified into sub-samples during initial sorting were counted as well. As mentioned earlier, all seeds contain a hilum, or scar that is present on the exterior of the seed coat from its attachment during development. Because each seed only has one hilum, this element was used as an indicator for calculating MNI. Total counts for the Sapotaceae samples recovered are listed in Table 12. Unfortunately due to time constraints and logistical issues that prevented a more complete analysis within the

time frame supported by this project, presently little can be said about potential plant resources exploited by the inhabitants of Grand Bay. Continued analysis of the samples will occur in the future and will eventually contribute additional information related to paleodiet on Carriacou. However, the current results can be synthesized with other lines of existing evidence in order to provide some picture of subsistence.

Table 9. Measurements of Complete Sapotaceae seeds.

Seed	Length (mm)	Diameter (mm)	hilum length (mm)
1	1.426	11.95	7.64
2	14.28	11.64	
3	14.1	12.33	

Table 10. Inventory and MNI for Recovered Sapotaceae.

Sample No.	Find No.	Whole Seeds	Case frag. w/ hilum	case w/out hilum	interior seed frag	interior seed	total MNI
46	05CGB001059SEC			1			1
54	07CGB001229CHA	11	12	67	12	3	25
56	05CGB001074CHA	4	13	203	52		17
66	05CGB000690SACH	3	22	235	86	4	26
68	08CGB001546CHA	2	14	164	34		16
78	04CGB000342SACH		6	100	62		6
							91

Additionally, fragments of charcoal, wood, and seeds that were recovered during the sieving process were classified into sub-samples based on screen size. From these sub-samples, one distinct taxon containing wood and charcoal remains as well as a distinct taxon

of seed were recovered and identified as Taxon 1 and Taxon 2, respectively. Though the taxa are recognizable and grouped as distinct, specific taxonomic identifications have yet to be determined. Basic counts of each taxa, as well as unidentified fragments that have been recovered, are listed by screen size in Tables 13, 14, and 15. The majority of recovered botanical remains are from the 2 mm screen, which is not surprising considering these samples are larger and easily apparent with a quick visual assessment. The smallest number of recovered remains comes from the 0.5 mm screen, which involved examination under a microscope twice to ensure that any smaller remains were recovered. Currently, additional samples are being sorted into sub-samples classified by sieve size. No identifiable botanical remains have been recovered to date, though there are still a number of samples left to analyze.

Table 11. Inventory of Recovered Botanical Remains from 2mm Sieve.

Sample No.	Find No.	Taxon	Count
10	05CGB000916SASOIL	Taxon 1 Wood	2
10	05CGB000916SASOIL	Taxon 1 Charcoal	3
46	05CGB001059SEC	Taxon 1 Wood	2
46	05CGB001059SEC	Taxon 1 Charcoal	1
46	05CGB001059SEC	Taxon 2 Seed	1
56	05CGB001074CHA	unid. Plant	4
72	04CGB000310SACH	unid. Charcoal	120
78	04CGB000342SACH	unid. Charcoal	79
	Totals (2mm sieve)		212

Table 12. Inventory of Recovered Botanical Remains from 1mm Sieve.

Sample No.	Find No.	Taxon	Count
10	05CGB000916SASOIL	Taxon 1 Charcoal	20
10	05CGB000916SASOIL		3
56	05CGB001074CHA	unid plant	8
72	04CGB000310SACH	unid. Charcoal	60
	Totals (1mm sieve)		71

Table 13. Inventory of Recovered Botanical Remains from 0.5mm Sieve.

Sample No.	Find No.	Taxon	Count
10	05CGB000916SASOIL	Taxon 1 Charcoal	1
54	07CGB001229CHA		
68	08CGB001546CHA		
78	04CGB000342SACH	taxon 2 seed	2
	Totals (0.5 mm sieve)		3

Faunal Analysis

Vertebrates

The inhabitants on Carriacou exploited a wide variety of both vertebrate and invertebrate fauna from both marine and terrestrial contexts. Subsistence patterns at Grand Bay and Sabazan are similar to general exploitation patterns in the Caribbean, though Grand Bay appears to have some atypical patterns. Reflecting Grand Bay's proximity to extensive coral reef, shallow water, and pelagic environments, the majority of the vertebrate species exploited were marine (Fitzpatrick et al. 2009, Lefebvre 2007). Terrestrial finds include several introduced mammals, suggesting Carriacou may have played an important role in terms of the translocation of taxa from the mainland to the islands. Due to excellent preservation of faunal bone, the majority of the total analyzed assemblage weight was

identifiable to at least the taxonomic class (Table 16). The assemblage's overall taxonomic diversity and equitability were high (1.278 and 0.821, respectively), which reflects not only a large number of different represented taxa, but also an even abundance of individual taxa within the sample.

The majority of the marine vertebrate assemblage was comprised of bony fish (Osteichthyes), primarily comprised of herrings (Clupeidae), jackfish (Carangidae), grunts (Haemulidae), parrotfish (Scaridae) and surgeonfish (Acanthuridae) based on MNI. The average width of precaudal fish vertebrae was 3.1 ± 1.7 mm, with a range of 1.7-15.7 mm. Based on these measurements, estimated average weight of fish from Grand Bay was 224.7 ± 925.7 g, with a range of 48.7-7838.4 g. The large standard deviation for the weight is skewed due to a few large groupers included in the sample. When these outliers were removed, the mean weight was 133.0 ± 446.6 g (Fitzpatrick et al. 2009, Lefebvre 2007).

Non-fish marine vertebrates identified at Grand Bay include shark (Chondrichthyes) and sea turtle (Cheloniidae). Sea turtle are the second most abundant marine vertebrate at the family level and constitute 2% of the MNI and 20% of the total weight despite being representative of one individual. The sheer abundance of sea turtle in the faunal assemblages at Grand Bay is atypical—at least four have been recovered from upper layers of midden deposits. The presence of sea turtle at Caribbean archaeological sites is rare, which implies that Grand Bay is somewhat anomalous given the relative abundance of turtle in the assemblage (Keegan et al. 2008). The majority of the specimen was identified by plastron and carapace fragments. Taphonomic indicators, including cut marks from processing, as well as the presence of a variety of skeletal elements, suggest that sea turtles were being

butchered and processed at Grand Bay. It is possible that turtles were taken while nesting on beaches or feeding in shallower nearshore water (Fitzpatrick et al. 2009). A shark was represented by two teeth recovered from ¼ in. screen samples; however, they are not identifiable to a lower taxonomic category due to the high diversity of shark species in the area and the lack of diagnostic features on the teeth (Lefebvre 2007).

Table 14. Identified Vertebrate Taxa from Grand Bay (Fitzpatrick et al. 2009).

Taxon		Common Name	Habitat	NISP	% Total NISP	MNI	% Total MNI	Weight (grams)	% Total Weight
Total Identified Chondrichthyes				2	0.15	1	0.91	0.2	0.06
	Clupeidae	Herrings	CR/OFS/PW	331	24.25	7	6.36	0.9	0.32
	Muraenidae	Eels	CR	1	0.07	1	0.91	0.0	0.00
	Exocoetidae	Flying fish family	OFS/PW	28	2.05	1	0.91	0.2	0.07
	Belonidae	Needlefish family	CR	2	0.15	1	0.91	0.0	0.01
	<i>Holocentrus rufus</i>	Squirrel fish	CR	1	0.07	1	0.91	0.0	0.00
	<i>Holocentrus</i> sp.	Squirrel fish	CR	4	0.29	--	--	0.1	0.05
	Serranidae	Grouper and Seabass family	CR	6	0.44	--	--	2.0	0.69
	<i>Epinephelus</i> sp.	Grouper	CR	3	0.22	2	1.82	0.7	0.24
	<i>Mycteroperca</i> sp.	Grouper	CR	1	0.07	1	0.91	2.6	0.92
	Carangidae	Jack fish family	CR/ISW	40	2.93	--	--	1.0	0.34
	<i>Selar crumenophthalmus</i>	Bigeye scad	CR	34	2.49	26	23.64	0.5	0.16
	<i>Caranx</i> sp.	Jack fish	CR	1	0.07	1	0.91	0.6	0.22
	<i>Trachinotus</i> sp.	Pompano	CR	1	0.07	1	0.91	0.1	0.02
	Lutjanidae	Snapper family	CR	2	0.15	--	--	0.1	0.03

Table 14, continued.

Taxon		Common Name	Habitat	NISP	% Total NISP	MNI	% Total MNI	Weight (grams)	% Total Weight
	<i>Lutjanus apodus</i>	Schoolmaster	CR	1	0.07	1	0.91	0.0	0.01
	<i>Lutjanus</i> sp.	Snapper	CR	8	0.59	3	2.73	0.1	0.05
	Cf. <i>Ocyurus chrysurus</i>	Compares to Yellowtail snapper	CR	1	0.07	1	0.91	0.0	0.0
	Haemulidae	Grunt Family	CR	24	1.76	--	--	3.5	1.21
	<i>Haemulon aurolineatum</i>	Tomtate	CR	1	0.07	1	0.91	0.0	0.00
Mammalia	<i>Didelphis</i> sp.	Opposum	TR	11	0.81	2	1.82	3.4	1.19
	Rodentia	Rodent	TR	15	1.10	--	--	0.7	0.25
	<i>Oryzomys</i> sp.	Rice rat	TR	21	1.54	4	3.64	0.9	0.31
	Agoutidae	Agouti family	TR	4	0.29	--	--	1.6	0.55
	<i>Dasyprocta</i> sp.	Agouti	TR	10	0.73	1	0.91	4.8	1.66
	cf. <i>Dasyprocta</i> sp.	compares to Agouti	TR	1	0.07	--	--	0.4	0.14
	Total Identified Mammalia			62	4.54	7	6.36	11.8	4.10
Unid. Mammalia				50	--	--	--	24.6	--
Aves									
	Columbidae	Pigeon family	TR	1	0.07	1	0.91	0.2	Pigeon family
	Total Identified Aves			1	0.07	1	0.91	0.2	
Unidentified Aves				12	--	--	--	2.1	--
Reptilia	Cheloniidae	Sea Turtle	ISW	89	6.52	1	0.91	186.3	64.63
	Iguanidae	Iguana	TR	2	0.15	1	0.91	13.4	4.64
	Sauria	Lizard	TR	26	1.90	--	--	2.4	0.85
	Serpentes	Snake	TR	5	0.37	1	0.91	0.1	0.03
	Total Identified Reptilia			122	8.94	3	2.73	202.2	70.14
Amphibia	Anura	Frog/toad	TR/AQ	2	0.15	1	0.91	0.0	0.00
	Total Identified Amphibia			2	0.15	1	0.91	0.0	0.00
Chondrichthyes	Chondrichthyes	Shark	ISW/OF S/PW	2	0.15	1	0.91	0.2	0.06

Table 14, continued.

Taxon	Common Name	Habitat	NISP	% Total NISP	MNI	% Total MNI	Weight (grams)	% Total Weight
<i>Haemulon chrysargyeum</i>	Smallmouth grunt	CR	3	0.22	3	2.73	0.1	0.05
<i>Haemulon sciurus</i>	Bluestriped grunt	CR	3	0.22	3	2.73	0.0	0.01
<i>Haemulon</i> sp.	Grunt	CR	19	1.39	10	9.09	0.4	0.13
Sparidae	Porgie family	CR	2	0.15	--	--	0.2	0.06
<i>Calamus</i> sp.	Porgy	CR	1	0.07	1	0.91	0.0	0.01
Sciaenidae	Drum family	CR	1	0.07	1	0.91	0.1	0.03
<i>Halichoeres</i> sp.	Wrass	CR	2	0.15	2	1.82	0.1	0.02
Scaridae	Parrotfish family	CR	160	11.72	--	--	8.1	2.8
<i>Sparisoma</i> sp.	Parrotfish	CR	43	3.15	6	7.27	5.2	1.8
Acanthuridae	Surgeon fish family	CR	208	15.24	--	5.45	10.3	3.59
<i>Acanthurus</i> sp.	Surgeon fish	CR	28	2.05	11	--	13.4	4.66
Scombridae	Tuna and mackrel family	OFS/PW	38	2.78	--	10.00	1.3	0.46
<i>Scomberomorus</i> sp.	Tuna	OFS/PW	1	0.07	1	--	19.2	6.65
Balistidae	Triggerfish family	CR	133	9.74	--	0.91	0.9	0.31
<i>Balistes</i> sp.	Triggerfish	CR	3	0.22	2	1.82	1.5	0.53
<i>Balistes</i> sp.	Triggerfish	CR	3	0.22	2	--	0.7	0.23
<i>Lactophrys</i> sp.	Boxfish	CR	4	0.29	1	0.91	0.1	0.02
Total Identified Osteichthyes	1176	86.15	97	88.18	74	25.65	74.0	25.65
Unidentified Osteichthyes	3354	--	--	--	23 9.9	--	239.9	--
Total Identified Vertebrate	1365	--	110	--	28 8.3	--	288.3	--

Terrestrial fauna includes bird, amphibians, reptiles and mammals. Bird, amphibian, and reptile elements were minimal and appear to have represented one pigeon (Columbidae), toads and/or frogs (Anura), lizards (Sauria), iguanas (Iguanidae), and snakes (Serpentes). Together, these taxa comprised approximately 1% of the NISP (Fitzpatrick et al. 2009, Lefebvre 2007). Five translocated mammalian taxa have been identified at Grand Bay—

guinea pig (*Cavia porcellus*), armadillo (*Dasyopus* sp.), peccary (*Tayassu/Peccari* sp.), opossum (*Didelphis* sp.), and agouti (*Dasyprocta* sp.). Though the majorities of the mammalian remains are fragmentary and contribute little to the overall NISP and MNI (2% and 7%, respectively), their identification is particularly significant due to the high diversity of mammalian taxa, something that has yet to be found on other islands in the Lesser Antilles (Lefebvre 2007, Giovas et al. in review).

Estimates of habitat biomass show that vertebrate exploitation on Carriacou is primarily centered on marine resources which is a common occurrence in the West Indies, particularly during the Ceramic Age. Based on US Department of Commerce National Oceanic and Atmospheric Administration (NOAA) parameters that were used to characterize marine habitats near Puerto Rico, as well as taxa specific information, habitat designations for the faunal assemblages at Grand Bay were determined. These were based on the primary habitat a species occupies during adult life, such as beach shoreline, rocky shoreline, coral reefs, seagrass beds, and others (Lefebvre 2007). Coral reef fishes and inshore water animals contribute to 36 and 35% of the overall biomass; however, 97% of the total inshore water biomass consisted of a single turtle, thus skewing the results. Offshore and pelagic marine animals contributed 12% of the biomass which is dominated by tuna or mackerel (Scombridae) and flying fish (Exocoetidae). Terrestrial animals make up 17%, the majority of which is likely tied to human exploitation and agricultural activities (Keegan et al. 2008, Lefebvre 2007).

Most of the vertebrate assemblages are similar between the Grand Bay and Sabazan sites. Like Grand Bay, the Sabazan faunal assemblage consists primarily of marine resources,

particularly fish. Major contributors from the ¼ in. screen sample are parrotfish (Scaridae), surgeonfish (Acanthuridae), groupers and bass (Serranidae), grunts (Haemulidae), and tuna (Scombridae). Tuna is represented in much larger quantities at Sabazan than at Grand Bay. In the 1/16 in. screen samples, small reef fishes are the primary contributors, including jacks (Carangidae), as well as many of the species common in the ¼ in. sample. Damselfish (Pomacentridae) are also fairly common at Sabazan, but rare at Grand Bay. Terrestrial resources at Sabazan are similar to Grand Bay and contribute a relatively small amount to the overall assemblage (Giovas, personal communication).

Invertebrates

The invertebrate assemblages at both Grand Bay and Sabazan are also dominated by numerous marine taxa, with an emphasis on species that are easily harvested (Table 17). The overwhelming majority of the specimens are marine mollusks (over 96% of the total MNI), most of which are Queen conch (*Strombus gigas*), nerites (*Nerita sp.*, mostly *Nerita tessellata*), West Indian top snail (*Cittarium pica*), and chiton (particularly *Chiton tuberculatus*). These species are typically found in rocky intertidal habitats along beachrock outcrops, where they can be easily collected (Giovas, personal communication, Fitzpatrick et al. 2009, Keegan et al. 2008).

Table 15. Identified Marine Invertebrates from Grand Bay (Fitzpatrick et al. 2009).

Taxon		Common Name	NISP	% Total NISP	MNI	%Total MNI	Weight (grams)	% Total Weight
Bivalvia								
	<i>Brachidontes exustus</i>	Scorched mussel	3	0.35	2	0.61	4.0	0.16
	Lucinidae	Lucine family	4	0.47	2	0.61	1.7	0.07
	<i>Codakia orbicularis</i>	Tiger lucine	2	0.23	2	0.61	15.1	0.61
	<i>Chione cancellata</i>	Cross-barred venus	1	0.12	1	0.30	0.3	0.01
	Tellinidae	Tellin family	1	0.12	---	---	0.4	0.02
	<i>Tellina</i> sp.	Tellin	1	0.12	1	0.30	10.6	0.43
	Psammobiidae	Sand clam family	1	0.12	---	---	1.0	0.04
	<i>Asaphis deflorata</i>	Gaudy asaphis	3	0.35	2	0.61	10.9	0.44
	Total Identified Bivalve			16	1.87	10	3.04	44.0
Total Identified Bivalve			16	1.87	10	3.04	44.0	1.78
Unidentified Bivalve			6				3.4	
Gastropoda - Marine								
	<i>Fissurella barbadosis</i>	Barbados keyhole limpet	2	0.23	2	0.61	4.1	0.17
	<i>Cittarium pica</i>	West Indian top snail	106	12.41	40	12.16	1839.2	74.57
	<i>Tegula excavata</i>	Green-base teguala	11	1.29	3	0.91	3.6	0.15
	<i>Lithopoma caelatum</i>	Carved star snail	3	0.35	3	0.91	16.6	0.67
	<i>Lithopoma tuberosum</i>	Green star snail	6	0.70	2	0.61	11.3	0.46
	Neritidae	Nerite family	1	0.12	---	---	0.2	0.01

Table 15, continued.

Taxon		Common Name	NISP	% Total NISP	MNI	%Total MNI	Weight (grams)	% Total Weight
	<i>Nerita peloronta</i>	Bleeding tooth nerite	2	0.23	2	0.61	4.7	0.19
	<i>Nerita versicolor</i>	Four-toothed nerite	26	0.03	20	6.08	44.2	1.79
	<i>Nerita tessellata</i>	Tessellate d nerite	139	16.28	118	35.87	96.3	3.90
	<i>Nerita sp.</i>	Nerite	12	1.41	---	---	5.7	0.23
	<i>Tectarius muricatus</i>	Beaded periwinkle	7	0.82	7	2.13	7.6	0.31
	<i>Supplanaxis nucleus</i>	Black Atlantic planaxis	4	0.47	4	1.22	1.6	0.06
	<i>Crepidula maculosa</i>	Spotted slippersnai l	13	1.52	13	3.95	5.3	0.22
	<i>Natica sp.</i>	Natica/Moonsnail	1	0.12	1	0.30	3.0	0.12
	<i>Cypraea sp.</i>	Cowry	1	0.12	1	0.30	4.6	0.19
	<i>Cymatium nicobaricum</i>	Gold-mouth triton	1	0.12	1	0.30	1.3	0.05
	<i>Plicopurpura patula</i>	Wide-mouthed purpura	1	0.12	1	0.30	1.0	0.04
	<i>Stramonita rustica or haemastoma</i>	Rock snail	5	0.59	5	1.52	15.0	0.61
	<i>Nassarius polygonatus</i>	Black-spot nassa	1	0.12	1	0.30	0.3	0.01
	<i>Engoniophos uncinatus</i>	Guadeloupe phos	1	0.12	1	0.30	0.6	0.02
	Olividae	Olive family	1	0.12	---	---	1.0	0.04
	<i>Oliva sp.</i>	Olive	1	0.12	1	0.30	1.4	0.06
	<i>Bulla striatus</i>	Common Atlantic bubble	2	0.23	2	0.61	2.6	0.11
Total Identified Marine Gastropod			347	40.63	228	69.30	2071.2	83.98
Unidentified Marine Gastropod			88				41.1	
Gastropoda - Terrestrial (Land Snails)	Bulimulidae	Bulimulid family	2	0.23	---	---	0.3	0.01

Table 15, continued.

Taxon		Common Name	NISP	% Total NISP	MNI	%Total MNI	Weight (grams)	% Total Weight
	<i>Orthalicus undatus</i>	Wavy orthalicus	11	1.29	6	1.82	7.4	0.30
	<i>Megalobulimus</i> sp.	<i>Megalobulimus</i> land snail	3	0.35	1	0.30	2.0	0.08
	Camaenidae	Camaenid family	5	0.59	---	---	0.9	0.04
	<i>Pleurodonte</i> aff. <i>perplexa</i>	<i>Pleurodonte</i> land snail	3	0.35	3	0.91	1.6	0.06
Total Id. Terrestrial Gastropod			24	2.81	10	3.04	12.1	0.49
Unidentified Terrestrial Gastropod			2				0.0	
Polyplacophora (Chitons)	Chitonidae	True chiton family	1	0.12	---	---	0.6	0.02
	<i>Chiton marmoratus</i>	Marbled chiton	38	4.45	10	3.04	34.4	1.39
	<i>Chiton tuberculatus</i>	West Indian chiton	337	39.46	56	17.02	211.2	8.56
	<i>Chiton viridis</i>	Green chiton	1	0.12	1	0.30	0.1	0.00
	<i>Chiton</i> sp.	Chiton	3	0.35	---	---	0.7	0.03
	<i>Acanthopluera granulata</i>	Fuzzy chiton	47	5.50	11	3.34	84.4	3.42
Total Identified			426	49.88	78	23.71	330.7	13.41
Unidentified Polyplacophora					2	1.5		
Total Identified Mollusc			813	95.20	326	99.09	2458	99.66
Unidentified Mollusc			10				1.8	
Echinoidea		Sea urchin	34	3.98			4.8	0.19
Malacostraca (Order: Decapoda)	<i>Portunidae</i> sp.	Swimming crab	1	0.12	1	0.30	0.1	0.01
	<i>Cardisomana guanhumi</i>	Blue land crab	1	0.12	1	0.30	1.8	0.07
	<i>Gecarcinus</i> sp.	Gecarcinid land crab	4	0.47	1	0.30	1.2	0.05

Table 15, continued.

Taxon		Common Name	NISP	% Total NISP	MNI	% Total MNI	Weight (grams)	% Total Weight
Total Identified Decapod			6	0.70	3	0.91	3.1	0.13
Unidentified Decapod			10				4.4	
Total Identified Invertebrate			853		329		2465.87	
Unidentified Invertebrate			2				0.2	

Conch represents the vast majority of the overall assemblage, but due to the specimens' large size (Table 18), this taxon was quantified in the field using the shell apex as an MNI count and not transported or curated away from the Grand Bay site (Fitzpatrick et al. 2009). Numerous chiton specimens that have been recovered are also burned, suggesting they were cooked over an open fire. Bivalves contribute fairly little to the assemblage (3% of the MNI) and include tiger lucine (*Codakia orbicularis*) and gaudy asaphis (*Asaphis deflorata*).

Other invertebrates include land crab (Gecarcinidae sp.) and terrestrial snails. Land crab contributes very little to the overall assemblage (< 1% of MNI), which is consistent with a regional trend for Ceramic Age sites in which land crabs are more commonly exploited in earlier deposits but are gradually replaced by marine mollusks later in time (Fitzpatrick et al. 2009, Newsom and Wing 2004). Terrestrial snails contribute about 3% of the total MNI, though it is unclear whether they are representative of accidental incorporation or not (Fitzpatrick et al. 2009).

Table 16. MNI of Conch (*Strombus* sp.) at Grand Bay distributed by provenience.

		MNI
Trench 415	Planum 1	5
	Planum 2	31
	Planum 3	150
	Planum 4	434
	Planum 5	189
	Planum 6	171
	Planum 7	21
	Total	1001
Trench 446	Planum 1	21
	Planum 2	210
	Planum 3	480
	Planum 4	182
	Planum 5	96
	Planum 6	91
	Planum 7	33
	Planum 8	52
	Planum 9	44
	Total	1209
Trench 561	Planum 1	18
	Planum 2	14
	Planum 3	2
	Planum 4	--
	Planum 5	7
	Total	41
Trench 563	Planum 1	12
	Total	12
Trench 592	Planum 1	26
	Planum 2	13
	Total	39

Stable Isotope Analysis

The 15 samples analyzed for carbon and nitrogen came from a variety of different proveniences and represent both males and females ranging in age from about 10-14 years old to adulthood. The ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ are listed for each individual sample in Table 18 and plotted in terms of both isotopic signatures in Figure 14. The bone collagen data for $\delta^{13}\text{C}$ is mostly clustered from -11.7 to -13.8‰, suggesting that plant food contributions were

mostly derived from taxa using C₄ photosynthetic pathways, such as amaranth, trianthema, or maize. C₄ plants typically possess δ¹³C signatures that range from -9 to -21‰, thus placing the Grand Bay samples well within this range.

The δ¹⁵N values for the Grand Bay samples cluster around 10.4 to 12‰, which suggests that the primary forms of protein came from marine resources, such as fish and mollusks. Marine protein resources typically show higher δ¹⁵N values upwards of 15-20‰ whereas terrestrial resources typically show a much lower δ¹⁵N signature that is usually around 6-10‰ (deFrance et al. 2008, Pestle 2010, Stokes 2005). Due to the site's proximity to the coast and the fact that the δ¹⁵N values are higher than those typically expected for terrestrial protein consumers, it is likely that these ratios reflect some combination of diet that includes a significant portion of marine protein sources. The majority of the samples share a very similar isotopic signature, implying that there were no major changes in diet among individuals regardless of age or sex. However, individual 07CGB001230, who was a 10-14 year old, showed a much more negative δ¹³C level than any of the others (-15.2), which implies either higher consumption of C₃ plants or terrestrial herbivores with a C₃ diet.

Table 17. List of Stable Isotope Samples and Carbon and Nitrogen Isotopic Ratios.

Sample ID	Site	Weight [%] Nitrogen	Weight [%] Carbon	d13C (permil, vs VPDB)	d15N (permil, vs AIR)	C:N ratio	Find Number	Age	Sex
C-9-1554	Grand Bay	12.64	35.86	-13.4	11.8	3.3	04CGB000025	Adult	F
C-9-1557	Grand Bay	14.60	41.07	-11.7	10.4	3.3	04CGB0000390	20-25	F
C-9-1560	Grand Bay	12.00	34.49	-12.5	11.4	3.4	06CGB001145	Adult	F
C-9-1562	Grand Bay	12.14	35.28	-13.2	11.0	3.4	07CGB001307	mid-Adult	F
C-9-1565	Grand Bay	13.72	38.40	-12.0	10.4	3.3	07CGB001444	Adult	F
C-9-1564	Grand Bay	12.30	35.27	-12.4	11.3	3.3	07CGB001419	Adult?	F?
C-9-1556	Grand Bay	14.83	41.69	-12.9	11.7	3.3	04CGB0000388	Adult	M
C-9-1558	Grand Bay	14.18	38.81	-11.8	10.6	3.2	05CGB001024	25-35	M
C-9-1559	Grand Bay	13.22	37.49	-12.7	11.6	3.3	06CGB001121	Adult	M
C-9-1563	Grand Bay	9.14	27.06	-12.9	10.8	3.5	07CGB001375	14-15 yrs	M
C-9-1555	Grand Bay	13.32	37.69	-13.8	11.6	3.3	04CGB0000022	10-14 yrs	M?
C-9-1566	Grand Bay	13.13	37.26	-12.4	11.1	3.3	08CGB001660	Adult	M?
C-9-1567	Grand Bay	10.99	32.06	-11.9	10.8	3.4	08CGB001616	Adult	M?
C-9-1553	Grand Bay	15.18	41.62	-13.3	12.0	3.2	03CAR0000095	Adult	unassigned
C-9-1561	Grand Bay	14.34	39.73	-15.2	10.8	3.2	07CGB001230	10-14 yrs	unassigned

VI. DISCUSSION

The above results reflect a preliminary examination of paleodiet at Grand Bay. The data shows that both marine and terrestrial resources were exploited, which supports my hypothesis that diet at Grand Bay was varied with resource contributions from multiple ecosystems. However, the stable isotope analysis reflects some unexpected results, namely the consumption of C₄ plants despite the archaeological evidence for C₃ plants in the form of manioc. Patterns in LEH frequency appear to be related to specific age-related instances of stress, with the exception of a few isolated instances. These will be discussed more in depth, as well as an overall examination of paleodiet.

Linear Enamel Hypoplasia

Many previous studies report a higher prevalence of LEH on the anterior teeth, and as a result, much research focuses only on the incidence of LEH on the incisors or canines. Goodman and Armelagos (1985) argue that variation in the location of LEH events in the dentition is due to the increased susceptibility of these teeth to enamel disruption due to their potential position as polar teeth within developmental fields. Though this could be likely, the age at which such hypoplastic events occur in relation to their location on the dentition also needs to be considered. Based on the aging method proposed by Reid and Dean (2000) that was used in this study, the formation of LEH on any decile of the incisors or canines would occur between one and six years of age. A common explanation for physiological stress in children lies in the dietary shift associated with weaning. In most societies the age at which weaning occurs is between two and four years of age, which corresponds with the time at which the anterior teeth are in the midst of enamel deposition. As a result, higher prevalence

of LEH could be due to enamel formation timing associated with nutritional shifts or compromised immune systems associated with weaning, which is commonly cited as a reason for enamel disruption (Larsen 1997).

In the case of the Carriacou sample, which consists of 13 individuals from Grand Bay and two individuals from Harvey Vale, this seems to be a valid explanation for the slightly higher prevalence of LEH in the anterior teeth. The majority of the LEH events identified occurred between the ages of 2.5 and 4 years of age, which is the time most societies wean children. Weaning typically represents a shift to a less nourishing diet, loss of nutrients and maternal antibodies supplied by breast milk which compromises the immune system. As the child grows and is exposed to increased number of pathogens, it is no surprise that the result is an event of physiological stress that can result in enamel hypoplasias (Blakey et al. 1994, Larsen 1997). Studies conducted using African-American slave populations, nineteenth century Italians, and Native Americans from Dickson Mounds, among others have all found patterns of LEH occurring during this age interval that has been attributed to weaning (Blakey et al. 1994, Goodman et al. 1984, Moggi-Cecchi et al. 1994).

There are some additional hypoplastic events that are present in various individuals examined that occur later than weaning age. As stated earlier, there are two individuals who show evidence of LEH aged at between nine and 10 years of age. There are also four individuals possessing LEH aged to around five years of age. All of these incidences are likely too late to be considered as related to weaning, so they must be related to other causes. Because they are not seen as patterns among more than a few individuals within the sample,

it is most likely that the causes of LEH in these cases are the result of individual stresses, such as diseases or specific nutritional deficiencies.

Based on the lack of significant differences in occurrence of LEH between age and sex groups, if the primary cause of LEH in the Grand Bay sample is related to diet than it can be inferred that diet is fairly homogenous throughout the population. Overall, it appears that people inhabiting Grand Bay were consuming a fairly healthy diet, and incidences of stress were related to either isolated events or a specific life cycle related event that appears to be stressful in most populations (i.e. weaning). If the population was stressed due to poor health or nutrition, the frequencies of LEH would be more dispersed throughout the dentition and suggest that individuals at all ages were undergoing physiological stress. However, because the frequencies are concentrated primarily in a two year age range, it appears likely that LEH events are the result of something more specific. Due to the availability of both marine and terrestrial resources in close proximity to the site, as well as the lack of evidence for intensive agriculture, I expected the overall diet to be varied and as a result, fairly rich in nutrients, thereby resulting in low prevalence of LEH events. I also did not expect there to be much of a difference in LEH frequency among different categories of age or sex based on a lack of archaeological evidence that describes differential access to resources based on such categories within Caribbean prehistoric groups. However, I did not expect to see evidence for weaning-based physiological stress. As a result of my hypothesis that paleodiet at Grand Bay would be sufficient in terms of nutrient availability, I assumed that the shift from breast milk to a resource-based diet would be fairly smooth. However, the types of potential resources available for consumption, particularly if children are first weaned onto a carbohydrate-rich,

nutrient-poor food that is easy to chew and digest, may not be sufficient despite the diverse types of food resources available. In many agricultural societies it is common to wean children first onto a cereal-based softer food that is easier to chew and digest until later in life when the dentition is more fully developed and individuals are more able to consume an adult diet (Blakey et al. 1994, Larsen 1997).

Paleobotany

The identification of Taxon 1 as belonging to the Sapotaceae family is not particularly surprising—various species of Sapotaceae plants, including mamey sapote (*Pouteria sapota*), star apple (*Chrysophyllum cainito*), Sapodilla (*Manilkara zapota*), and mastic bully (*Sideroxylon*) are fairly common finds at sites located throughout the Caribbean (Newsom and Pearsall 2003, Newsom and Wing 2004). The family consists of a variety of different flowering fruit trees that are native throughout Central and South America, as well as the Caribbean. In addition to their fruit being used as a valuable food resource, Sapotaceae trees have fairly dense wood which works well for fuel. Also, some species contain a white sap that acts like a gummy latex and can be used as an adhesive (Newsom and Pearsall 2003).

Without knowing the exact species of Sapotaceae that has been identified, making certain inferences related to cultivation is not yet possible. It is likely that native Caribbean species were cultivated for food or that settlers brought mainland species with them to cultivate in home gardens. However, the presence of Sapotaceae remains at Archaic Age sites (namely Krum Bay in St. Thomas) illustrates that the introduction of non-native Sapotes occurred early in Caribbean prehistory. At Krum Bay, sapodilla seeds (*Manilkara* sp.) have

been identified and narrowed down to *M. zapota*, a plant native to southern Mexico and Central America, or wild species native to Puerto Rico and the Virgin Islands. Both are likely scenarios, as yellow sapote and avocado were also introduced to the region from the same mainland area during this time period (Newsom and Pearsall 2003).

Therefore, it is possible that the Sapotaceae seeds found at Grand Bay are the result of the introduction of fruit trees from the mainland, although the species of fruit tree has yet to be determined. Sapotaceae frequency tends to increase over time at other sites, which implies that regardless of which variety is being utilized, increased growth is encouraged. The frequency at which the seeds have been recovered at Grand Bay is fairly typical of other sites; however, their high concentrations in samples recovered from the western wall of trench 446 is somewhat anomalous. Almost half of the Sapotaceae seeds were found in this area which was located near a hearth feature. Many of the seeds recovered are also charred, which suggests that either the Sapotaceae fruit was being cooked or the wood of these trees was being burned in the remnants of this hearth.

The presence of other taxa in the samples examined reflects evidence of at least one other type of wood being burned (based on the presence of Taxon 1 charcoal within samples recovered from the hearth area). The identification of a seed from Taxon 2 means that other seed-bearing fruits were either being consumed or were found in the area at Grand Bay. However, because they have yet to be identified to specific taxa, little can be said about these plants' potential uses and growth at the site. Although it is too soon to say much in terms of paleobotanical contributions to overall diet at Grand Bay, it was expected that the assemblage would reflect the presence of plant taxa that are similar to those found throughout the

Caribbean, including the use of small-scale home gardens with tropical root crops such as manioc and sweet potato, as well as fruit trees such as avocado and mastic bully. The identification of seeds that could potentially be mastic-bully or a related fruit species suggests that botanical dietary resources are likely similar to other Caribbean paleobotanical assemblages.

Faunal remains

Marine Resources

The abundance of parrot fishes, surgeon fishes, jack fishes, and grunts at Grand Bay is a common occurrence at other sites in the Lesser Antilles during Ceramic Age occupancy, and their high prevalence, as well as higher frequencies of other bony fish species imply that fish played a significant role as a primary protein source. Several of the species found in large amounts at Grand Bay (jack fishes, parrot fishes), are smaller sized reef fishes, some assumptions can be made about capture techniques. Most of these fish utilize schooling behavior, so large quantities of individuals would be present in an area at one time. Grunts, surgeon, and wrasses are known to feed in large schools at coral reefs (Lefebvre 2007). The location of coral reefs shortly offshore at Grand Bay suggests that large schools of reef fish could easily be obtained with the appropriate fishing technology. Probably the most efficient way to capture a large school of small sized fish would be to use fine-gauge nets. Such technology would not typically preserve well in archaeological contexts, which would explain the lack of evidence found thus far.

The presence of pelagic fishes such as flying fish, tuna, and mackerel that have been recovered in the Grand Bay assemblages not only imply that people were taking boats to fish

further out in open water, but also that different technology could have been used, including nets and hook and line. Some pelagic fishes like flying fish are also schooling species, so it is likely that nets could have been used in this context as well as in reef environments.

However, larger species such as tuna and mackerel are more solitary species; therefore, nets would not be a practical capture method. Hook and line is a likely fishing technology that could have been used at Grand Bay; this has been further supported by a recent discovery of several *C. pica* fishhooks in faunal samples recovered from Sabazan and Grand Bay (Giovas, personal communication).

The presence of non-fish marine taxa in the assemblage imply that although fish played a significant role in the Grand Bay diet, other marine species such as shark, turtle and various invertebrate species were also important. The abundance of sea turtle remains is particularly significant, as the presence of turtles at most Caribbean sites is fairly rare. Carriacou is known to play a role in sea turtle nesting in the area, as several known nesting grounds are located around the island. Because the remains were found at the site and not at a separate processing area, it can be inferred that nesting grounds were located in close proximity to Grand Bay, as the large size of turtle species would inhibit bringing an entire carcass back to the site after capture (Lefebvre 2007). Because the shark remains from Grand Bay consist of so few elements, little can be said about the dietary contributions of sharks until further analysis and larger samples are collected.

Based on the high quantities of various marine invertebrates found at the site, it is clear that collecting different shellfish species such as West Indian top snail, queen conch, nerites, and chiton was an important part of the subsistence. The overwhelmingly high

number of conch shells found at Grand Bay has implications for both dietary and cultural use of the species. Historical and modern records state that due to the relative weight of an individual related to meat yield, conch processing typically involves removing the snail on shore and discarding the shells. Therefore, the high number of conch shells at Grand Bay suggests that they may have been stockpiled for some purpose. Shell tools and adzes are common finds in Caribbean assemblages that are typically made from *Strombus* species. It is likely that the accumulation of conch shell at the site was for manufacture of tools and other ornaments (Fitzpatrick et al. 2009).

Based on the high quantities of marine taxa found over a thousand year period, it would not be surprising to encounter evidence of overexploitation. Although the majority of the samples examined are from later periods of site occupation, classic evidence of overexploitation in the form of shifts from coral reef habitat use to inshore and pelagic fishes is not present (Lefevbre 2007). This is somewhat surprising considering coral reefs are considered to be highly dynamic and highly sensitive marine habitats that are common victims of overexploitation in both prehistoric, historic, and modern contexts (Cooper 2010, Newsom and Wing 2004). Thus far, relative abundance of marine taxa appears fairly stable through the occupation of Grand Bay. Shifts to smaller sized individuals over time are another form of evidence for overexploitation—measurements of precaudal vertebrae from Grand Bay are fairly small. Though the sample could be representative of the end of marine exploitation at Grand Bay and the small size of recovered fish the result of earlier overexploitation, it is also possible that the samples used represent juvenile fish captured in place of larger adults that were already exploited. Therefore it appears that some evidence of

overexploitation may have occurred at Grand Bay, though future examination of samples in relation to chronology will surely shed more light on this possibility (Fitzpatrick et al. 2009, Lefevbre 2007). Overall, it appears that marine species played a primary role in subsistence through a combination of reef fish collected through net capture, exploitation of nesting sea turtles, and collections of coastal marine invertebrates, though whether any particular species were overharvested remains unclear.

Terrestrial Resources

The presence of terrestrial faunal remains at Grand Bay further implies that this marine-based diet was supplemented by various species found on land, including mammals, birds, reptiles, and amphibians. The bird, reptile, and amphibian remains do not represent a large part of the overall assemblage. Although iguanas, lizards, and amphibians are all common finds at archaeological sites in the West Indies (Newsom and Wing 2004), it is unclear whether they played a significant dietary role or if their presence is the result of natural or other cultural reasons. Iguana is consumed by some Carriacouans today, so it is possible that they were eaten in prehistoric times as well. The presence of a single bird individual in the assemblage means that there may have been some level of avian contribution to diet at Grand Bay (Lefevbre 2007).

Mammals, however, are directly associated with human activity. The presence of five introduced taxa of terrestrial mammals is especially interesting. Juvenile peccary were recovered from midden contexts. Considered native to South America and Tobago, this species was hunted by prehistoric peoples and has been recovered from sites on Vieques, Jamaica, and Grenada. Guinea pig, a species domesticated in the Andes, is found at pre-

Columbian sites throughout the circum-Caribbean. However, until recently, the only known specimens in the prehistoric Caribbean were found on northern islands. The identification of this taxa at Grand Bay is representative of the southernmost occurrence of guinea pig in the Antilles (Giovas et al. in press). Armadillo has been identified by two dermal scutes from the abdominal armor that were recovered from a single excavation layer at Sabazan and dated by associated charcoal to cal. AD 730-990. Though there are no diagnostic features that can be used to identify the finds to the species level, all seven members of *Dasyopus* are found in South America and the nine-banded armadillo (*D. novemcinctus*) seems to be the most likely candidate due to its extended range throughout the Americas and evidence for its presence on Grenada, Trinidad, and Tobago. Multiple specimens of opossum (*Didelphis*) have been recovered from different temporal and spatial contexts at both Sabazan and Grand Bay. Dates for the specimens range from AD 730-1150 at Sabazan and post-AD 1200 at Grand Bay. Archaeological deposits of *Didelphis* sp. have been recovered from sites throughout the Lesser Antilles, including Trinidad, Grenada, and Saint Lucia. The most plentiful mammal recovered was agouti (*Dasyprocta* sp.) with 47 specimens recovered from both Grand Bay and Sabazan that have been dated to cal. AD 730-1400. Four different species of *Dasyprocta* have distributions through the circum-Caribbean, three of which are still located there today. Because of the agoutis' abundance and naturalization to the region as a result of post-Columbian introductions, determining their prehistoric introductions in relation to present-day distribution is difficult. Generally, agouti occurs in archaeological contexts throughout much of the Lesser Antilles in deposits dated to post 500 BC (Giovas et al. in review).

Not a single one of the taxa discussed above are known to be present in Carriacou or the West Indies before human occupation, and all lack the adaptations necessary for successful rafting or swimming to the islands from the mainland. Therefore, their presence on Carriacou is indicative of human translocation. Additionally, the presence of all the taxa, except for agouti, are evidence for expanded ranges of Caribbean occupation that had been previously established. With the exception of opossum, none of these mammals are present on Carriacou today, which is a pattern seen on other islands and suggests that these taxa were dependant on the presence of humans and a relationship that most likely involved some form of captive management (Giovas et al. in review, Newsom and Wing 2004). None of the taxa are particularly abundant; however, the presence of their disarticulated remains in midden contexts suggests they were used as food resources and potentially for symbolic or ritual purposes (Giovas et al. in review). Their potential as objects of ritualistic or symbolic importance raises some questions related to the emergence of social complexity in the Caribbean. The small numbers of each taxa suggest that only a select few people had access to these resources or were keeping captive individuals. Therefore those individuals or groups within the population that were allowed to raise or utilize these taxa likely played a significant social role (Giovas et al. in review).

Paleodietary Use

Due to Grand Bay's proximity to the coast and close offshore coral reefs, it was expected that the faunal contribution to overall diet at the site would be focused on marine taxa, including fish and marine invertebrates. The contribution of terrestrial fauna is not unheard of at other Caribbean sites, but the diversity of taxa found at Grand Bay is

interesting. Overall, it appears the primary source of dietary resources was located on shore where sea turtles could be easily caught during nesting season and shellfish were plentiful, as well as in nearby coral reefs that provided a variety of small sized fish species that could be caught in large quantities using nets or hook and line. Pelagic fishes were also consumed, though it is unclear if they were more significant in later periods as a result of overexploitation of closer reef habitats or if they played a more supplementary role. Terrestrial mammals were managed as captive resources and possibly used as supplementary protein sources, thus providing a fairly reliable faunal resource base for the inhabitants at Grand Bay.

Stable isotope analysis

The overall ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in the analyzed sample from Grand Bay reflect a diet focused mostly on marine fish protein, coupled with terrestrial herbivores and a variety of local carbohydrate resources in the form of C_4 plants. Though the prevalence of marine protein and fish is not surprising, the contributions of terrestrial herbivores and C_4 plants were unexpected. The presence of multiple terrestrial mammal taxa within the faunal assemblages captively managed would explain the contribution of terrestrial herbivores to the isotopic signature.

What is particularly surprising about these results is that they reflect the consumption of C_4 plants as a carbohydrate resource. Most Caribbean paleobotanical studies have shown that prehistoric plant diets throughout the region focused on small-scale home gardens in which fruit trees and tropical root crops were grown, including manioc and sweet potato. This evidence has been further supported by the presence of ceramic griddles in

archaeological contexts used for cooking manioc into cassava bread at later Ceramic Age sites and historical references to their activity. However, manioc and the majority of fruit trees are C₃ plants (Stokes 2005). Manioc, also known as cassava, originated in Latin America and quickly expanded globally after European contact for a variety of reasons. Manioc is a particularly useful crop because its starchy roots are fairly high in caloric value and vitamin C, while the leaves can be used as feed for animals or processed and also consumed by humans. The plant's inherent tolerance of poor growing environments further supplements its dietary benefits. In optimal tropical growing conditions, manioc can produce high yields, but in periods of drought, adaptations in its photosynthetic mechanisms allow the plant to continue to grow and produce crops in poor conditions (El-Sharkawy 2003). The reason for this adaptation is due to the plant's possession of C₄ plant enzymes, despite its classification as a C₃ plant. In periods of extended drought, manioc is able to utilize the C₄ enzymes in combination with its fine root system to both take advantage of deeper groundwater and improve its photosynthetic productivity (El-Sharkawy 2003). It is unclear whether or not this adaptation and use of C₄ enzymes are reflected in a skewed isotopic signature, but it could be a potential reason why the isotopic signatures at Grand Bay are reflecting a focus on consumption of C₄ plants despite the presence of multiple C₃ plant resources.

Another explanation is that there is simply no botanical evidence yet that reflects the presence of C₄ plants at Grand Bay. The most well-known New World crop that utilizes a C₄ photosynthetic pathway is maize. Based on the timing of occupation at Grand Bay and throughout the Caribbean, it is possible that maize was grown and consumed. However,

maize is a labor and water-intensive crop that provides much lower caloric value per square hectare in comparison to other common carbohydrate New World staples like manioc. Very little has been found in terms of macroremains or phytolith proof of maize cultivation in the Caribbean, the majority of which has been found at sites in the Greater Antilles—larger islands with freshwater sources—two attributes that would make maize cultivation a more realistic subsistence strategy (Newsom and Deagan 1994). Other C₄ plants found in the Caribbean that could have been cultivated or consumed at Grand Bay include tropical crops such as amaranth, trianthema, and panicoid grasses. Amaranth and trianthema both produce grains that are high in protein and known at other sites located throughout the region as far back as the Archaic period (Newsom 2010, Newsom and Pearsall 2003, Newsom and Wing 2004).

Although it is unclear which botanical plants were playing a primary role in paleodiet based on the isotopic evidence, the various options that include manioc, maize, amaranth, trianthema, and panicoid grasses are all reflections of similar dietary patterns found throughout the region (Newsom and Pearsall 2003, Newsom and Wing 2004). Further isotopic analysis using bone apatite coupled with continuation of the paleobotanical analysis at Grand Bay will hopefully shed light on this issue in the future.

Paleodiet and nutrition at Grand Bay

Paleodiet at Grand Bay was expected to be fairly similar to other dietary patterns seen at sites located throughout the Caribbean which include a mixture of marine and terrestrial resources, with fish and marine invertebrates playing a prominent role, and tropical root crop horticulture, including both local and introduced fruit tree species. Based on the

zooarchaeological, paleobotanical, and stable isotope analyses conducted to date, it appears that Grand Bay is somewhat similar to other sites in the region with a few notable differences. Based on the high contribution of marine fishes to the faunal assemblage, as well as the fairly high $\delta^{15}\text{N}$ levels found, it is clear that the primary protein source at Grand Bay was likely smaller marine fishes primarily captured in coral reef environments offshore. Marine invertebrates were also supplementary protein resources as indicated by their substantial presence in the faunal samples. However, given such high contributions of marine protein sources, one would expect the $\delta^{15}\text{N}$ levels to be even higher and upwards of 15-20‰ (deFrance et al. 2008, Stokes 2005). Due to nitrogen fixing in coral reef environments, however, it is possible that the $\delta^{15}\text{N}$ levels were brought down by such high contributions of reef fishes to the overall diet (Keegan and DeNiro 1988). The $\delta^{15}\text{N}$ would have decreased even more as a result of the contribution of terrestrial mammals to the dietary resources available. Faunal analysis has found evidence of five introduced mammalian taxa to Grand Bay, which were likely kept for captive management and supplementary animal protein resources (Giovas et al. in review). Therefore, the overall resources used for animal protein at Grand Bay are somewhat reflective of Caribbean paleodiet in terms of a primary focus on marine taxa, though the contribution of several terrestrial mammals makes the site and island somewhat unique.

In terms of plant resources, there is still some clarification needed that will only come with more time and research. The stable isotope results indicate that Grand Bay inhabitants were primarily consuming C_4 plants, which could include maize, amaranth, or trianthema if similar crops to those found at other sites in the region were used in Carriacou (Newsom and

Pearsall 2003, Newsom and Wing 2004). Based on the initial botanical analysis conducted using Grand Bay samples, it is clear that fruit trees, including some Sapotaceae taxa, were likely used for a variety of reasons, such as subsistence, fuelwood, and possibly for an adhesive substance manufactured from tree sap (Newsom and Pearsall 2003). The lack of a C_3 plant isotopic signature is surprising given that many fruit trees common in the Caribbean, as well as manioc, (a known prehistoric Caribbean staple) possess C_3 photosynthetic pathways. A possible explanation for this is that manioc's adaptation to stressful growing environments is utilizing C_4 plant enzymes which could shift the plant's isotopic signature (El-Sharkawy 2003).

The presence of ceramic griddles used to cook manioc into cassava bread have been found in the excavations at Grand Bay, so despite the lack of botanical and possibly isotopic evidence, it appears to have been grown as a food source in Carriacou. Additional dental evidence observed by Burnett (2011, personal communication) during his study of dental pathology at Grand Bay includes evidence of a wear pattern characteristic of manioc processing and consumption. Referred to as lingual surface attrition of the maxillary anterior teeth (LSAMAT), the occurrence of tooth wear on the maxillary anterior lingual tooth surfaces without corresponding wear on the mandibular dentition has been linked to food processing in tropical horticultural groups who use their teeth for extramasticatory functions (Irish and Turner, 1987, Turner and Machado 1983). It has been noted particularly in groups in Central and South American who use their teeth to peel the inedible outer root shell off manioc. LSAMAT has been observed in the Grand Bay skeletal sample along with a high

caries rate (which is also associated with consumption of starchy root crops) (Burnett, personal communication).

Based on the hypothesis that paleodiet at Grand Bay would include a variety of different plant and animal resources from both marine and terrestrial environments, it was expected that this would provide access to sufficient nutrients for a fairly healthy population. As a result, low rates of LEH were anticipated. Unexpectedly, patterns of weaning stress appear to have been apparent in the Grand Bay population, occurring between the ages of 2.5 and 4 years of age. This could be explained by the potential availability of plant resources at the site. In many societies where maize is cultivated, dietary shifts associated with weaning typically involve an initial diet of softer carbohydrate-rich foods such as maize until children are old enough to consume foods typical of an adult diet (Blakey et al. 1994). Although manioc has a higher nutrient content than maize in terms of vitamin C, it is still a starchy carbohydrate source, so it is likely that populations using manioc as a staple crop and as a transitional softer food for weaning children would experience a similar loss of critical nutrients. Therefore, if the C_4 plant contribution to the isotopic signatures sampled is the result of maize consumption, this could be a contributing factor in the prevalence of LEH at weaning ages. However, if this is the case, then overall dental health would be poor and include high rates of carious lesions (Larsen 1997) which are not particularly apparent in the sample. Further botanical analysis to shed light on the potential resources responsible for the C_4 isotopic signature will hopefully help explain possible causes of LEH related to weaning stress.

VII. CONCLUSIONS

The initial examination of paleobotany and linear enamel hypoplasias at Grand Bay used in conjunction with existing stable isotope and zooarchaeological data provides valuable information about the overall paleodiet and potential for physiological stress in a prehistoric Caribbean population. This is also the first look at subsistence strategies on the island of Carriacou using multiple lines of evidence. Although some of these analyses are still in progress and will hopefully continue to shed light on diet and health at Grand Bay, the initial findings suggest that paleodiet consisted of a combination of marine and terrestrial resources focused on mostly marine protein sources and terrestrial plant resources, including various tropical grasses and fruits.

Stable isotope analysis in conjunction with faunal analysis suggests that protein sources were derived from a combination of marine and terrestrial resources, including fish, marine invertebrates, sea turtles, and terrestrial mammals such as guinea pig, agouti, and peccary. The addition of paleobotanical analysis to the stable isotope data suggests that plants utilizing a C_4 photosynthetic pathway were prevalent and included amaranth, trianthema, manioc, and possibly maize. Though botanical analysis has yet to lend full support to this notion at Grand Bay, it does reflect the use of fruit trees as further supplementary subsistence resources. Some clarifications are needed to fully understand the botanical dietary contributions, but a basic pattern seems to be emerging that reflects a diet similar to that of other Caribbean sites.

Based on this general picture of paleodiet, dental evidence suggests that overall health at Grand Bay is good, with the exception of a period of physiological stress commonly

associated with weaning in some individuals. Additionally, some individuals exhibit evidence of single stressful events that occur later in childhood; but, because they are not reflected in any larger group patterns, it has been assumed that they are the product of isolated events. There are no significant differences in the rates of LEH based on age or sex within the population, which implies that diet was fairly homogenous among the group.

Further analyses related to paleodiet and health at Grand Bay is possible using both existing data and further excavation. Future field seasons of excavation are planned at the site, which will likely yield new information related to the earlier stages of occupation at the site. Currently, paleobotanical analysis continues and will hopefully yield more botanical remains that can be identified to help explain the apparent C₄-focused diet reflected in isotopic signatures. Further stable isotope analysis examining the bone apatite fraction in addition to the existing bone collagen data can help to explain differences between protein resources (Stokes 2005, Pestle 2010). Future faunal analysis plans include examination of assemblages within a temporal context to explore potential shifts in exploitation practices over time (Lefevbre 2007). Continued osteological analysis of the Carriacou human remains will help to place LEH within the context of overall health and nutrition. Eventually, comparing overall paleodiet and human health at Grand Bay to other sites located throughout the Caribbean region will help to place Carriacou's role within regional development and possible inter-island interactions.

This initial analysis provides the first look at population nutrition and diet at both Grand Bay and the island of Carriacou that uses multiple lines of evidence. Further excavation and analysis will continue to shed light on resources used for food consumption,

subsistence strategies, and their nutritional contributions to overall health. In conjunction with other regional data, a more complete picture of prehistoric Caribbean diet and discrepancies between islands throughout the area will develop.

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