LATE AND TERMINAL CLASSIC MAYA SUBSISTENCE: STABLE ISOTOPE ANALYSIS AT CHAC BALAM AND SAN JUAN ON NORTHERN AMBERGRIS CAYE, BELIZE

by

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DEDICATION

This paper is lovingly dedicated to the memory of my “Grandaddy”, Gerald White Williams, whose family farm in North Carolina inspired my curiosity of the past and love of all things old, and who always believed I would one day become an archaeologist.

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ABSTRACT

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Skeletal populations from several Maya sites during the Late and Terminal Classic periods exhibit pathologies indicative of poor health and malnutrition, while populations from other sites appear comparatively healthy. Chac Balam and San Juan from Ambergris Caye in Belize are examples of flourishing sites with skeletal populations that possess few indicators of nutritional stress. Analysis of stable carbon and nitrogen isotopes on bone collagen and carbon isotopes on bone apatite from 30 individuals was conducted to elucidate dietary intake of the populations from Chac Balam and San Juan. Results indicate dietary possibilities typical for an island population, with primary food sources coming from the sea supplemented with terrestrial plants and fauna. No significant differences were found between males and females or adults and juveniles from these sites. Differences found between social groups indicate lower status individuals relied more on local resources and higher status individuals/elites perhaps had differential access to imported meat or produce.

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CHAPTER 1

INTRODUCTION

Many diverse approaches have been employed by archaeologists to study prehistoric diet. Investigation of subsistence technology, studies of floral and faunal remains, trace element analysis, and analysis of skeletal pathologies are commonly used methods (Keegan 1989). Skeletal changes such as dental hypoplasias, dental caries, porotic hyperostosis, Harris lines, osseous lesions, and variations in stature may reflect dietary habits. Stable isotope analysis, a direct measurement of long-term consumption (Keegan 1989), is frequently used in addition to information gained from a gross anatomical examination of skeletons, to understand more fully the health and diet of ancient people. For example, at the ancient Maya site of Copán in Honduras, the skeletal population displayed many pathological conditions such as porotic hyperostosis, dental enamel hypoplasias and dental caries that are typically attributed to a diet high in maize or other carbohydrates and low in protein (Whittington 1999; Whittington and Reed 2006). Stable isotope analysis based on carbon and nitrogen values confirmed a diet high in maize content (Gerry 1994; Reed 1994, 1999; Whittington and Reed 2006).

Palaeopathological studies of Maya skeletal remains are cited by researchers to link the state of health of the ancient Maya populations with the Classic Maya collapse (Webster 2002; Webster et al. 2000; Whittington 1999). Pathologies such as porotic hyperostosis, Harris lines, dental enamel hypoplasias and periodontal degeneration are known potentially to be caused by nutritional deficiency; therefore palaeopathology is evaluated in populations close to the Maya collapse. Many studies find evidence to support deteriorating health conditions leading up to the collapse. However, not all populations are found to suffer from severe health maladies.

Two Late and Terminal Classic Maya populations that appear to have been relatively healthy are from the sites of Chac Balam and San Juan on northern Ambergris Caye in Belize, Central America. Osteological analysis suggests that the populations of Chac Balam and San Juan were more healthy and robust than other Classic Maya populations because they manifested greater stature and fewer incidents of porotic hyperostosis (Glassman 1995). The Ambergris inhabitants lived in an island setting with plentiful marine resources and no direct evidence of agriculture on the island. Most of Ambergris is mangrove swamp with saline waters, so maize agriculture would be impossible in those areas (Glassman and Garber 1999; Guderjan and Garber 1995; Guderjan, personal communication 2010). Despite the suggestion by the local ecology of a high protein diet, gross anatomical exams reveal a skeletal population with a high incidence of calculus build-up, usually associated with high carbohydrate foods. It has been suggested that the pH values of particular marine resources might have led to the calculus build up by increasing pH levels of saliva enough for mineral crystals to form on the teeth (Glassman and Garber 1999).

The goal of this project is to conduct stable isotope analysis of the skeletal populations from the ancient Maya sites of Chac Balam and San Juan on Ambergris Caye, Belize in order to answer questions about their diet. This project aims to better elucidate the diet through analysis of carbon and nitrogen isotopes. Specifically, the relative differences of carbohydrates, lipids and protein should be differentiated through the analysis of ratios of ^{13}C to ^{12}C and ^{15}N to ^{14}N in bone collagen as well as ^{13}C and ^{12}C ratios in bone apatite. To better understand the range of diet and how diet might have affected population health around the time of the collapse, information acquired from this analysis will be incorporated into a broader survey of health and diet during the Late and Terminal Classic periods at other Maya sites.

Evaluation of isotope results, alongside of osteological profile information and archaeological evidence will address several questions. What types of foods were the people of San Juan and Chac Balam eating? Can dietary differences be seen between males and females, adults and juveniles, and social groups? If differences can be seen, were elite individuals eating more maize or other foods than commoners, possibly because they had more access to imported goods? These questions will be viewed in light of published information from other Maya sites to see if visible trends exist.

CHAPTER 2

LITERATURE REVIEW

Maya Osteology

Osteological studies play a prominent role in Maya archaeology by contributing to the understanding of health and cultural dynamics of ancient populations (White 1999). The importance of these studies has increased throughout the past century with the changing direction of research.

Marie Danforth and colleagues (2006) compiled a thorough indexed bibliography of prehistoric and early historic Maya human osteology. Referencing Danforth's bibliography, Jane Buikstra (2006) reviewed trends in Maya osteology. Buikstra's review shows an early twentieth century emphasis on topics such as cranial deformation, dental modification and biological distance/inherited features. However, Maya osteology has moved away from traditional description toward more health-related bioarchaeology, and in the past 30-40 years there has been a major shift in the focus which recognizes the importance of osteological studies in reconstructing both life experiences and the effects of culture and environment on biology (Buikstra 2006)

At Tikal, William Haviland (1967) used stature as a reflection of cultural change and complexity, and at Altar de Sacrificios, Frank Saul (1972) produced one of the earliest osteobiographies of a population. Today there is an abundance of data similar to these studies reflecting interpretive value of many of the previously published descriptions of skeletal material (White 1999).

Palaeopathological studies of Maya populations frequently cite variation in diet and nutritional deficiencies as possible causes for skeletal changes. Adding stable isotope analysis to the typical repertoire of gross anatomical examinations can give insight into dietary habits that might have led to these skeletal changes.

Isotope Principles

Stable isotope measurements have been applied successfully to the resolution of fundamental problems in the earth sciences, human sciences, biological sciences, and several subdisciplines of chemistry, with a noticeable increase since the 1970s (Sharp 2007). In bioarchaeology stable isotope ratios are analyzed by taking samples from human and animal bone collagen and apatite, tooth enamel, and hair, and can provide information about paleoclimate, social correlates, and diet reconstruction. Information about paleoclimate can be gathered from the analysis of stable isotopes because ratios of oxygen isotopes in terrestrial water vary in relation to climate (Larsen 1997). Isotopes of strontium have been used to determine whether the residents of ancient sites were born locally or if they were immigrants. Strontium isotope ratios vary in soil and rock at different geographical settings, which in turn affects the ratios in food and water sources and can provide a signature for a region (Aufderheide 1989). Carbon and nitrogen isotope studies have been the most used by archaeologists in reconstructing ancient diets because carbon and nitrogen are the foundation of organic molecules and reflect the movement of nutrients through food chains (Keegan 1989). Analysis of stable carbon and nitrogen isotopes can be used to complement other dietary studies.

What Is an Isotope?

Isotopes are atoms whose nuclei contain the same number of protons but a different number of neutrons. The term “isotope” is derived from Greek (meaning equal places) and indicates that isotopes occupy the same position in the periodic table. Isotopes can be divided into two fundamental kinds, stable and unstable (radioactive) species (Hoefs 2004). Radioactive isotopes are the basis for radiometric dating methods. An example of an unstable or radioactive isotope is ^{14}C. The ^{14}C isotope decays over time which allows it to be used as a dating method.

Unlike ^{14}C or other unstable isotopes, stable isotopes do not decay over time (Hoefs 2004; Keegan 1989).

The value of stable isotopes comes from their relative abundance in various environments. Isotopes of the same element have very similar chemical properties due to their identical electron configuration, but they have different masses due to the difference in number of neutrons (Keegan 1989; Sharp 2007). These slight differences in mass result in differing strengths of bonds to other elements. In turn, these slight differences in bond strengths are responsible for fractionation of the different isotopes between coexisting phases undergoing a physical or chemical reaction and provide the foundation for all of stable isotope geochemistry (Sharp 2007). For example, during a diffusion process whereby a certain type of plant uptakes CO_2, the lighter isotopes of carbon might diffuse more easily than the heavier isotopes, therefore there might be a higher ratio of the light to heavy isotope. This process is called “fractionation” and it is the fractionation of isotopes that gives the ratios that allow for comparisons of differences in physical and chemical properties in certain plants and elements (Sharp 2007).

History of Isotopic Analysis

The first suggestion that physical and chemical processes could cause isotopic fractionation of light elements in natural substances was made by British scientists Henry Briscoe and Percy Robinson (1925), who observed a variation in the atomic weight of boron in minerals from various localities. They proposed that processes such as solution, crystallization, melting, and volatilization would likely cause isotopic variations in nature. The following year Russian scientist Vladimir Vernadasky (1926) suggested that isotopic fractionation of the light elements should occur in living matter as well. By the 1930s, Harold Urey and his colleagues at Columbia University were conducting experiments and developing the theory of isotope exchange reactions. Urey is considered the father of modern stable isotope geochemistry. Alfred Nier and his colleagues at the University of Minnesota were making mass spectrometric measurements of variations in the stable isotope ratios of several light elements in natural materials. One of the first practical applications of isotope analysis was discovered in the 1940s with the analysis of oxygen isotopes to determine fresh water or marine origin of limestone, coral and shells. It also was concluded that temperatures of ancient oceans could be discovered from oxygen isotope analyses of calcium carbonate in fossil shells (Sharp 2007).

In bioarchaeology, the use of stable isotope analysis to evaluate ancient diets is a recent innovation. In the 1960s and 1970s isotope studies focused on the calibration of radiocarbon dates, which involved comparisons between $^{14}C/^{12}C$ ratios and $^{13}C/^{12}C$ ratios. As a result of these investigations it became apparent that human skeletons have varying ^{13}C levels (Tykot 2006; van der Merwe 1982). In 1964 Patrick Parker noted that isotope values in animals were similar to those of the foods they eat. Over a decade later controlled feeding experiments by Michael DeNiro and Samuel Epstein (1978, 1981) validated the idea that isotope values in the tissues of animals correspond to the values of the foods they eat. In the 1970s van der Merwe and Vogel paved the way for human dietary studies with their groundbreaking carbon isotope analyses of human bone collagen (van der Merwe 1982). Some of the earliest applications of this technique to studying the human diet were efforts to identify the introduction of corn to the New World (Keegan 1989; van der Merwe 1982). The 1980s ushered in the development of research examining stable isotope ratios of nitrogen in bone collagen with particular attention paid to marine versus terrestrial diets and trophic levels (Keegan and DeNiro 1988; Schoeninger and DeNiro 1984; Schoeninger et al. 1983). Methods for the analysis of carbon isotope ratios in inorganic bone apatite as an alternative to collagen (Lee-Thorp et al. 1989; Sullivan and Krueger 1981) were also developed.

How Can Diet Be Inferred through Carbon and Nitrogen?

The stable isotopic ratios (δ) of carbon (^{13}C to ^{12}C) and nitrogen (^{15}N to ^{14}N) in archaeological human bone provide substantive information about the composition of prehistoric diet. The isotopic composition of plants is preserved in the tissues of animals that consume them (DeNiro and Epstein 1978; Tieszen et al. 1983) and is measured as a ratio between two isotopes in relation to a standard of known composition. The isotopic composition of a tissue is considered "heavy" or "isotopically enriched" when it contains a higher proportion of the heavier isotope and "light" when less of the heavy isotope is present (Wright 2006).

The natural distribution of the two stable isotopes of carbon (^{13}C and ^{12}C) is largely due to the photosynthetic mechanisms used by plants. During photosynthesis, less ^{13}C is incorporated into plants than what is available in the air. This results because the heavier ^{13}C isotope forms stronger chemical bonds in carbon dioxide and therefore diffuses more slowly into the plant than the lighter ^{12}C isotope. Plants employ one of two major photosynthetic pathways: C_3 (Calvin), which metabolizes a three-carbon product during carbon fixation and C_4 (Hatch-Slack), which metabolizes a four-carbon product. The two pathways produce distinct ratios in the plants' tissues. C_4 plants are more enriched in ^{13}C than are C_3 plants. A third photosynthetic pathway is CAM (Crassulacean Acid Metabolism). CAM plants tend to have heavy $\delta^{13}C$ values like C_4 plants, but can be more variable and occasionally resemble the isotopic signature of C_3 plants (Wright 2006). Examples of C_3 plants are temperate grasses, trees, shrubs, fruits, nuts, root crops, and tubers. C_4 plants are primarily tropical grasses such as maize, sugarcane, and sorghum. Pineapple is an example of a CAM plant (Keegan 1989).

Unlike carbon isotopes, nitrogen isotopes in plants differ due to the nitrogen source available to a plant. The relative proportions of ^{15}N to ^{14}N are dependent upon whether nitrogen is incorporated into plant tissues from a soil or an air source. Most nitrogen in plants comes from the soil, where it occurs as nitrates and ammonium; however legumes have nitrogen-fixing symbiotic bacteria and obtain nitrogen directly from the air. Because soil nitrogen ratios are much heavier than atmospheric nitrogen, the $\delta^{15}N$ values of plants using bacterial fixation are much lighter (Wright 2006). Additionally, nitrogen isotope values in marine plants are characteristically higher than in terrestrial plants because dissolved nitrate in water is isotopically heavy (Wright 2006).

Because of these general differences in carbon and nitrogen synthesis, isotopic ratios measured in human bone can be attributed to either terrestrial plant or marine sources. Terrestrial plants can be divided into the three aforementioned photosynthetic types: Calvin (C3-based), Hatch-Slack (C4-based) or Crassulacean Acid Metabolism (CAM). Nitrogen can be used to distinguish between legumes versus non legumes and marine versus terrestrial plants (Reed 1999; Whittington and Reed 2006; Wright 2006).

The measurement of the isotopic composition of a material is expressed in units per mil (‰) as the deviation of the heavy to light isotope ratio in the sample from the ratio in a standard reference. The notation for carbon is $\delta^{13}C$ and the reference is Vienna Pee Dee Belemnite (VPDB), a sample that has been calibrated to the depleted original reference material (PDB), which was a Cretaceous marine fossil (*Belemnitella americana*) recovered from the Pee Dee formation in South Carolina (Tykot 2006). The notation for nitrogen is $\delta^{15}N$ and the reference is ambient air (AIR) (Reed 1999; Whittington and Reed 2006; Wright 2006). The carbon and nitrogen ratios are calculated as:

$$[(^{13}C/^{12}C)_{SAMPLE}/(^{13}C/^{12}C)_{VPDB} - 1]1000$$

$$[(^{15}N/^{14}N)_{SAMPLE}/(^{15}N/^{14}N)_{AIR} - 1]1000$$

Plants and animals can be characterized by their carbon and nitrogen isotope ratios. The following findings have been summarized by Coyston et al. (1999), Keegan (1989), Reed (1999), van der Merwe (1982), and Williams et al. (2009), and are compiled in Table 2-1 and Table 2-2. Most food plants are C_3 plants which have an average $\delta^{13}C$ ratio of -27‰ with a range of -34 to -22‰. C_4 plants (which include maize) have higher, less negative $\delta^{13}C$ values which average -12.5‰ and range from -16 to -9‰. CAM plants have $\delta^{13}C$ values between C_3 and C_4 plants that encompass these ranges; however CAM plants are not a staple in Maya diets. Legumes have $\delta^{15}N$ values of +1‰ and nonlegumes average +2 to +4‰.

The nitrogen isotope composition of collagen also can be used to identify the source of dietary protein because ^{15}N is enriched in a meat eater’s tissues, so eating meat produces higher

$\delta^{15}N$ values in collagen than does consumption of plants. Terrestrial herbivores have $\delta^{15}N$ values less than or equal to 7‰, and $\delta^{15}N$ values greater than or equal to 9‰ are typical for carnivores but may also indicate the use of freshwater fish. Nitrogen isotopes have been used to distinguish between marine animals and terrestrial plant sources. Marine animals typically have $\delta^{15}N$ values greater than 12‰ and terrestrial plants have values between 0‰ and 10‰.

Table 2-1 $\delta^{13}C$ values of plants by photosynthetic type

Photosynthetic Pathway	Average Value	Range of Values	Examples
C_3	-27‰	-34‰ to -22‰	beans, fruits, nuts, roots, tubers, trees
C_4	-12.5‰	-16‰ to -9‰	maize, tropical grasses
CAM	between C_3 and C_4 values	encompasses C_3 and C_4 values	cacti, pineapple

Table 2-2 $\delta^{15}N$ values of various plants and animals

Plant or Animal Type	Range of Values
Legumes	+1‰
Non-legumes	+2 to +4‰
Terrestrial Herbivores	≤7‰
Carnivores or Fresh Water Fish	≥9‰
Marine Animals	>12‰
Terrestrial Plants	0 – 10‰

The isotopic signal of a plant or food resource is transferred to animals with some fractionation between trophic levels and that is what gives the varying ratios (DeNiro and Epstein 1978, 1981). In humans, carbon is fractionated by about +5‰ between diet and collagen (van der Merwe and Vogel 1978), and estimates range from +9.8‰ to +13‰ for bone carbonate (Lee-

Thorp et al. 1989). $\delta^{15}N$ ratios are enriched by +2 to +4‰ relative to the diet at each trophic level (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984; Tykot 2006).

Interpretation of Isotope Values

Stable carbon and nitrogen isotope analysis, used in conjunction with archaeological data and other ethnobiological techniques, can be a valuable technique for testing and refining reconstructions of past human diets. However, it is important to understand the natural variations in plants and their consumers, metabolic and/or environmental factors which influence isotopic enrichment or depletion during assimilation, and any potential diagenetic effects (Heaton 1999; Tieszen 1991). Several factors must be kept in mind in order to cautiously interpret the values of stable carbon and nitrogen isotope ratios.

Isotopic Variability in Plant Values

When comparing isotope ratios in bone to those found in plants there are uncertainties associated with any attempt to estimate the typical $\delta^{13}C$ values of a specific plant food at a particular place and time in the past. The $\delta^{13}C$ values in animal and human bone are sensitive to the influences of spatial, species and temporal variations in the $\delta^{13}C$ values of plants (Heaton 1999). In fact, an ideal sample for comparison could be defined as a "collection of the food parts from many individuals of the plant species, fully representative of the 100-1000km^2, 10-40 year territory/life time average, from the place and time of interest" (Heaton 1999, p.645). Two common examples of variation found in modern day plants versus archaeological specimens are due to the effects of the industrial revolution and use of chemical fertilizers. $\delta^{13}C$ values of modern day plants are lower than they were in the past because the use of fossil fuels has lowered the $\delta^{13}C$ of atmospheric CO_2 by approximately 1.5‰ since the industrial revolution (Coyston et al. 1999; Tieszen and Fagre 1993). In addition, $\delta^{15}N$ values of some modern day plants might be lower than the values of their archaeological counterparts due to the incorporation of chemical nitrogen fertilizer (DeNiro and Hastorf 1985).

Isotopic Variability in Bone

Another common issue encountered with isotopic interpretation is the variability of carbon isotope values in bone collagen, the main constituent of the organic phase of bone versus bone apatite, the mineral phase of bone. Most often today both collagen and apatite procedures are combined to provide different insights into the composition of diets because the combined analyses can give information about the relative contributions of dietary components.

Collagen has typically been the preferred sample for isotopic analysis because it retains the isotopic ratios from life and is easily isolated by appropriate procedures (DeNiro 1985; Lee-Thorp et al. 1989). However, values of bone collagen may not provide accurate estimates of the proportions of C_3 and C_4 foods consumed. Several studies demonstrate that the composition of collagen may primarily reflect the $^{13}C/^{12}C$ ratio of dietary proteins (rather than whole diet) since carbon from protein is preferentially routed to collagen (Ambrose and Norr 1993; Tieszen and Fagre 1993). An example relating to Maya diets is that if $\delta^{13}C_{CO}$ (from collagen) ratios are influenced primarily by carbon from proteins, and are not uniformly influenced by carbon from all the macronutrients, elevated $\delta^{13}C_{CO}$ values of ancient Maya individuals may be a result of consuming both maize and maize-fed animals, thus estimates of the amount of maize directly consumed may be exaggerated (Coyston et al. 1999). Alternatively, bone apatite may provide a more reasonable estimate of the composition of the whole diet (Lee-Thorp et al. 1989; Sullivan and Krueger 1981).

Jim and colleagues (2004) suggest that bone cholesterol might be a new source of palaeodietary information. Their results confirm that bone collagen $\delta^{13}C$ values reflect mainly that of dietary protein and apatite $\delta^{13}C$ values reflect that of the whole diet. The study shows that bone cholesterol $\delta^{13}C$ values reflect whole diet values. These results demonstrate that bone collagen and apatite $\delta^{13}C$ values can provide different and complementary insights into diet, and bone cholesterol $\delta^{13}C$ values can complement the studies as well as serve a role in evaluating the isotopic integrity of apatite $\delta^{13}C$ values (Jim et al. 2004).

Apatite/Collagen Spacing

When interpreting the meaning of $\delta^{13}C$ values it is important to evaluate the difference between $\delta^{13}C$ values in bone apatite and collagen. The relationship between apatite and collagen $\delta^{13}C$ values is affected by trophic level because the principal macronutrients in the diet (proteins, carbohydrates and lipids) assume greater or lesser importance in different diets. For example, herbivores derive protein from plant proteins and energy from carbohydrates. Carnivores derive protein directly from prey protein and energy from prey lipids and proteins. Apatite reflects the energy aspect of diet (carbon from proteins, carbohydrates and lipids derived from blood bicarbonate), and collagen reflects the growth aspect of diet (amino acids from proteins directed from the blood to growing tissues). As a result the relationship of apatite $\delta^{13}C$ values to collagen $\delta^{13}C$ values will vary with different trophic levels and can indicate the importance of meat in the diet (Lee-Thorp et al. 1989; Williams et al. 2009). Lee-Thorp and colleagues (1989) found the following differences between apatite and collagen $\delta^{13}C$ values (called spacing): 6.8 ± 1.35‰ for herbivores, 5.2 ± 0.8‰ for omnivores, 4.3 ± 1.0‰ for carnivores, and 2.6 ± 1.0‰ for a population of prehistoric coastal hunter-gatherers from the southwestern Cape coast in Africa. The smaller spacing found in the Cape population is likely due to the unique combination of foods found in a marine diet.

Marine Diets

Some diets, such as those in coastal environments, consist of foods with similar isotopic signatures. Marine plants and their consumers are more enriched in ^{13}C, so in populations whose diet consists of seafood the isotopic signature may resemble that of a diet consisting of maize or other C_4 plants. To assess the relative contributions of maize and seafood in the diet it is important to look at the difference between $\delta^{13}C$ values in bone apatite and collagen (the aforementioned "spacing") to understand the importance of meat in the diet. An additional line of evidence is that seafood is enriched in ^{15}N and maize is not. Therefore when studying populations in coastal or island regions it is necessary to analyze nitrogen isotopes in bone collagen along with carbon isotopes in both collagen and apatite (Tykot 2006; Williams et al. 2009).

Schoeninger and colleagues (1983) compared nitrogen levels in various historic and prehistoric populations. In prehistoric populations Mesoamerican maize agriculturalists have a mean $\delta^{15}N$ value of +9‰, marine hunter-gatherers of Mugu have a mean $\delta^{15}N$ value of +16‰, Danish Mesolithic period fisher-gatherers have a mean $\delta^{15}N$ value of +14‰, and a group of Bahamian fisher-agriculturalists have a mean $\delta^{15}N$ value of +11‰. The Bahamian group's lower $\delta^{15}N$ values compared to other marine groups might be explained by the larger amount of nitrogen fixation that happens in coral reefs. It is expected that animals around coral reefs would have lower $\delta^{15}N$ values than those of organisms in the open ocean because of the larger amount of nitrogen fixation that occurs in coral reefs.

Diagenetic Change

When analyzing isotope values, it is important to consider whether or not bone samples might have been affected by diagenesis, a general term which refers to all post-mortem changes. Poor preservation of bone can lead to loss of collagen, so it is necessary to assure that a sufficient amount is present for measurement. This can be done by ensuring that the percentage of collagen produced from the whole bone sample is greater than 1% and that the C/N ratio falls between 2.9 and 3.6 (DeNiro 1985; van der Merwe 1989).

Bone apatite can be influenced by diagenesis because precipitation of calcite from the burial matrix onto bone surfaces and exchange with groundwater carbonate readily occur in bone apatite and may obfuscate the regular dietary signal. It is suggested that chemical pretreatment methods (such as soaking the bone in acetic acid) can remove these diagenetic surface carbonates (Lee-Thorp and van der Merwe 1991; Sullivan and Krueger 1981). Tooth enamel apatite can be analyzed and appears to be more resistant to diagenesis, as concluded by Lee-Thorp and van der Merwe (1991), whose study showed that the isotope ratios of tooth enamel changed less after pretreatment than did those of bone and that the ratios fell into the expected ranges for the animal species analyzed.

Maya Health and Diet

Several Maya skeletal populations from the Late and Terminal Classic Periods (600-1000 A.D.) show severe health maladies associated with high carbohydrate diet and lack of protein (Saul 1972; Whittington 1999; Whittington and Reed 2006). Some Mayanists speculate that poor health and diet might have been factors contributing to the collapse of Classic Maya society (Webster 2002; Webster et al. 2000). Early osteological studies such as Hooton's (1940) analysis of skeletons from the Cenote of Sacrifice at Chichen Itza, Saul's (1972) osteobiographic analysis from Altar de Sacrificios, and Haviland's (1967) research on stature at Tikal paved the way for ecological models positing that poor state of health caused by nutritional deficiencies is reflective of overpopulation and environmental degradation.

Alternative research shows that populations during the Classic period were differentially affected by health maladies (Glassman 1995) and several studies now show that the collapse in the Maya lowlands was not one major event, but a series of smaller, regional changes. (See Aimers 2007 for a review of Terminal Classic Maya Lowland studies). While some populations show the poor health indicators typically associated with the Late Classic Maya, others exhibit relatively good health. Diet, as analyzed by osteological and chemical methods, appears to vary between populations as well. Whereas the typical Classic Maya population is generally seen to be heavily reliant on maize, research shows that there is actually much more variability in diet than once thought (White 1999; Wright 2006).

Diet can be associated with social, political, economic, ecological, and nutritional factors (White 1999). Dietary differences may reflect hierarchical relationships and thus be utilized to explore social and political change. As Maya populations had access to diverse foods based on their region, it has been suggested that social status might have allowed for differential access to foods within a population (Coyston et al. 1999, Reed 1994, White et al. 1993, Wright 2006).

Socially meaningful patterns in food consumption are found at several sites. Chemical analysis of diet can elucidate whether or not elite residents ate a diet that varied substantially from that of commoners, and if males had different diets from females, and juveniles from adults. Alternatively, variability of Maya diet might be dictated more by region rather than social factors and settlement density perhaps plays a more significant role in regional variation than does micro-environment (Gerry 1994, 1997).

Specific examples of health and dietary patterns can be found at the sites of Altar de Sacrificios, Copán, Lamanai, Pacbitun, Marco Gonzalez and San Pedro. These ancient Maya sites are representative of site and dietary variability found in the lowland region. (See maps in Figure 2-1, Figure 2-2 and Figure 2-3 at end of this chapter. Isotope data from the Late and Terminal Classic periods of these sites is summarized in Table 3-2, Chapter 3.)

Altar de Sacrificios

Altar de Sacrificios is a low lying site situated on two rivers in the southwestern Peten region of Guatemala. Though the site is smaller than some Maya centers, its significance is seen in its many carved and dated monuments (Willey 1973), and its strategic location on the confluence of two rivers offered opportunity for control and observation of all river travel (Smith 1972). Ceramic evidence reveals initial occupation of the site around 900-600 B.C. during the Middle Preclassic period, and abandonment during a Late Classic/Early Postclassic transition (950 A.D.). The final phase is believed to be represented by an intrusive culture (Smith 1972, Willey 1973).

The inhabitants of Altar de Sacrificios show a high incidence of skeletal pathologies relating to malnutrition. Lesions such as porotic hyperostosis, ossified hemorrhages, periodontal degeneration and enamel hypoplasia suggest the presence of nutritional deficiency disorders such as anemia and scurvy. It is proposed that the population was exposed to an unhealthy ecological setting (Saul 1972).

Diet conforms to the traditional view of Classic Maya subsistence with a heavy reliance on maize (Gerry 1994, 1997, Wright 2006). Analysis of stable carbon and nitrogen isotope ratios from a group of 19 skeletons (6 Early Classic and 13 Late Classic) from the core and periphery of the site proposes that meat was of minor importance and protein was derived primarily from maize and other terrestrial plants like beans and squash. The differences in elite and commoner diet are not strong enough to exemplify a great diversity in diet, but it is speculated that there were qualitative differences in the types of meat that elites were eating (Gerry 1994, 1997).

A second analysis of carbon and nitrogen ratios from 41 individuals spanning the Preclassic to Terminal Classic periods posits a rise in importance of maize from the Preclassic to the Late Classic and a slight decline during the Terminal Classic. Greater importance was placed on meat and Late Classic elites were eating more meat than commoners. Only slight differences are apparent in male and female diets, with males possibly eating more maize than females (Wright 2006).

Copán

Copán is distinct from other Maya centers in that it is a highland site positioned on the southeastern periphery of the Maya area. The site is located in the westernmost valley of the Copán river system in Honduras and is situated near a rapid, winding stream and enclosed by high mountains with open pine forests. Cooler daily temperatures, seasonal changes and river terraces allow for high agricultural potential (Fash 1991; Gerry 1994; Gordon 1896). Maya presence at Copan appeared by 400 A.D., but the population remained very small prior to the seventh century. During the seventh and eighth centuries the population rose dramatically and then began to decline as people settled the outlying areas of the Copán Valley. By the early thirteenth century there is no evidence of occupation (Webster and Freter 1990). Being a large site with dense settlement, Copán functioned as a major center of Maya civilization during the Classic period (Gerry 1994).

The Copán skeletal population exhibits pathological conditions with particularly high frequencies of porotic hyperostosis, enamel hypoplasias and dental caries in both elite and commoner groups (Storey 2005, 2006; Whittington 1991, 1999; Whittington and Reed 2006).

Analysis of stable carbon and nitrogen ratios on 18 individuals from Copán's Main Group as well as 29 from satellite settlements in the Copán Valley suggests that inhabitants of Copán had a primarily vegetarian diet especially dependent on maize and beans/legumes. All of the skeletons are from the Late Classic period with the exception of two individuals from the Early Classic (Gerry 1994, 1997).

Additional studies of carbon and nitrogen isotope ratios on 61 and 82 Late and Post Classic burials propose that diet was primarily terrestrial, vegetarian and maize based with small amounts of other foods and little reliance on deer meat. Elites probably had a more varied diet than did commoners. Some differences are seen between males and females with males having a more restricted diet and eating more maize. Maize consumption appears to have declined with age, particularly in adult females (Reed 1994, 1999; Whittington & Reed 2006).

Lamanai

Lamanai is a large site in northern Belize located on the western shore of the New River Lagoon. The site is situated near a diverse range of habitats such as tropical forests, a pine ridge and riverine zones, and had easy access to the Caribbean coast via the New River. One of the longest continually occupied Maya sites, Lamanai archaeological evidence shows habitation from the Middle Preclassic through Historic times, and descendants live in nearby Indian Church today. Its success as a metropolitan site that continued to grow while other sites in the area declined or collapsed during the Late Classic might be attributed to its lacustrine setting or more broadly to the accessibility of its inhabitants through the New River to more of Mesoamerica (Coyston et al. 1999; Pendergast 1981).

Life on the lake with produce locally grown in raised fields provided Lamanai's inhabitants a richer and more diverse choice of foods than did other more land-locked Maya sites

(Pendergast 1981). Stable carbon and nitrogen isotope ratios were analyzed in bone collagen and apatite, and collagen was analyzed for the trace elements strontium, magnesium and zinc in 57 individuals spanning the Preclassic to Historic periods. Results indicate that diet at Lamanai was heavily reliant on maize, but less so than other inland sites, and incorporated more aquatic and marine resources than other inland sites. During the Late and Terminal Classic periods, diet shifted so that the inhabitants were eating less maize; however protein sources appear to remain unchanged. This shift to a reduced intake of maize is reflected in the decrease of dental pathologies. The elite were probably eating less maize and a wider variety of protein. There appears to have been gender and age equality in the diet at Lamanai (Coyston et al. 1999; White 2006; White and Schwarcz 1989).

Pacbitun

Pacbitun is a medium sized site in west-central Belize and is situated at the foothills of the Maya Mountains 80 km southwest of Lamanai. The site's unique location at the juncture of a lowland tropical rainforest and nearby upland pine ridge gave its inhabitants an ecologically diverse setting (Healy 1990). Nearby small streams added to the diversity, but the inhabitants did not have easy access to riverine or coastal regions (Coyston et al. 1999; White et al. 1993). Pacbitun was first settled around 900 B.C. in the Middle Preclassic period and appears to have been abandoned by 900 A.D. during the Terminal Classic (Healy 1990).

The occupants of Pacbitun took advantage of fertile soils encircling the site by using hillslope terracing for large scale agriculture. Stable carbon and nitrogen isotope analysis of bone collagen and apatite on 33 individuals from the Late Preclassic to Terminal Classic suggests that maize made up a considerable portion of the diet at Pacbitun, and in comparison to Lamanai the inhabitants were more reliant on maize agriculture. Though attempts to boost maize production increased, isotope analysis shows that less maize was consumed during the Late and Terminal Classic periods. Protein resources remained relatively stable throughout time. Somewhat unique to the site of Pacbitun is that maize appears to have become more valued towards the final periods of the site's occupation. It appears that elites ate more maize, and that females and children, who typically have lower ascribed status, consumed fewer C_4 foods such as maize (Coyston et al. 1999; Healy 1990; White 2006; White et al. 1993).

Marco Gonzalez and San Pedro

Marco Gonzalez and San Pedro are sites located on the southern portion of the island of Ambergris Caye in northern Belize. Marco Gonzalez is on the leeward side of the island and is a large site with formal architecture and possible trade ties to Lamanai (Graham and Pendergast 1989; Walper 1999). Though continuous use of the site has not been documented, excavations provide evidence of occupation from the Late Preclassic to Postclassic, from around 100 B.C. through the early fourteenth century A.D. (Graham and Pendergast 1989).

San Pedro dates from the Terminal Postclassic to the Historic period (1400-1650 A.D.) and is situated on the windward side of the island. The site appears to have been a small fishing village with no formal architecture; it shared pottery styles with Lamanai in the sixteenth century (Pendergast and Graham 1991; Williams et al. 2009).

The inhabitants of Marco Gonzalez and San Pedro have lower frequencies of porotic hyperostosis and cribra orbitalia (lesions indicative of anemia) than do Classic Maya from other sites. Frequencies of periostitis (non-specific infection), scurvy (vitamin C deficiency), and spondyloarthropathy (an arthritic condition) are high (White et al. 2006).

The populations from these sites are the first documented ancient Maya populations whose diet consisted of mostly marine resources with little reliance on maize. Analysis of stable carbon and nitrogen isotope ratios in bone collagen and apatite suggest that both populations heavily relied on marine plants and animals, but the inhabitants of Marco Gonzalez consumed more maize and terrestrial animals (Williams et al. 2009). The skeletal populations from Marco Gonzalez and San Pedro, consisting of 38 and 29 individuals respectively, are from the Postclassic period and are being used for comparison because of the similar island habitat as that of Chac Balam and San Juan in northern Ambergris Caye.

Chac Balam and San Juan, Northern Ambergris Caye, Belize

The sites of Chac Balam and San Juan, subjects of the present study, are located on the northern portion of Ambergris Caye. Ambergris Caye is a large offshore island in northern Belize stretching approximately 39 km in length and varying in width between 1.5 and 7.5 km (Guderjan and Garber 1995). Technically, Ambergris Caye is not an island, but an extension of the Xkalak Peninsula. It is separated from the peninsula by a very a narrow channel (Boca Bacalar Chico Passage) on the north, which may have been excavated by the Maya no later than 600 A.D. and perhaps much earlier. Principles of physical geography cannot explain the presence of the canal or its course; therefore it is possible that the Maya excavated the canal to facilitate access to both the leeward and windward sides of the island (Guderjan 1995a). To the east, a barrier reef that runs parallel to the island is a source of considerable marine resources, and creates shallow, calm waters that are suited for safe canoe passage. To the west of the island lie the Chetumal and Corozal Bays, into which drain the Río Hondo and the New River. Many of the large and more important prehistoric sites of the region, such as Lamanai, lie along these rivers and bays (Guderjan 1995b).

The sites of Chac Balam and San Juan are located on the northern part of the island near the Boca Bacalar canal. This location would have provided an ideal setting for servicing the long-distance maritime trade network that made use of the canal as passage from the Caribbean Sea into the Chetumal Bay system. Archaeological evidence suggests that the sites functioned as religious and administrative centers as well as for habitation. The island habitat provided a very different ecological setting from the agriculturally based subsistence patterns of mainland populations (Glassman and Garber 1999; Guderjan 1995b; Guderjan and Garber 1995).

Occupation of Chac Balam might have been initiated as early as the Late Preclassic (300 B.C. to 300 A.D.), but this occupation is evidenced only by a single mammiform sherd in a surface collection of the site. By the Late Classic period around 600 A.D. the first construction phase was underway. Architecture at Chac Balam consisted of formally arranged structures and an area of public space. Artifacts found at the site include exotic trade goods that support the theory that Chac Balam was involved in maritime trade. Occupation continued through the Terminal Classic and into the Early Postclassic before it was abandoned (Driver et al. 1995; Guderjan 1995a; Guderjan and Garber 1995).

Initial construction of the site of San Juan began at approximately 600 A.D. during the Late Classic period. Multiple construction phases show that development continued into the Terminal Classic. A two-tiered round structure built on San Juan shows architectural affinities with the Yucatan, and coupled with exotic trade goods, especially green obsidian, maintains the idea that the inhabitants participated in long distance trade. Cessation of construction and evidence of termination ritual activity indicate that San Juan was abandoned by the end of the Terminal Classic (Driver et al. 1995; Guderjan 1995a; Guderjan and Garber 1995).

The populations of Chac Balam and San Juan appear to have been small but concentrated for their diminutive island home (Glassman and Garber 1999). Osteological analysis of 34 individuals from Chac Balam and nine from San Juan establishes that the inhabitants were more healthy and robust than were other Classic Maya populations (Glassman 1995; Glassman and Garber 1999). The average stature of individuals from Chac Balam and San Juan is higher and there are few indicators of porotic hyperostosis and enamel hypoplasias. Infection frequency is high, but probably is not related to nutritional stress. Harris lines were present on some individuals and indicate that episodic disease might have affected growth during childhood. Degenerative joint disease is common, which may reflect occupational stress associated with fishing and canoeing activities. High status individuals at Chac Balam and San Juan are taller than low status individuals, and it is postulated that social position might have led to better diet and health for higher status individuals. It is likely that the coastal habitat provided an environment that afforded the Ambergris Maya a stable food supply, which ensured them relatively good health (Glassman 1995; Glassman and Garber 1999).

An interesting relationship exists between dental caries and calculus rates in the population, with caries rates being low and calculus rates high (Glassman and Garber 1995). Because dental caries and calculus are typically associated with a diet high in carbohydrates, the low caries rate is not surprising due to the island setting that would offer high protein/low carbohydrate resources. However, an explanation is needed for the high calculus rates if a low carbohydrate diet is assumed. Glassman and Garber suggest that “the ingestion of particular marine resources was responsible for increasing pH levels of the saliva necessary for mineral crystals to form on the teeth but was not conducive to subsequent fermentation of bacteria and lowering of pH levels required for the acid-related decalcification of enamel” (Glassman and Garber 1995:125).

Archaeological evidence of diet at Chac Balam and San Juan indicates that large scale agriculture was unlikely. Land available for agriculture is extremely limited due to lagoons and mangrove swamps located throughout the island. In addition the acidic soils of northern Ambergris Caye are not good for agricultural pursuits, and surveys of the area surrounding Chac Balam and San Juan did not reveal raised fields or dark soil concentrations that are indicative of agriculture. However, the presence of manos and metates indicates that maize was being used to some extent. Small local gardens could have been maintained in limited areas or maize might have been traded to the site rulers in return for the use of the Boca Bacalar Chico passage (Garber 1995; Glassman and Garber 1999).

Diet probably consisted of seafood, terrestrial fauna and small amounts of maize. Faunal evidence for diet comes from assemblages recovered from Chac Balam, San Juan and the neighboring northern Ambergris site of Ek Luum, which produced the most extensive and documented faunal assemblage of the northern Ambergris sites. Though Ek Luum is a windward site, it is the geographically closest of the Ambergris sites to Chac Balam and San Juan, and its formal architecture along with evidence of trade at the site allow for a reasonable comparison of fauna. Several species of mollusks were found at Chac Balam and San Juan, though many probably were not a large contributor to diet because they occur naturally on the island today and are unlikely related to the prehistoric occupation of the site (Driver et al. 1995). Various species of mollusks and marine gastropods that probably were used for food indicate exploitation of shallow waters between the coastline and reef, the reef, intertidal environments and brackish waters of the lagoons. Reptilian and mammalian bones were found at Chac Balam and San Juan, but are far outnumbered by various species of bony fish. At Ek Luum, 76% of the bone sample came from bony fish, which originate mostly from deep waters and waters around the reef. Barracuda is the most commonly represented species of bony fish. Deer elements (leg and antler) and tapir fragments (rib) were found at Ek Luum and suggest that meat was brought to the site, possibly through trade (Glassman and Garber 1999; Shaw 1995). The current project employs stable isotope analysis of human skeletal samples from the populations of Chac Balam and San Juan to add chemical evidence of diet to the existing archaeological and faunal data.

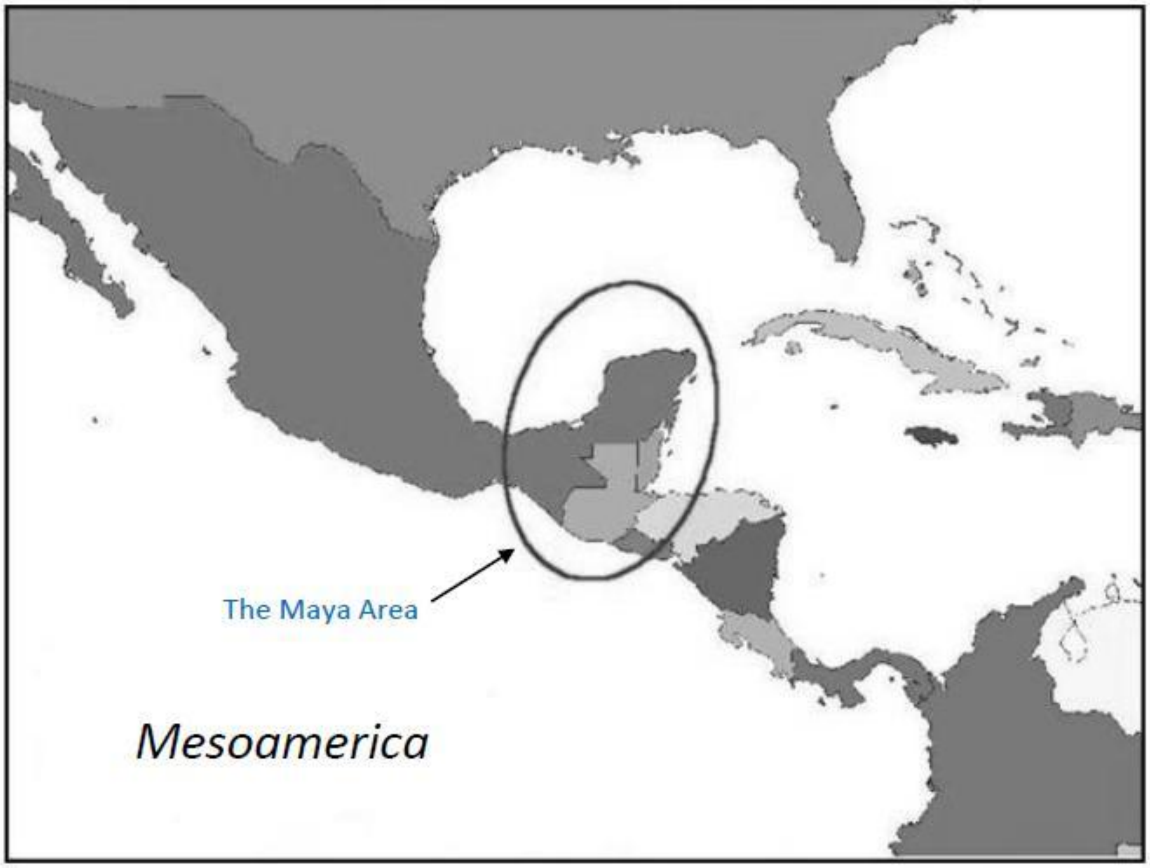

Figure 2-1 Map of Mesoamerica

Map adapted from Walter R. T. Witschey and Clifford T. Brown,
The Electronic Atlas of Ancient Maya Sites © Copyright 2010

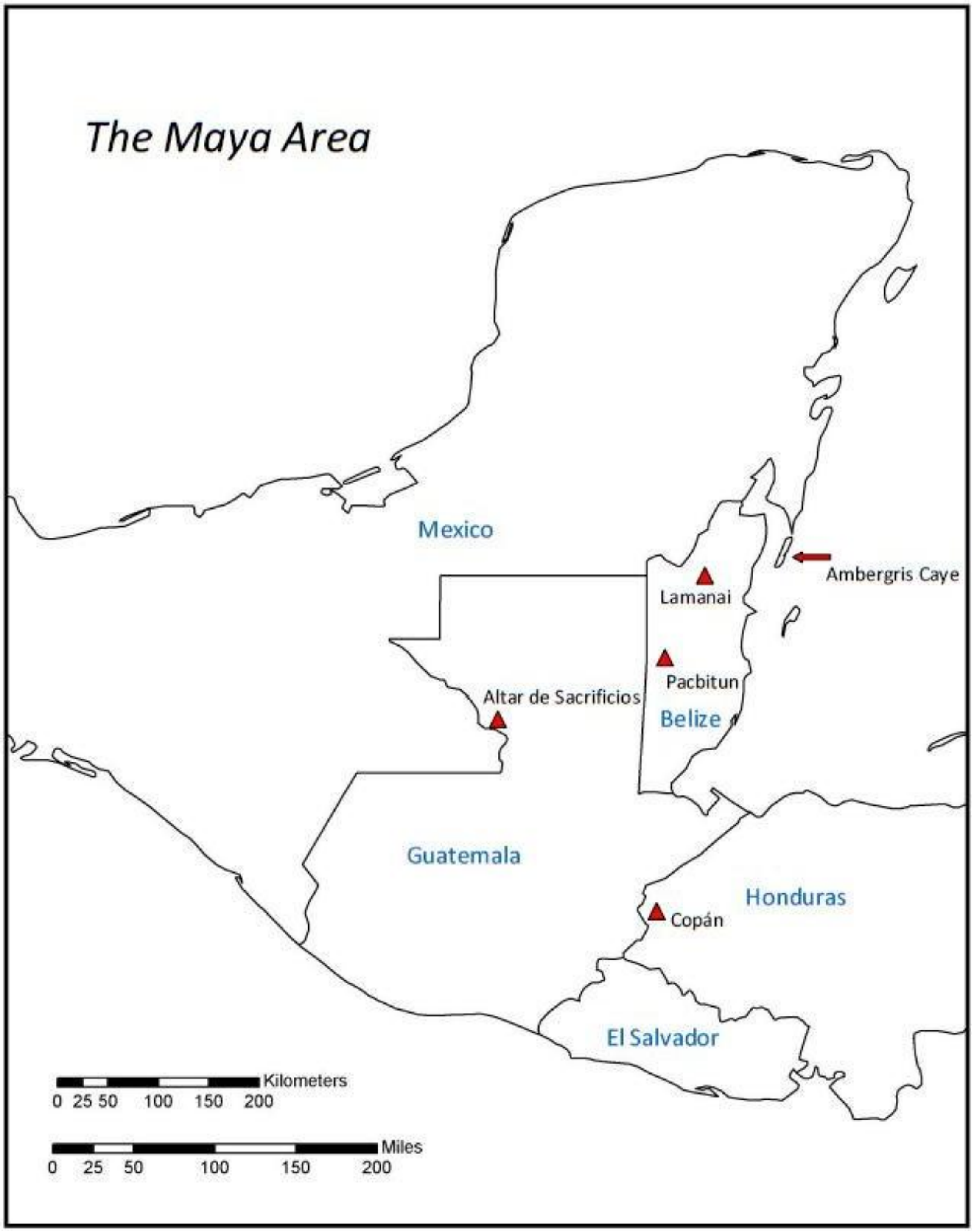

Figure 2-2 Map of the Maya area

Map adapted from Walter R. T. Witschey and Clifford T. Brown, The Electronic Atlas of Ancient Maya Sites © Copyright 2010

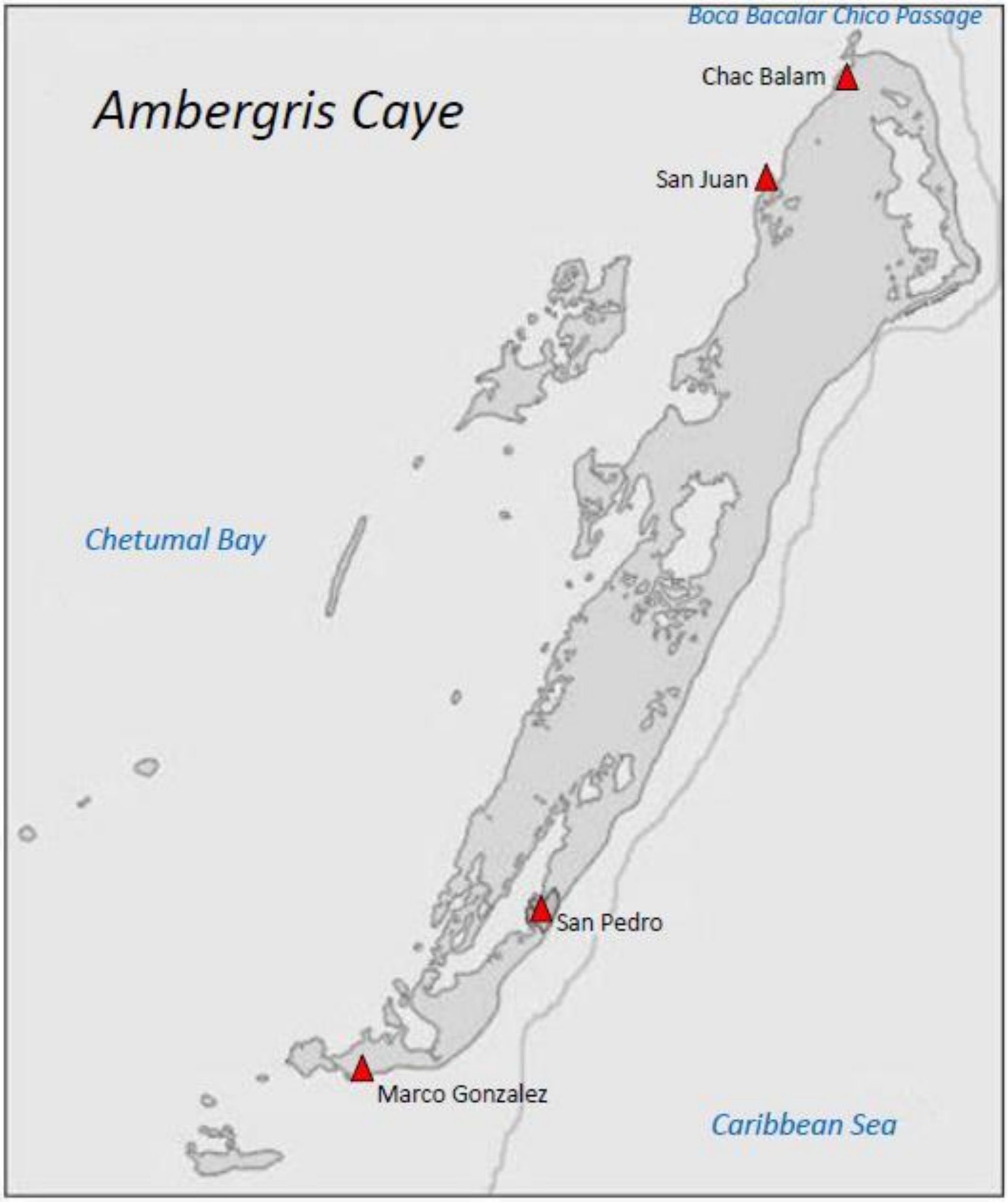

Figure 2-3 Map of Ambergris Caye

Map adapted from Belize Yacht Club Marina Inc. © Copyright 2007

CHAPTER 3

MATERIALS AND METHODS

Analysis of stable carbon and nitrogen isotopes on bone collagen and carbon isotopes on bone apatite from 30 individuals was conducted to elucidate dietary intake of the skeletal populations from Chac Balam and San Juan from Ambergris Caye, Belize. The original combined skeletal population consisted of 43 individuals, 34 from Chac Balam and nine from San Juan. The individuals were excavated from 38 burials dating to the Late and Terminal Classic (Glassman 1995).

Published osteological and archaeological analyses of the Chac Balam and San Juan burials are used in this study as a framework for interpreting results from the stable isotope analysis. Osteological analysis of the skeletal material was completed by David M. Glassman, Ph.D. (1995), while at Texas State University (then Southwest Texas State University). Dr. Glassman is a forensic anthropologist who also specializes in bioarchaeology. Each individual was evaluated by Glassman for sex, age, stature, dental enamel hypoplasia formation, presence of porotic hyperostosis, and presence of Harris lines. James F. Garber, Ph.D., a specialist in Mesoamerican archaeology at Texas State University, assigned a subjective social position to each burial based on the quantity, type, and source of grave furnishings as well as the burial location within the sites (Glassman 1995; Glassman and Garber 1999).

Thomas H. Guderjan, Ph.D., faculty member at the University of Texas at Tyler is president of the Maya Research Program, director of the Blue Creek Project in Belize and co-director of The Ambergris Caye Archaeological Project. Dr. Guderjan discussed the Chac Balam and San Juan stable isotope analysis project with Dr. John Morris at the Institute of Archaeology in Belize and received permission to conduct destructive analysis. (See Appendix A for letter of recommendation from Guderjan to the Institute of Archaeology.)

Sample

During the course of this project the Chac Balam and San Juan skeletal populations were curated at the University of Texas at Arlington. Access to the collection was made possible by Gabriel Wrobel, Ph.D., professor of anthropology at the University of Mississippi, who was in possession of the skeletal assemblage when this study began. Dr. Wrobel is one of the most active and trusted bioarchaeologists in Belize so David Glassman transferred his Belize collections to Wrobel's lab when he left the field. Upon receipt of the collection, an inventory was conducted to compare received burials to those noted in Glassman's study (Appendix B). Present for analysis were 38 of the original 43 individuals in various states of preservation. Some skeletons are almost complete and relatively well-preserved and others are represented by small fragmentary remains, for example a single mandibular fragment or a small collection of fragments from various locations in the body.

A group of 30 individuals was chosen for sampling. All skeletons with a reasonably complete osteological profile consisting of sex, age, and pathologies were selected. Individuals were eliminated from analysis if they lacked a basic osteological profile or if the remains were so minimally represented that destructive analysis risked future research potential of the skeleton. For example, one infant burial consisted only of a single long bone and therefore was not sampled. See Table 3-1 for sex, age and status of each burial and description of samples taken for destructive analyses.

Table 3-1 Chac Balam and San Juan burials and samples collected

Burial #	**Sex**	**Age**	**Status**	**Description of Sample**	**Weight of Sample**
CB-1	?	3-5 years	low	3 rib fragments	2.936 g
CB-2a	f?	adult	middle	6 non-diagnostic fragments & 1 long bone shaft fragment	3.477 g & 3.537 g
CB-2b	m?	adult	high	1 rib fragment 1 long bone shaft fragment (additional sample)	4.440 g 2.352 g
CB-3a	?	6-8 years	high	2 rib fragments	2.968 g
CB-6a	f?	adult	high	1 long bone shaft fragment	3.572 g
CB-6b	?	13-15 years	high	1 rib fragment 1 long bone shaft fragment (additional sample)	2.606 g 2.718 g
CB-9	?	2-4 years	low	4 rib fragments	1.743 g
CB-11	f	20-35 years	low	1 rib fragment	2.651 g
CB-13	?	6-12 months	low	1 long bone fragment	3.792 g
CB-14	m	35-50 years	elite	1 rib fragment	2.418 g
CB-15	f	20-35 years	low	1 rib fragment (near vertebral end)	4.335 g
CB-17	m?	30-45 years	low	2 rib fragments 1 long bone shaft fragment (additional sample)	2.743 g 2.306 g
CB-18	?	adult	middle	1 long bone shaft fragment	2.561 g
CB-19	m?	20-35 years	high	1 rib fragment	2.413 g
CB-20	?	4.5-5.5 years	middle	3 non-diagnostic long bone fragments & 1 long bone fragment	3.942 g & 3.201 g
CB-22	m	30-45 years	low	3 rib fragments	3.435 g
CB-23	m	25-45 years	high	1 rib fragment 1 rib fragment (additional sample)	2.630 g 3.518 g
CB-24	f	18-25 years	low	1 rib fragment 1 long bone shaft fragment (additional sample)	2.676 g 3.392 g

Table 3.1 - *Continued*

CB-25	?	6.5-8.5 years	middle	2 rib fragments	3.155 g
CB-26	?	2-4 years	low	2 rib fragments	2.421.g
CB-27	m	25-45 years	middle	1 rib fragment	2.799 g
CB-29	?	5.5-7.5 years	middle	1 rib fragment 1 long bone shaft fragment (additional sample)	2.472 g 2.183 g
SJ-1	?	2.5-4 years	high	4 rib fragments	2.930 g
SJ-2	m	40+ years	elite	1 rib fragment	2.490 g
SJ-3	f	adol. or adult	high/ elite	2 rib fragments	2.412 g
SJ-4	f	23-35 years	middle	1 rib fragment	2.943 g
SJ-5	m	20-35 years	middle/ high	1 rib fragment 1 long bone shaft fragment (additional sample)	3.592 g 2.862 g
SJ-6	f	adult	low	3 small rib fragments & 1 larger rib fragment	2.484 g & 3.082 g
SJ-7	?	9-12 years	middle	1 rib fragment 1 long bone shaft fragment (additional sample)	2.147 g 2.863 g
SJ-8	f	13-16 years	low	1 rib fragment	2.377 g

Procedures

One to four grams of dense, well preserved bone was collected from each individual for analysis. Bone samples were preferentially chosen from fragments that were non-diagnostic and also displayed good bone quality. Generally fragments of ribs were selected when available. Some samples consisted of a single fragment and others contained multiple fragments to satisfy the one to two gram weight requirement. A Fischer Scientific balance with 0.001 g resolution was borrowed from Dr. Qinhong Hu's lab in the Department of Earth and Environmental Sciences at

UTA, and Dr. Dana Austin, forensic anthropologist for the Tarrant County Medical Examiner and adjunct faculty member at University of Texas at Arlington, assisted with initial collection of samples.

During the collection process each sample was weighed and placed in a temporary paper envelope labeled with the burial number, weight and description of the sample. For documentation and curation purposes samples were individually photographed on a black felt background with a Sony Cybershot DSC-W70 7.2 megapixel camera using available overhead florescent lab lighting. Two photographs were taken of each sample, one photo of the sample only and one of the sample with a metric ruler and burial number label. Finally, each sample was transferred to a plastic zipper top baggie labeled inside and out with the burial number, weight and description of sample, and type of analysis being requested (collagen and apatite). Sender's name and university affiliation were printed on the outside label. The samples were padded with bubble wrap, boxed and sent for analysis to Robert H. Tykot, Professor of Anthropology and Director of the Laboratory for Archaeological Science at the University of South Florida. The cost of preparation and analysis of each sample was $35 for collagen and $30 for apatite. Both collagen and apatite analyses were requested for each sample.

Dr. Tykot prepared all samples and conducted analysis of stable carbon and nitrogen isotope ratios from the organic bone collagen and analysis of carbon isotope ratios from the inorganic bone apatite. Dr. Tykot (personal communication 2010) explained:

> Bone collagen was extracted by demineralizing whole bone using 2% hydrochloric acid for 72 hrs, dissolving base-soluble contaminants using 0.1 M sodium hydroxide (24 hrs before and after demineralization), and separating residual lipids with a mixture of methanol, chloroform and water for 24 hrs. Collagen pseudomorphs were analyzed for carbon and nitrogen isotopes using a CHN analyzed coupled with a Finnigan MAT Delta Plus stable isotope ratio mass spectrometer using continuous flow. Along with visual analyses and data from the sample preparation, C:N ratios of the analyzed gases were calculated to determine the preservation of collagen and the reliability of the isotope results.
>
> Apatite/enamel carbonate samples were also extracted using established techniques, with removal of organic components using sodium hypochlorite (24 hrs for enamel, 72 hrs for apatite), and of non-biogenic carbonates using buffered 1 M acetic acid (24 hrs). Apatite and enamel samples were analyzed with a second Finnigan MAT Delta Plus instrument using a Kiel III

> device with 100% phosphoric acid at 90º C. For both collagen and apatite results, carbon and nitrogen isotope ratios are reported using the delta (δ) notation, in parts per mil (‰) relative to the PDB and AIR standards respectively. The precision of the mass spec analyses is about 0.1‰ for δ13C and 0.2‰ for δ15N.

The analytical techniques used in this study are similar to those from other studies of Mesoamerican remains. The use of bone collagen and bone apatite is the most commonly used sampling method in other Mesoamerican studies, and established techniques were used by Rob Tykot's lab during analysis. Because of limitations imposed by singular collagen or apatite analysis, results from both analyses were combined to give a more accurate picture of dietary intake.

Collagen results were produced for 24 individuals and apatite results were produced for all 30. Dr. Tykot provided isotope data including information on reliability of the samples and the results. Ten of the initial 30 samples did not produce enough collagen for analysis. Additional samples were taken from eight of those individuals of which four yielded enough collagen for analysis.

The populations of Chac Balam and San Juan were combined in this analysis as no significant disparity in diet was shown in the carbon and nitrogen content. The mean values of δ^{13}Cco, δ^{15}N, δ^{13}Cap, and δ^{13}Cap-co for each population showed no statistically significant differences. Both of the sites are located on the leeward side of the island and are in very close proximity to each other, so it is not surprising that the diets are similar.

A food web from Ambergris Caye adapted from Williams et al. (2009:Figure 3) was used for comparison of δ^{13}Cco and δ^{15}N values in plants and animals available for consumption to similar values in the Chac Balam and San Juan population. Data incorporated into the food web are derived from Williams et al. (2009), Keegan and DeNiro (1988), and Wright (2006) and are represented by rectangles incorporating mean δ^{13}Cco and δ^{15}N values, plus one standard deviation (Figure 4-1).

To compare the diets of males and females, adults and juveniles, and three social groups (low, middle, high/elite) with the small sample size available in this study, questionable females (CB-2a, CB-6a) were considered to be female and questionable males (CB-2b, CB-17, CB-19) were considered to be male. Individuals estimated to be under the age of 18 were considered to be juveniles and those 18 and older were deemed adults. Burial SJ-3, which was estimated as being an adolescent or adult, was considered to be an adult because if she were an adolescent she likely would have been at the upper end of the adolescent range, of child-bearing age and therefore treated socially as an adult. The two elite individuals (CB-14 and SJ-2) were combined with the high status individuals to create one group designated “high/elite”. The combination of the high and elite groups allowed for greater use of statistical measures to explore variability, and was justified as stratification in this population was not as widely separated as that in other Mesoamerican populations (Guderjan, personal communication). Burial SJ-3, assigned the status of high or elite, was considered elite because the burial placement was in the middle of a structural mound adjacent to the other elite burial, SJ-2. SJ-5, who was assigned a middle or high status, was deemed middle status because of his further distance from the associated structure.

The mean values of δ^{13}Cco, δ^{15}N, δ^{13}Cap, and δ^{13}Cap-co for the male/female and adult/juvenile sub-populations were calculated and independent samples t-tests run to assess significant differences within the sub-populations. The mean values for three groups of social groups (low, middle, high/elite) were compared by running a one-way ANOVA with a Tukey HSD post-hoc test.

Average δ^{13}Cco and δ^{15}N values from the present study of Chac Balam and San Juan were combined with similar data from previously published studies in order to survey the diet of Late and Terminal Classic populations from several Maya sites (Table 3-2). Carbon isotope ratios from apatite were eliminated in this combined data set because some of the included sites did not have published data for δ^{13}Cap values. The listed δ^{13}Cco and δ^{15}N values for each site include data only from Late and Terminal Classic burials (with the exception of Marco Gonzalez and San Pedro, which are Postclassic populations). Mean δ^{13}Cco and δ^{15}N values from each site, plus one standard deviation (represented by ellipses) were plotted on a chart (Figure 4-2) in order to illustrate the variety of diet among the included Maya sites. Sites incorporated into the survey are Altar de Sacrificios in Guatemala, Copán in Honduras, Lamanai and Pacbitun in Belize, and San Pedro and Marco Gonzalez on Ambergris Caye in Belize.

Table 3-2 δ^{13}C and δ^{15}N collagen values at Chac Balam/San Juan and other Maya sites

Site	δ^{13}Cco Mean	δ^{13}Cco Std. Dev.	δ^{15}N Mean	δ^{15}N Std. Dev.	Reference
Chac Balam/San Juan	-8.3	1.3	11.4	0.7	Current study
Altar de Sacrificios 1	-9.0	0.5	9.1	0.8	Gerry 1994
Altar de Sacrificios 2	-8.8	N/A	8.8	N/A	Wright 2006
Copán 1	-9.3	0.7	7.6	0.5	Reed 1994
Copán 2 (Main Group)	-10.0	1.1	7.6	0.7	Gerry 1994
Copán 3 (Copán Valley)	-10.3	0.8	7.5	0.8	Gerry 1994
Lamanai	-15.0	1.2	10.0	0.3	Coyston et al. 1999; White & Schwarcz 1989
Marco Gonzalez	-7.5	1.2	10.5	1.1	Williams et al. 2009
Pacbitun	-10.1	1.4	9.3	0.7	Coyston et al. 1999; White et al. 1993
San Pedro	-6.5	1.1	9.9	1.0	Williams et al. 2009

CHAPTER 4

RESULTS

In order to evaluate possible diets of inhabitants from the ancient Maya sites of Chac Balam and San Juan on Ambergris Caye, Belize, stable isotope analysis was conducted on samples from 30 Late and Terminal Classic individuals, 22 from Chac Balam and 8 from San Juan. Values from four factors are considered in this project: δ^{13}Cco (carbon isotope ratios in collagen), δ^{15}N (nitrogen isotope ratios in collagen), δ^{13}Cap (carbon isotope ratios in apatite), and δ^{13}Cap-co (the difference between the values of carbon isotope ratios in apatite and collagen). Carbon and nitrogen isotope ratios are reported using the delta (δ) notation, in parts per mil (‰) relative to the PDB and AIR standards respectively. The C:N ratio is given as a measure of collagen preservation and indicates reliability of the isotope results for collagen.

Samples from six individuals did not yield sufficient collagen for analysis. The remaining 24 individuals produced sufficient collagen and had acceptable C:N ratios between 2.9 and 3.6 as established by DeNiro (1985). Apatite was produced for all individuals. At the time of publication one of the collagen samples and three of the apatite samples are in queue for reanalysis on the mass spectrometer and their values are not reported in this paper. In addition, the low δ^{13}Cap value for SJ-6 is significantly less enriched than the δ^{13}Cco value. Typically apatite is more enriched in carbon than is collagen, which makes the low δ^{13}Cap value of SJ-6 an outlier, therefore the sample also is in queue for reanalysis at the time of publication. The δ^{13}Cap and the δ^{13}Cap-co values for SJ-6 are presented here, but were not used in calculating statistics. The isotopic values for each individual are shown in Table 4-1.

Table 4-1 Chac Balam and San Juan burials and results of isotope analysis

Burial #	Sex	Age	Status	δ^{13}Cco (‰)	δ^{15}Nco (‰)	δ^{13}Cap (‰)	δ^{13}Cap-co (‰)	C:N ratio
CB-1	?	3-5 years	low	-8.5	12.3	-6.1	2.4	3.3
CB-2a	f?	adult	middle	-	-	-6.2	-	-
CB-2b	m?	adult	high	-	-	-[a]	-	-
CB-3a	?	6-8 years	high	-8.6	11.6	-7.0	1.6	3.4
CB-6a	f?	adult	high	-10.2	10.7	-7.7	2.5	3.3
CB-6b	?	13-15 years	high	-8.4	10.9	-6.2	2.2	3.2
CB-9	?	2-4 years	low	-6.5	12.4	-5.5	1.0	3.3
CB-11	f	20-35 years	low	-6.8	12.0	-5.6	1.2	3.3
CB-13	?	6-12 months	low	-5.6	12.2	-4.3	1.3	3.3
CB-14	m	35-50 years	elite	-7.7	11.5	-[a]	-	3.2
CB-15	f	20-35 years	low	-7.4	11.8	-5.9	1.5	3.3
CB-17	m?	30-45 years	low	-6.2	12.8	-6.7	-0.5	3.3
CB-18	?	adult	middle	-8.0	11.5	-6.0	2.0	3.3
CB-19	m?	20-35 years	high	-9.8	10.9	-7.3	2.5	3.3
CB-20	?	4.5-5.5 years	middle	-10.2	11.3	-[a]	-	3.4
CB-22	m	30-45 years	low	-10.0	10.6	-7.6	2.4	3.2
CB-23	m	25-45 years	high	-	-	-7.5	-	-
CB-24	f	18-25 years	low	-8.7	11.1	-8.1	0.6	3.2
CB-25	?	6.5-8.5 years	middle	-9.5	10.9	-6.5	3.0	3.3
CB-26	?	2-4 years	low	-7.4	11.7	-6.9	0.5	3.2
CB-27	m	25-45 years	middle	-9.9	11.9	-8.9	1.0	3.3
CB-29	?	5.5-7.5 years	middle	-	-	-8.4	-	-
SJ-1	?	2.5-4 years	high	-	-	-7.8	-	-

Table 4-1 - *Continued*

SJ-2	m	40+ years	elite	-[a]	10.7	-4.9	-	3.3
SJ-3	f	adol. or adult	high/ elite	-8.4	9.9	-5.9	2.5	3.3
SJ-4	f	23-35 years	middle	-8.7	11.7	-6.9	1.8	3.3
SJ-5	m	20-35 years	middle/ high	-	-	-5.7	-	-
SJ-6	f	adult	low	-8.7	12.0	-10.9[ab]	-2.2[b]	3.2
SJ-7	?	9-12 years	middle	-8.9	10.6	-6.8	2.1	3.3
SJ-8	f	13-16 years	low	-6.7	11.6	-6.7	0.0	3.2

[a] sample in queue for reanalysis at time of publication
[b] value not used in statistics calculations

Intrasite Results

Population Diet

The populations of Chac Balam and San Juan are combined in this study and referenced throughout the remaining Results and Discussion chapters as the singular “Chac Balam/San Juan” population and site. The isotopic composition of tissues of individuals from both sites was compared to assess whether dietary differences were detectable between the sites. A two-tailed t-test was run and no statistically significant differences were found between the site population means of δ^{13}Cco, δ^{15}N, δ^{13}Cap, and δ^{13}Cap-co (Table 4-2). Comparisons were not made between subpopulations of the sites (for example Chac Balam males to San Juan males, etc.) due to small sample size. The combined Chac Balam/San Juan population results on all four variables are reported in Table 4-3.

Table 4-2 Chac Balam and San Juan isotope values

	Site Name	N	Mean	Std. Deviation	Minimum	Maximum
δ^{13}Cco (‰) t = -.029, d.f. = 21 Sig .977	Chac Balam	18	-8.3	1.5	-10.2	-5.6
	San Juan	5	-8.3	0.9	-8.9	-6.7
δ^{15}N (‰) t = 1.495, d.f. = 22 Sig .149	Chac Balam	18	11.6	0.6	10.6	12.8
	San Juan	6	11.1	0.8	9.9	12.0
δ^{13}Cap (‰) t = -.773, d.f. = 24 Sig .447	Chac Balam	19	-6.8	1.1	-8.9	-4.3
	San Juan	7	-6.4	1.0	-7.8	-4.9
δ^{13}Cap-co (‰) t = -.073, d.f. = 18 Sig .943	Chac Balam	16	1.6	0.9	-0.5	3.0
	San Juan	4	1.6	1.1	0.0	2.5

* two-tailed hypothesis, alpha = .05

Table 4-3 Chac Balam/San Juan (combined population) isotope values

	N	Mean	Std. Deviation	Minimum	Maximum
δ^{13}Cco (‰)	23	-8.3	1.3	-10.2	-5.6
δ^{15}N (‰)	24	11.4	0.7	9.9	12.8
δ^{13}Cap (‰)	26	-6.7	1.1	-8.9	-4.3
δ^{13}Cap-co (‰)	20	1.6	0.9	-0.5	3.0

Results of isotope sampling of carbon from both collagen and apatite probably indicate seafood intake with little reliance on maize or other C_4 plants as a staple in the diet. The enriched levels of carbon (-8.3 ± 1.3‰ for δ^{13}Cco and -6.7 ± 1.1‰ for δ^{13}Cap) indicate a diet consisting primarily of carbon enriched foods such as C_4 plants or seafood. However, the narrow spacing between the carbon apatite and collagen levels (δ^{13}Cap-co = 1.6 ± 0.9‰) indicates a more carnivorous diet, and more specifically falls within the range (2.6 ± 1.0‰) of a population of prehistoric coastal hunter-gatherers from the southwestern Cape coast in Africa (Lee-Thorp et al. 1989). The very small spacing found in this Cape coastal population is possibly due to the unique combination of marine foods that include isotopically enriched proteins and isotopically depleted lipids and carbohydrates (Lee-Thorp et al. 1989). The small carbon apatite-collagen spacing found for the Chac Balam/San Juan population likely indicates that seafood, rather than maize or other C_4 plants, is the primary contributor to the enriched C_4 signal.

Nitrogen levels are moderately enriched in the Chac Balam/San Juan population ($\delta^{15}N$ = 11.4 ± 0.7‰) indicating consumption of foods from higher trophic levels. Foods such as marine fish and animals, and some terrestrial animals and/or plants are likely sources of nitrogen enriched foods. The nitrogen levels found at Chac Balam/San Juan are similar to the average $\delta^{15}N$ value (11‰) found for a group of prehistoric Bahamian fisher-agriculturalists (Schoeninger et al. 1983). The unique range of this population falls above that found for purely agriculturalists, yet below the range found for other groups of marine fishers. It is postulated that these unique nitrogen ratios are due to the consumption of animals around coral reefs that have lower $\delta^{15}N$ values than animals in the open ocean because of the larger amount of N fixation that occurs in coral reefs (Schoeninger et al. 1983).

A food web of potential dietary choices available to the inhabitants of Ambergris Caye (Williams et al. 2009:Figure 3) was modified for this project to show mean isotopic values of δ^{13}Cco and $\delta^{15}N$ food sources as well as values for the Chac Balam/San Juan population (Figure 4-1). Actual δ^{13}Cco and $\delta^{15}N$ values of the Chac Balam/San Juan tissue samples are shown in the figure as well as values corrected to reflect diet. Diet corrections were calculated by subtracting 5‰ from tissue carbon values (van der Merwe and Vogel 1978) and subtracting 3‰ from tissue nitrogen values (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984; Tykot 2006).

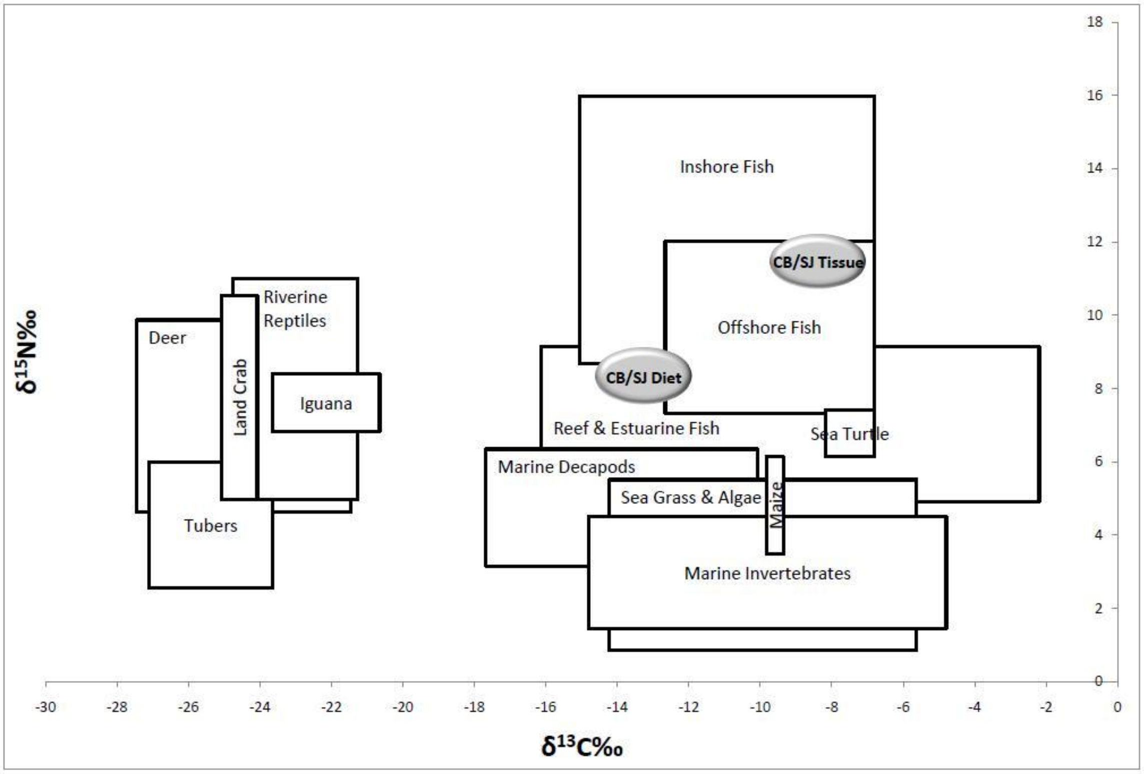

Figure 4-1 Food web comparing δ^{13}C and δ^{15}N values in Chac Balam/San Juan population tissue (collagen) and diet to values of probable Ambergris Caye food sources

The location of Chac Balam/San Juan diet values in the figure aids in visualizing possible combinations of food choices available to the population. For example, the intermediary position of the diet values on the carbon/nitrogen axes could indicate a scenario of primary reliance on reef and estuarine fish with supplementation of terrestrial fauna and/or C_3 plants. Another scenario might be a combination of offshore fish, maize and C_3 foods. However, due to the small apatite-collagen spacing (as mentioned above), maize is not likely to be a large contributor to diet. Clearly seafood sources are the main contributors to diet, but since the diet values fall to the left (depleted) side of the seafood values, C_3 foods are likely incorporated.

Diet Variability within Population

No significant differences were found between diets of males and females or adults and juveniles from Chac Balam/San Juan (Table 4-4 and Table 4-5). To determine whether significant differences exist between males and females and adults and juveniles at the sites, the means of the subpopulations were compared and independent t-tests for equality of means run.

A one-way ANOVA analysis shows statistically significant differences between the δ^{13}Cco, δ^{15}N, and δ^{13}Cap-co values of different social groups (Table 4-6). Based on post-hoc tests (Tukey HSD) it is concluded that differences are seen in δ^{13}Cco levels between the low and middle groups, δ^{15}N levels between the low and high/elite groups, and δ^{13}Cap-co levels between the low and high/elite groups. Eta-squared suggests that the relationship between these three variables and social status is somewhat strong. Social status accounts for about 35%, 38%, and 36% of the variability in δ^{13}Cco, δ^{15}Nco, and δ^{13}Cap-co values respectively

Table 4-4 Chac Balam/San Juan isotope values by sex (adults)

	Sex	N	Mean	Std. Deviation	Minimum	Maximum
δ^{13}Cco (‰) t = .657, d.f. = 11 Sig .525	female	8	-8.2	1.2	-10.2	-6.7
	male	5	-8.7	1.7	-10.0	-6.2
δ^{15}N (‰) t = -.118, d.f. = 12 Sig .908	female	8	11.4	0.7	9.9	12.0
	male	6	11.4	0.8	10.6	12.8
δ^{13}Cap (‰) t = .551, d.f. = 13 Sig .591	female	8	-6.6	0.9	-8.1	-5.6
	male	7	-6.9	1.3	-8.9	-4.9
δ^{13}Cap-co (‰) t = .125, d.f. = 9 Sig .903	female	7	1.4	0.9	0.0	2.5
	male	4	1.3	1.4	-0.5	2.5

* two-tailed hypothesis, alpha = .05

Table 4-5 Chac Balam/San Juan isotope values by age

	Age	N	Mean	Std. Deviation	Minimum	Maximum
δ^{13}Cco (‰) t = .832, d.f. = 21 Sig .415	juvenile	10	-8.0	1.4	-10.2	-5.6
	adult	13	-8.5	1.3	-10.2	-6.2
δ^{15}N (‰) t = .636, d.f. = 22 Sig .531	juvenile	10	11.6	0.6	10.6	12.4
	adult	14	11.4	0.8	9.9	12.8
δ^{13}Cap (‰) t = .374, d.f. = 24 Sig .712	juvenile	11	-6.6	1.1	-8.4	-4.3
	adult	15	-6.7	1.1	-8.9	-4.9
δ^{13}Cap-co (‰) t = -.040, d.f. = 18 Sig .968	juvenile	9	1.6	1.0	0.0	3.0
	adult	11	1.6	1.0	-0.5	2.5

* two-tailed hypothesis, alpha = .05

Table 4-6 Chac Balam/San Juan isotope values by social status

	Social Status	N	Mean	Std. Deviation	Minimum	Maximum
δ^{13}Cco (‰) F = 5.388*, d.f. = 2 Sig .013	low*	11	-7.5	1.3	-10.0	-5.6
	middle*	6	-9.2	0.8	-10.2	-8.0
	high/elite	6	-8.9	1.0	-10.2	-7.7
δ^{15}Nco (‰) F = 6.395*, d.f. = 2 Sig .007	low*	11	11.9	0.6	10.6	12.8
	middle	6	11.3	0.5	10.6	11.9
	high/elite*	7	10.9	0.6	9.9	11.6
δ^{13}Cap (‰) F = .719, d.f. = 2 Sig .498	low	10	-6.3	1.1	-8.1	-4.3
	middle	8	-6.9	1.1	-8.9	-5.7
	high/elite	8	-6.8	1.0	-7.8	-4.9
δ^{13}Cap-co (‰) F = 4.847*, d.f. = 2 Sig .022	low*	10	1.0	0.9	-0.5	2.4
	middle	5	2.0	0.7	1.0	3.0
	high/elite*	5	2.3	0.4	1.6	2.5

* Significant at the .05 level

Intersite Comparison

The range of values shown in Figure 4-2 reflects the variety of diets at select Maya sites during the Late and Terminal Classic periods. δ^{13}Cco and δ^{15}N values from Chac Balam/San Juan were plotted on a graph along with values from Altar de Sacrificios in Guatemala (two studies), Copán in Honduras (three studies), Lamanai and Pacbitun in Belize, and San Pedro and Marco Gonzalez on Ambergris Caye. (See Table 3-2 for specific values and references.) The San Pedro and Marco Gonzalez populations are from the Postclassic, and all other populations date approximately to the Late and Terminal Classic. Chac Balam/San Juan's values add a new dimension to the survey, reflecting the highest δ^{15}N values. As expected the δ^{15}N and δ^{13}C values of Chac Balam/San Juan lie nearest the values from Marco Gonzalez and San Pedro, the other two island populations. The maize-reliant populations (Altar, Copán and Pacbitun) are clustered and Lamanai is clearly the outlier of these sites.

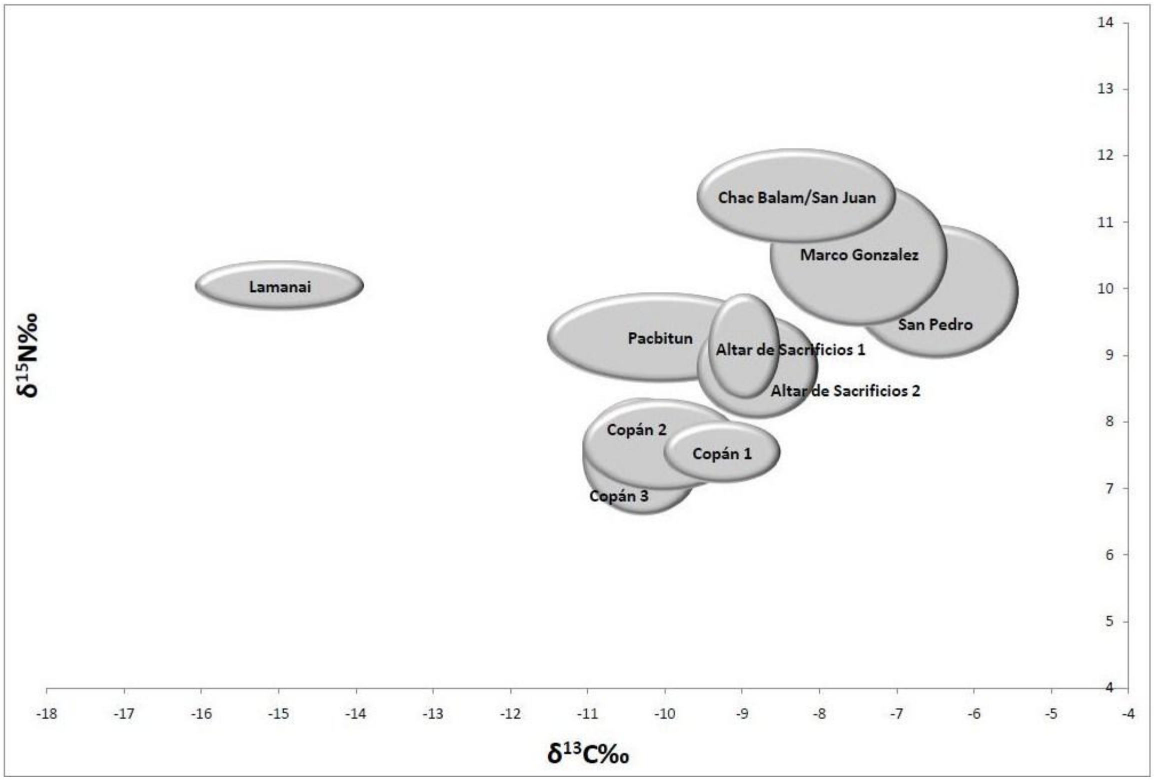

Figure 4-2 δ^{13}C and δ^{15}N collagen values at Chac Balam/San Juan and other Maya sites

CHAPTER 5

DISCUSSION

The overall isotope results for the population from the sites of Chac Balam and San Juan are not surprising for a seafaring community. Based on location and archaeological evidence, it is likely that this population was relying heavily on food from the sea as a major component of diet, with supplemental terrestrial foods that were available to the site occupants through trade. Results from analyses of stable carbon and nitrogen isotope ratios in the tissues from Chac Balam/San Juan individuals support this evidence.

Intrasite Results

Population Diet

Reconstructing ancient diet requires evidence from multiple sources. Isotopic results are more clearly explained when using archaeological and other data to aid in the interpretation. Archaeological evidence of diet for Chac Balam/San Juan suggests exploitation of both marine and terrestrial resources. Faunal archaeological evidence of diet at Chac Balam/San Juan is taken primarily from the neighboring site of Ek Luum. Marine resources make up the majority of the Ek Luum faunal assemblage (about 82%). Terrestrial and fresh/brackish water species are represented at approximately 12% and 5%, respectively (Shaw 1995). Though small deer populations could originate locally on Ambergris, the discovery of only leg bones and antler fragments hint that the meat had been transported to the area, possibly through trade. Since there is limited grazing area on Ambergris, it would not be unusual for overhunting, or overpopulation and limited food sources, to deplete the local deer populations and necessitate trade with the mainland. The importation of a locally unavailable animal resource (specifically deer) is likely seen at Cozumel as well (Hamblin 1980).

In addition to the fauna at Ek Luum, several culturally modified queen conch shells, which are a deep water species, were found at the earliest level of occupation at San Juan. Their presence lends evidence to the theory that the Boca Bacalar Chico canal was open as early as 600 A.D. (Guderjan 1988). This canal would have offered the occupants of northern Ambergris Caye access to the resources from the barrier reef and the deeper waters of the Caribbean Sea.

The possibility of maize consumption is evidenced by manos and metates that were found at both Chac Balam and San Juan. The forms and condition of the manos and metates indicate use and were typical of Late Classic lowland Maya sites (Garber 1995). There is little room for large scale agriculture, nor direct evidence of it, on Ambergris Caye (Guderjan, personal communication), so if maize was being consumed it likely was imported from the mainland. The importation of maize would make it a socially valuable commodity that might only be available to the higher status individuals. Evidence from mainland Belize sites (White and Schwarcz 1989; White et al. 1993) shows that maize might have been a limited resource during the Late and Terminal Classic periods, therefore even more valuable if available only in small quantities.

The tissues of individuals from Chac Balam/San Juan (Table 4-3) were enriched in carbon. The average δ^{13}Cco is -8.3 ± 1.3‰ (range -10.2 to -5.6‰) and the average of δ^{13}Cap is -6.7 ± 1.1‰ (range -8.9 to -4.3‰). When taking into account fractionation between diet and tissues, these values fall into the lower end of the range of C_4 foods and various marine foods. (See Figure 4-1 for food web.) Foods fitting into this carbon range that were likely available to the inhabitants of Ambergris were maize, fish (inshore, offshore, reef and estuarine), sea turtle and multiple types of shellfish. The fact that the population diet values are on the lower (depleted) end of the C_4 range implies that there was dietary supplementation with C_3 plants such as root crops, legumes, squash, fruits and/or the meat of C_3 consumers such as deer and reptiles.

Evaluation of the spacing between δ^{13}Cap and δ^{13}Cco ratios can help to deduce the meaning of the enriched carbon values in the samples. The average apatite-collagen spacing is quite small at 1.6 ± 0.9‰ (range -0.5 to 3.0‰) and is indicative of a seafood eating population.

Lee-Thorp and colleagues (1989) found the following differences between apatite-collagen $\delta^{13}C$ values (spacing) in animals: 6.8 ± 1.35‰ for herbivores, 5.2 ± 0.8‰ for omnivores, and 4.3 ± 1.0‰ for carnivores. In light of these values, Lee-Thorp et al. evaluated isotope ratios in a population of prehistoric coastal hunter-gatherers from the southwestern Cape coast in Africa and found an unusually low spacing of 2.6 ± 1.0‰. Because the collagen value primarily reflects the protein portion of the diet and the apatite value more accurately reflects whole diet, they suggested that the smaller spacing between the apatite and collagen values can be attributed to a combination of isotopically enriched protein and isotopically depleted fuel (such as marine lipids and C_3 carbohydrates). The Chac Balam/San Juan population's even smaller carbon spacing probably indicates a high consumption of marine foods (enriched carbon reflected in the collagen value) along with consumption of C_3 plants or marine lipids (depleted carbon reflected mostly in the apatite value). This would point to less reliance on maize, an enriched C_4 plant.

Analysis of $\delta^{15}N$ values helps to discern protein intake as well as terrestrial versus marine origin of foods and gives yet another means of isotope interpretation. Chac Balam/San Juan's $\delta^{15}N$ values were moderately enriched with an average value of 11.4 ± 0.7‰ (range 9.9 to 12.8‰). These enriched nitrogen levels could reflect reliance on nitrogen enriched terrestrial plants, terrestrial animals, and/or marine animals from higher trophic levels. Schoeninger and colleagues (1983) found mean $\delta^{15}N$ values for the following populations: Mesoamerican maize agriculturalists (9‰), a group of prehistoric Bahamian fisher-agriculturalists (11‰), Danish Mesolithic period fisher-gatherers (14‰), and marine hunter-gatherers of Mugu, California (16‰). The Chac Balam/San Juan population mean matches very closely the Bahamian value. Populations relying heavily on agricultural type foods typically have lower $\delta^{15}N$ values due to their dependence on $\delta^{15}N$ depleted plants and animals. The coastal populations who rely on marine foods from the open ocean have higher $\delta^{15}N$ values because their seafood sources are heavily enriched in nitrogen. The Chac Balam/San Juan population and the Bahamian group have nitrogen levels more enriched than the agriculturalists, yet less enriched than the other marine populations. The moderately enriched nitrogen levels in the Chac Balam/San Juan and Bahamian populations can be expected because animals around coral reefs have lower $\delta^{15}N$ values than those of organisms in the open ocean due to the larger amount of nitrogen fixation that occurs in coral reefs (Schoeninger et al. 1983).

Overall, it is likely that the inhabitants of Chac Balam and San Juan were consuming a majority of foods originating from the sea. The combination of enriched carbon and nitrogen values and small carbon apatite-collagen spacing are classic characteristics of a seafood eating population. In addition to marine foods, the Chac Balam/San Juan occupants probably relied on terrestrial C_3 plants and animals and small amounts of maize or other C_4 plants. Because manos and metates were found at the sites, it is likely that some maize consumption contributed to the enriched $\delta^{13}C$ signal, but intake probably was limited because if large quantities of maize were being consumed the spacing between the $\delta^{13}Cco$ and $\delta^{13}Cap$ values should be larger.

Diet Variability within Population

The carbon and nitrogen isotope ratios in the Chac Balam/San Juan population demonstrate patterns that are indicative of a stratified society. The island sites of Chac Balam and San Juan were very small and geographically isolated from mainland sites, yet their proposed integral role in the complex Maya trade and economic system probably led to the emulation of inland ritual behavior (Guderjan 2004). The formal architecture at these sites as well as diversity in grave goods and burial practices is illustrative of a stratified community. Isotopic data support the archaeological evidence of a stratified community.

Though no statistically significant differences exist between the average isotope values of males and females (Table 4-4) or adults and juveniles (Table 4-5), significant variation was seen between the means of different social groups (low, middle, and high/elite) (Table 4-6). Statistically significant differences between groups are seen in $\delta^{13}Cco$ between the low & middle groups, in $\delta^{15}N$ between the low & high/elite groups, and in $\delta^{13}Cap\text{-}co$ between the low & high/elite groups. Even though differences between other groups are not statistically significant, a notable difference in values still exists and patterns are apparent. In general, changes can be seen between the lower status groups and the middle and high/elite status groups. The changes that are seen as status increases from the low to high are as follows:

δ^{13}Cco decreases (low -7.5‰, middle -9.2‰, high/elite -8.9‰)

δ^{13}Cap decreases (low -6.3‰, middle -6.9‰, high/elite -6.8‰)

δ^{13}Cap-co increases (low 1.0‰, middle 2.0‰, high/elite 2.3‰)

δ^{15}N decreases (low 11.9‰, middle 11.3‰, high/elite 10.9‰)

The overall decrease seen in the δ^{13}Cco values between the low status group and the middle and high/elite groups indicates more intake by the higher status individuals of isotopically depleted foods such as C_3 plants, terrestrial fauna, or marine decapods. Marine decapods likely would have been available to all individuals, so if differential consumption of foods was due to status, C_3 plants and terrestrial fauna are more appropriate candidates. The lower δ^{13}Cco values of the middle and high/elite populations suggest that they were consuming more C_3 plants such as root crops, beans and squash, and terrestrial fauna while the lower status population was more dependent on the locally available seafood.

The lower δ^{13}Cap values of the middle and high/elite groups in relation to the low status group also indicate a move towards C_3 resources and terrestrial fauna. These values are not as variable as the δ^{13}Cco values, so it is possible that the protein portion of the diet, which is reflected more in the δ^{13}Cco values, is more variable than the plant portion. Though interesting to note, the differences here are small and not statistically significant.

The δ^{13}Cap-co values increase on a gradient from low to high/elite groups, which indicates a shift towards a more terrestrial diet and away from seafood (though the actual values are still well within the range of a seafood diet). Because the δ^{13}Cco values are more variable than the δ^{13}Cap values, the carbon apatite-collagen spacing is perhaps affected more by changing protein sources rather than plant sources. Therefore higher status individuals are likely consuming more carbon depleted protein sources such as terrestrial fauna.

δ^{15}Nco values decrease as status increases, which indicates a shift to lower trophic level or terrestrial foods by the higher status individuals. C_3 plants and terrestrial fauna are sources of food that are nitrogen depleted. Consumption of terrestrial C_3 plants such as root crops, beans and squash could lead to lower δ^{15}N values, but these foods should change the δ^{13}Cap values more than the δ^{13}Cco values, since δ^{13}Cco values are more affected by the protein portion of the diet. Marine decapods and invertebrates, sea turtle and maize also are nitrogen depleted in relation to the Chac Balam/San Juan diet; however, these foods are carbon enriched and would increase the δ^{13}Cap and δ^{13}Cco values rather than lower them. Ingestion of terrestrial fauna and some C_3 plants is a plausible explanation for the lower δ^{15}N values seen in the higher status groups.

It is interesting to note that although carbon values in both collagen and apatite decrease overall as status rises from low to higher status groups, there is actually a small increase in values between the middle and high/elite groups. The sample for these two groups is very small and the differences are not significant, but nevertheless it is a pattern worth exploring. The higher δ^{13}Cco values and lower δ^{15}N values are typical for a shift to more maize or C_4 plants. The δ^{13}Cap-co values increase, which also supports increased maize consumption. However, a caveat is that adding maize should affect the δ^{13}Cap value more than the δ^{13}Cco value, but in these values the δ^{13}Cco values show more change. Sea turtle is enriched in carbon and depleted in nitrogen and its consumption could be a possible scenario. Because the sample size is so small, the variation could perhaps reflect an individual's personal taste.

The variation seen between the middle and high/elite groups could be due to the isotope values of a few specific individuals, such as the three elite individuals or other high status individuals who might have had a unique diet. Since the high and elite status individuals were combined for statistical purposes due to small sample size, it is interesting to look at the three elite burials in reference to the rest of the population (Table 5-1). CB-14 at the site of Chac Balam stands out from the rest of the population as being a decorated elite burial. The middle aged man was interred with an impressive collection of grave goods as well as a possibly sacrificed neonate (Guderjan 2004). The other two elite burials (SJ-2 and SJ-3) were located adjacent to each other near the middle of a circular mound of Structure 3, a unique Maya construction at San Juan. SJ-2 was a middle-aged male and SJ-3 was probably a young adult or adolescent female who was designated as a high status or elite individual. Glassman (1995) noted that the two elite male individuals were the tallest in this population and suggested that their greater stature might be due to better health or diet afforded to elite individuals.

The isotope values seen in these three elite individuals reflect the difference seen between the carbon values in the middle and high/elite groups. In particular, the δ^{13}Cap values for SJ-2 and SJ-3 are quite high and the δ^{15}N values are low, which is a strong indicator for the addition of maize to the diet of these two individuals. Unfortunately the carbon apatite sample for CB-14 and the carbon collagen sample for SJ-2 are being reanalyzed at the time of this paper's publication, so a complete picture is not yet available. CB-14's δ^{15}N values are between the averages for the low and middle status groups, which is interesting for this elite individual. Receipt of his apatite results will clarify whether his overall isotope values are more consistent with the lower or higher status populations.

Table 5-1 Isotope value comparison of elite individuals and populations

	δ^{13}Cco	**δ^{13}Cap**	**δ^{13}Cap-co**	**δ^{15}N**
CB/SJ Population Mean	-8.3	-6.7	1.6	11.4
Low Status Group Mean	-7.5	-6.3	1.0	11.9
Middle Status Group Mean	-9.2	-6.9	2.0	11.3
High/Elite Status Group Mean	-8.9	-6.8	2.3	10.9
CB-14	-7.7	-	-	11.5
SJ-2	-	-4.9	-	10.7
SJ-3	-8.4	-5.9	2.5	9.9

Taking all evidence into consideration when evaluating the pattern of isotopic variation seen between the low, middle and high/elite groups, I propose that the significantly decreasing δ^{13}Cco values along with the only slightly decreasing δ^{13}Cap values between the low and middle/high/elite groups are caused primarily by increased consumption of carbon depleted protein sources, such as terrestrial C_3 consuming fauna, by the higher status individuals. The decreasing δ^{15}N values, which are indicative of a protein change, lend credence to this supposition. A likely scenario to explain these values is differential consumption of deer meat and/or other terrestrial fauna, with higher status individuals consuming more meat. The skeletal deer remains found at the neighboring site of Ek Luum are represented only by certain portions of the deer, possibly because deer meat was coming to the site through trade. If deer meat and other terrestrial fauna were not available locally but were available through trade, then it would make sense that these commodities would be more accessible to the higher status/elite individuals in the population who would have more access to socially valuable imports. The differences seen between the middle and high/elite groups coupled with evaluation of the individual elite burials may indicate that certain high status/elite individuals had more access to maize. If maize was being imported and particularly if its supply on the mainland was limited, it likely would have been a highly valued commodity among the elite population.

An additional hypothesis to be considered is that some of these individuals might have been recent immigrants to the island. Because isotope values in collagen and apatite reflect diet from the past several years of an individual's life, persons coming from the mainland where a primarily terrestrial diet was the norm would have isotope values that reflect both their past terrestrial diets and their current seafood diets. The greater stature of the two elite males and the similarities in isotope values and burial location of the San Juan individuals might hint at the possibility of familial relations or origin from a different population. This would be an interesting scenario to explore since San Juan's unique Structure 3, a two-tiered round building, appears to be a result of Northern Yucatecan Maya influence. In addition an unusually high percentage of green obsidian was found at San Juan, but not at any other sites on Ambergris Caye.

Intersite Comparison

The sites of Chac Balam and San Juan add a new dimension to the survey of Maya sites (Figure 4-2). The population's isotope values reflect the highest $\delta^{15}N$ values in the group, which is indicative of a seafood eating population. The Late and Terminal Classic population of Chac Balam/San Juan has enriched $\delta^{15}N$ values and depleted $\delta^{13}C$ values relative to the Postclassic populations of Marco Gonzalez and San Pedro, which would be expected to have similar values due to their shared location on Ambergris Caye. These differences could be due to varying seafood exploitation such as heavier reliance by the population of Chac Balam/San Juan on offshore fish than on reef and estuarine fish. Offshore fish are more enriched in nitrogen and depleted in carbon than are reef and estuarine fish and faunal evidence supports the possibility of exploitation of offshore fish.

Differences in diet between the island and mainland sites are apparent. Chac Balam/San Juan, Marco Gonzalez and San Pedro's enriched $\delta^{13}C$ and $\delta^{15}N$ values reflect their protein rich seafood diet. In contrast are three inland sites, Altar de Sacrificios, Copán and Pacbitun whose enriched $\delta^{13}C$ and low $\delta^{15}N$ values reveal populations who were heavily dependent on maize. Copán is the extreme of these sites with very low $\delta^{15}N$ values that are illustrative of a primarily vegetarian diet. Altar's diet was probably supplemented with more meat and Pacbitun was slightly less reliant on maize than both Altar and Copán.

Lamanai appears as an outlier site on this survey, with the most depleted $\delta^{13}C$ values of all the sites. The $\delta^{15}N$ values are moderately enriched, similar to those at San Pedro. Lamanai's early dependence on maize steadily decreased throughout time, and by the Late and Terminal Classic the population was relying mostly on C_3 plants and fauna. The somewhat enriched $\delta^{15}N$ values indicate higher protein content with possible supplementation from seafood. Lower incidence of dental caries through time reflects the decreased amount of maize in the diet.

The Late and Terminal Classic populations of Altar de Sacrificios and Copán exhibited numerous skeletal indicators attributed to nutritional deficiencies. On the other hand the Late and Terminal Classic population of Chac Balam/San Juan and the Postclassic populations at Marco Gonzalez and San Pedro had far fewer skeletal indicators of nutritional deficiency. In addition average stature and robusticity appeared to be greater at Chac Balam/San Juan than at Copán. The rich seafood diet at the island sites, along with supplementation with foods available through trade, probably led to the better state of health of the island populations.

Sites that were more dependent on maize were located in environments with much less dietary diversity. Copán in particular was situated in a mountain valley at the periphery of the Maya world in an environment with fewer varied resources. Lamanai on the other hand probably had plentiful resources available to it based on its location and on its positioning in the Maya trade routes. For the sites surveyed, it appears that local ecology as well as involvement in trade relations plays a large part in dietary variation during the Late and Terminal Classic periods. More variable dietary choices with higher protein intake might also lead to better health as evidenced by the seafaring populations of Ambergris Caye. Of the seven sites surveyed in this paper, only Lamanai and Marco Gonzalez flourished beyond the Terminal Classic. Perhaps the variability of dietary resources along with their trade relations assisted in their survival.

Direction for Future Study

The addition of stable isotope analysis to the osteological analysis of the Chac Balam/San Juan population, along with archaeological evidence from the sites, has facilitated the construction of scenarios illustrating the types of foods that were being consumed at Chac Balam/San Juan as well as how social factors might have affected diet. Future studies can be incorporated to further clarify some of the hypotheses proposed in this project.

The diet at Chac Balam/San Juan appears to be high in protein and low in carbohydrates as expected, therefore there is no additional explanation for the high rate of dental calculus seen in the population. It might be interesting to see if there is a correlation between the caries and/or calculus rates and the isotope values of the particular individuals who might have been consuming more maize.

Additional chemical analyses of the skeletal population from Chac Balam/San Juan would be beneficial for a more accurate assessment of diet. The analyses of relative enrichments of trace elements in bone collagen and/or apatite can give information such as levels of meat, seafood and plant consumption, and also can help distinguish between various plant and animal types (White and Schwarcz 1989; Wright 2006). Analyzing the levels of strontium (Sr), magnesium (Mg) and zinc (Zn) in the Chac Balam/San Juan individuals could help clarify whether or not maize and deer were being consumed differentially by the varying social groups.

Isotope analysis can also help answer questions about population origins. Since strontium (Sr) isotope ratios vary in different geographical settings, they can often distinguish one site from another (Aufderheide 1989). A comparative analysis of strontium ratios could be made between deer found at Ek Luum and deer from other sites to see if the Ek Luum deer are imports. A similar analysis could be completed on the human population from Chac Balam/San Juan to see if certain individuals with unique strontium isotope ratios might have been recent immigrants to the area.

Other types of studies that could assist in reconstructing diet consist of palaeobotanical studies and climate studies. Palaeobotanical studies can add plant information to the archaeological evidence of diet. Research into Late and Terminal Classic climate might indicate whether or not climate change is part of the reason for the enriched $\delta^{15}N$ values in the population. $\delta^{15}N$ becomes more enriched as rainfall decreases possibly because of water stress on the urinary secretion system (White et al. 1993).

Importantly, limitations of the small sample size of the Chac Balam/San Juan population need to be recognized. Though results for overall diet and general dietary patterns are probably reliable, analysis of variability within the population should be interpreted with caution. In some instances, statistical analyses were run on groups with as few as four subjects, so it is easy for one individual to significantly affect the value of the group. Future studies could implement the use of statistical power analysis that would help determine appropriate sample size and aid in choosing more effective statistical procedures.

CHAPTER 6

CONCLUSION

What did the ancient Maya eat? Are social constructs within Maya populations disparate? How did Maya populations relate to other Maya or non-Maya populations? Did environmental degradation and declining health contribute to the collapse of some Maya polities? These are questions that can be investigated through the use of dietary studies. Whereas traditional dietary studies consisting of archaeological, paleobotanical, ethnohistorical and osteological elements give a broad understanding of the types of foods available to populations, the use of chemical analyses such as stable isotope analysis and trace element studies provides direct evidence of food consumption by individuals. Stable isotope analysis has become a useful tool to investigate larger questions in relation to the ancient Maya civilization.

The ancient Maya sites of Chac Balam and San Juan from northern Ambergris Caye, Belize offer a unique perspective of the changes that were happening during the Late and Terminal Classic periods. Whereas many inland Maya communities were experiencing vast declines in population size and health, Chac Balam and San Juan appear to have been thriving. It is likely that the plentiful resources from Ambergris Caye along with participation in Maya maritime trade networks afforded the inhabitants greater health and allowed Chac Balam and San Juan to flourish during the Late Classic when many other populations were declining.

Analysis of stable carbon and nitrogen isotope ratios in the tissues of individuals from the sites of Chac Balam and San Juan was conducted to answer questions about diet and social relationships within the populations. Results from analysis along with the archaeological and osteological evidence for diet illustrate healthy and robust seafaring populations who successfully exploited the resources of their local environment. Diet consisted primarily of fish and other marine animals that could be procured in the waters and reef offshore of Ambergris Caye. Terrestrial plants and animals provided supplementation to the intake of seafood. Agricultural and grazing potential was limited by the small island environment; therefore the inhabitants of Chac Balam and San Juan likely relied on trade as a source for some of these terrestrial meats and plants.

No significant differences in diet were found between the populations of Chac Balam and San Juan. Statistical analysis of the combined Chac Balam/San Juan population showed no significant differences between diets of males and females or juveniles and adults. Significant differences were found between varying social groups. Higher status individuals probably consumed more C_3 foods and terrestrial herbivores. Some of the highest status/elite individuals might have been consuming more maize. The differential consumption of C_3 foods, terrestrial herbivores and maize supports the idea that these products were being traded from the mainland and access was limited to the higher status individuals, while lower status individuals relied more on the local island resources.

Although Chac Balam and San Juan appear to have been healthy and thriving during the Late and Terminal Classic periods, San Juan was abandoned by the end of the Terminal Classic period and occupation at Chac Balam continued only into the Early Postclassic before its abandonment. Evidence from sites such as Copán, Altar de Sacrificios and to some extent, Pacbitun, indicates health and/or environmental stressors might have facilitated the collapse of those societies. Alternative evidence from the sites of Lamanai, Marco Gonzalez and San Pedro illustrates that a more diverse ecological setting might have led to better population health and the ability to flourish beyond the Late and Terminal Classic periods. Nevertheless, Lamanai and Marco Gonzalez were the only two of the surveyed sites whose communities continued into Historic times. Good health and ecological diversity apparently are not the only factors needed to encourage a site's continued existence.

Isotope evidence from Chac Balam and San Juan has given insight into the dynamics of sites existing during the Late and Terminal Classic periods. Research potential continues to exist within the skeletal populations and archaeological evidence from northern Ambergris Caye. Future projects should utilize these resources to contribute additional insight to our knowledge of the Late and Terminal Classic periods of the Maya civilization.

APPENDIX A

LETTER OF RECOMMENDATION FROM TOM GUDERJAN FOR STABLE ISOTOPE ANALYSIS OF THE CHAC BALAM AND SAN JUAN SKELETAL COLLECTIONS

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May 21, 2009

Dr. John Morris
Institute of Archaeology
National Institute of Culture and History
Belmopan, Belize

Dear Dr. Morris,

This is inform you that I am aware of and support Dana Parker's request to extract samples from the burials excavated by Dr. Garber and myself from northern Ambergris Cay during the period 1983-1986. Since the closure of Dr. Glassman's laboratory in San Ignacio, the materials have been curated at the University of Mississippi by Dr. Wrobel. Dana Parker is a graduate student at he University of Texas at Arlington under Dr. Kat Brown. It is my understanding that a formal request from Ms. Parker will arrive to you shortly through Dr. Brown. Ms. Parker plans to use the samples for isotopic analysis comparable to that reported in the most recent *Latin American Antiquity* from the sites on southern Ambergris.

I have long argued that Ambergris is a poor location for maize agriculture and that evidence of significant maize in the prehistoric diet of the Ambergris Maya would support my argument that the coastal trade network did not simply move elite prestige goods but tied large scale polities together economically through the transport of commodities such as food.

Ms. Parker's thesis plan has been underway for some time and it was fortuitous that comparable data from he southern Ambergris sites has now been published and seems to support this hypothesis.

Sincerely,

TH Guderjan

Dr. Thomas H. Guderjan

209 West Second Street No. 295, Fort Worth, Texas 76102
817-831-9011

APPENDIX B

INVENTORY OF CHAC BALAM AND SAN JUAN SKELETAL COLLECTION

Burial #	**Sex**	**Age**	**Status**	**Present upon Receipt from Mississippi**	**Sample Taken for Analysis**
CB-1	?	3-5 years	low	yes	yes
CB-2a	f?	adult	middle	yes	yes
CB-2b	m?	adult	high	yes	yes
CB-2c	?	?	?	no	n/a
CB-3a	?	6-8 years	high	yes	yes
CB-3b	?	older adult	high	yes	no
CB-4	?	?	low	yes	no
CB-5	?	adult	low?	yes	no
CB-6a	f?	adult	high	yes	yes
CB-6b	?	13-15 years	high	yes	yes
CB-7	?	?	middle	yes	no
CB-8	?	adult	?	yes	no
CB-9	?	2-4 years	low	yes	yes
CB-10a	?	child	low	yes	no
CB-10b	?	adol or older	low	yes	no
CB-11	f	20-35 years	low	yes	yes
CB-12	?	?	low	no	n/a
CB-13	?	6-12 months	low	yes	yes
CB-14	m	35-50 years	elite	yes	yes
CB-15	f	20-35 years	low	yes	yes
CB-16	?	infant	low	yes	no
CB-17	m?	30-45 years	low	yes	yes
CB-18	?	adult	middle	yes	yes
CB-19	m?	20-35 years	high	yes	yes
CB-20	?	4.5-5.5 years	middle	yes	yes

CB-21	?	newborn ±2 months	middle	no	n/a
CB-22	m	30-45 years	low	yes	yes
CB-23	m	25-45 years	high	yes	yes
CB-24	f	18-25 years	low	yes	yes
CB-25	?	6.5-8.5 years	middle	yes	yes
CB-26	?	2-4 years	low	yes	yes
CB-27	m	25-45 years	middle	yes	yes
CB-28	?	newborn	middle	no	n/a
CB-29	?	5.5-7.5 years	middle	yes	yes
SJ-1	?	2.5-4 years	high	yes	yes
SJ-2	m	40+ years	elite	yes	yes
SJ-3	f	adol. or adult	high/ elite	yes	yes
SJ-4	f	23-35 years	middle	yes	yes
SJ-5	m	20-35 years	middle/ high	yes	yes
SJ-6	f	adult	low	yes	yes
SJ-7	?	9-12 years	middle	yes	yes
SJ-8	f	13-16 years	low	yes	yes
SJ-9	?	newborn/stillborn	middle	no	n/a

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BIOGRAPHICAL INFORMATION

Dana began her collegiate academic career at Texas Wesleyan University where she earned a Bachelor of Science in Psychology in 1991. After working in the field of early childhood for fifteen years, she returned to school to study the life sciences and along the way discovered the diverse field of anthropology where she found her niche in the realms of physical anthropology and archaeology. Dana earned a Master of Arts in Anthropology from the University of Texas at Arlington in 2011. Her research interests include osteology, bioarchaeology, forensic anthropology and Mesoamerican archaeology. While attending UTA, Dana worked on archaeological projects in Belize and also held an internship and grant funded position working with the forensic anthropologist for the Tarrant County Medical Examiner. After graduation Dana plans to present and publish her research from the sites of Chac Balam and San Juan, volunteer at the medical examiner's office and stay involved with other anthropological endeavors.