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Dietary Study of The Postclassic Sites of El Rey and San Miguelito, Isla Cancun, Quintana Roo, Mexico

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DIETARY STUDY OF THE POSTCLASSIC SITES OF EL REY AND SAN MIGUELITO,

ISLA CANCUN, QUINTANA ROO, MEXICO

by

EMILY DUKE

Under the Direction of Jeffery B. Glover, PhD

ABSTRACT

This thesis is the isotopic dietary study of two Postclassic Maya archaeological sites of El Rey and San Miguelito on the Island of Cancun in the Yucatan Peninsula. A bone and tooth sample were used from the individuals in the selected study populations and processed to extract carbonate and collagen to be analyzed for carbon and nitrogen isotopes to determine the dietary utilization of maize and marine protein of these two populations. At this point, the collagen results have not been received from the laboratory and are not part of the conclusions. The carbonate results indicated that the populations were utilizing marine resources available to them. Previous research, based on Sr isotopic data, indicated that four of the individuals at El Rey were not from the island originally and the isotopic evidence indicates that these individuals

adopted the eating practices of the local populace of the Island of Cancun. The results indicate no stark differences in the diet, which indicates that the communities on the island were more egalitarian, or, at least, that status was not tied to food consumption.

INDEX WORDS: Diet, Isotopes, Maya, Postclassic, Carbonate, Collagen, Nitrogen, Carbon

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EMILY DUKE

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DIETARY STUDY OF ISLA CANCUN: ANALYSIS OF THE POSTCLASSIC SITES OF EL REY AND SAN MIGUELITO

by

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DEDICATION

This manuscript is dedicated to my mother who has always given me the freedom and support to find my own happiness and has always exploited her parental bragging rights, and to my father, whom I know, would have been proud of me too.

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1   INTRODUCTION

What we eat not only enables us to survive; it is also tied to our cultural practices. In present times, our economic status affects what food resources we have access to. Sometimes, what we believe, religious practices, affect what we will or will not eat, despite whether we can afford it. Trade and connections with other countries and cultures give us access to foods that would never have had available to us (White et al. 2001). Food is cultural, but food is also crucial to our survival. Our access to foods affects our bodies because we need that food to fuel our internal processes, and our culture, by regulating our access to foods, will affect our biology, making our bodies a product culture. This is the fundamental principle for interpretation of bioarchaeology, including dietary isotopic analysis (Argarwel and Glencross 2011). What we eat becomes nutrients to fuel our bodies, our organs, and our bones. These nutrients can then be analyzed to understand the diet of past populations.

Reconstructing diet has included the use of direct evidence, including faunal remains, microbotanical remains, pollen; and indirect evidence including skeletal pathology, dental caries and wear patterns. This evidence can inform us of menu items, but only give the estimate of how much was eaten by a group of people, not individuals. In the 1970s, dietary reconstruction using isotopic analysis added to diet reconstruction of individuals by direct analysis (Tykot 2004). In the Maya area, studies have focused on the importance of maize in the Maya diet. Ethnohistoric, iconography, and botanical remains, supported that maize was the dominant food staple of the Maya (White et al. 2001; White et al. 2006). Even the creation myth in the Popul Vuh recounts that humans were only successfully created from maize (White et al. 2006). This ideological and archeological significance and that maize is the dominate C_4 plant in the region, make investigation of the consumption of maize throughout the Maya world ideal for isotopic

analysis. Many of the first isotopic studies in Mexico; therefore, focused investigating the importance of maize (see Tykot 2002 for review). Most of these studies have been conducted in the Petén region, Belize, and Guatemala. These investigations span from the Preclassic to Postclassic time periods (Tykot 2002). There has been recent scholarship in the northern Maya Lowlands, exemplified by work at Xcambo.

My thesis project was conceived with the intent of utilizing isotopic dietary methodology to understand the dietary makeup of two populations from the Postclassic sites of El Rey and San Miguelito located on the Island of Cancun. The Island of Cancun offers ready access to marine resources indicating the communities could have had a more diverse diet rather than heavy reliance on maize typical for most Maya populations. The two burial populations were excavated from different contexts, the El Rey individuals were from ceremonial contexts and San Miguelito from residential ones (Cucina et al. 2018). Would the isotopic values indicate a difference between the sites? Could this be tied to status? Four individuals from the site of El Rey had strontium and oxygen isotopes values that indicate that they were not originally from the island, but from other areas of the Maya area, the west coast of the Yucatan, the central Maya region, Belize, and the northern Petén (Ortega et al. 2015). Did these individuals continue the foodways from their previous communities or did they adopt a similar diet of the local individuals? With this in mind, the following research questions were developed to frame the isotopic investigation.

1. Do the isotopic data indicate that communities of El Rey and San Miguelito were utilizing the marine resources that were so readily available or were they reliant on maize like the majority of the inland Maya communities? If they were using marine resources, what do the data show about the types of marine resources begun utilized?

2. Do the isotopic values within each site indicate differential access to food resources based on sex or age? In comparing the sites of El Rey and San Miguelito, are there similarities and differences? Do these differences indicate significant differences in food access?

3. Given the presence of four non-local individuals in the burial population at El Rey, and based on what we know about Contact coastal sites being multiethnic places, did these non-local people bring with them their own foodways or did they adapt to the local foodways? Also, do the dietary results indicate anything about the status of these individuals relative to the rest of the population?

The isotopic dietary investigation discussed in this thesis was conducted on individuals from the burial populations of El Rey and San Miguelito, who are housed at the Instituto Nacional de Antropología e Historia (INAH) facilities in Chetumal, Quintana Roo, Mexico. These sites are located on Cancun Island in the northeast of Quintana Roo, Mexico (Figure 1.1). These sites date generally to the Maya Postclassic period. The individuals from El Rey (N=43) were excavated between 1976 to 1978 and 2008 from areas in the site that had a ceremonial function (Cucina et al. 2018). The individuals from San Miguelito (N=36) were excavated in 2006 from residential areas at the site (Cucina et al. 2018). The total burial populations were not included in this study. Individuals were chosen based on the availability of both a bone and tooth sample. A total of 30 individuals from El Rey and 20 individuals from San Miguelito had both a femur bone and molar tooth sample extracted for isolation of bone and enamel carbonate and bone collagen. The carbonate, which indicates the consumption of protein, carbohydrates, and fats, is analyzed for carbon isotopic values ($\delta^{13}C$). The bone collagen is analyzed for both carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic values, to indicate the likely sources of dietary protein

(Katzenberg 2008; Schoening and Moore 1992; Tykot 2004) that had been consumed by the two communities. As noted above, collagen isotope analysis is ongoing due to slower rates of demineralization in femoral cortical bone; these data are forthcoming, following the completion of this thesis project.

Figure 1.1 Quintana Roo, Mexico
Source(s): Data SIO, NOAA, U.S. Navy, NGA, GEBCO

1.1 **Chapter Summaries**

The following thesis is divided into chapters that discuss the cultural history of the Maya area, biological anthropological theory, isotopic methods for the reconstruction of past diet, a research design chapter, the carbonate results, and a discussion and conclusion chapter that

interprets the results within the research questions. Chapter Two provides an environmental and cultural overview of the area in which the study populations are located. The discussion includes an overview of the climate, environment, and ecology. The chapter summarizes the time periods associated with the Maya, from the Preclassic to Contact periods, the Caste War, and the development of tourism at Cancun. In so doing, I explore the main characteristics and developments that define these periods, giving a slightly longer discussion on the Postclassic, because the sites of El Rey and San Miguelito date to this period. The chapter concludes with a discussion of the Island of Cancun and its Postclassic characteristics.

Chapter Three provides a basic overview of the theoretical trends in biological anthropology. The chapter discusses the racial typologies and obsession with racial traits that was pervasive in skeletal biology and the influence of the change theoretical trends of the 1960s. After the 1960s, the discipline has striven, and in some options, is still trying to rid itself of the legacy of racial typologiest. Argarwel and Glencross (2011) separate these trends into three phases of theoretical trends the first engaging with research by looking at environmental and adaptive responses. The second wave saw a divergence of research foci, one into applications of new technologies and the other engaging with the nature of skeletal populations. The third wave of theoretical engagement has been to anchor bioarchaeological research into more contexts with archaeological remains.

Chapter Four explores the methodologies used to frame this investigative endeavor. This chapter is an explanation of the dietary isotopic analysis conducted. The chapter begins with an introduction to basic concepts for isotopic analysis, and provides a historical overview development of dietary isotopic analyses beginning with its connection to Carbon-14 dating. The chapter then moves onto the fundamentals of isotopic analysis by describing an isotope and

isotope fractionation in foodwebs. The section discusses the materials (bone and teeth) used and the substances isolated (collagen and carbonate) from each for the analyses, and describing the elements (carbon and nitrogen) analyzed from collagen and carbonate. I also review the limitation of dietary analyses, specifically from the Maya area. The chapter concludes with a discussion of the methods used to isolate collagen and carbonate to be analyzed for the nitrogen and carbonate values and the specific methods used in this investigation.

Chapter Five details the research design including contextual information about El Rey and San Miguelito and other information amount the Maya area that influenced the formulation of the research questions that are then presented. The chapter describes the method for selecting the individuals for the study populations of El Rey and San Miguelito and a detailed description of the individuals and their burial contexts. The isotopic methods for isolating carbonate and collagen from the bone and tooth samples that would yield carbon and nitrogen values for each individual.

Chapter Six discusses the carbonate results. The collagen results have not been received from the University of Florida, and so will not be presented in this thesis. The results for each site are discussed, with special attention to individuals whose results are sorted by sex estimation and age. The results for El Rey and San Miguelito are then compared to determine any similarities or differences based on the bone and enamel carbonate distribution.

Chapter Seven is the concluding chapter. This chapter details the interpretation of the results guided by the research questions. This discussion highlights the two possible scenarios for the carbonate results present. One is that the communities were consuming C_4 plants, like maize, with some C_3 plants, like legumes and squash, or that the communities were consuming marine protein. Based the convenience of the marine resources versus growing or importing maize,

utilizing marine resources was more likely. The results indicate that the people from both sites were utilizing the marine resources regardless of any status differences. This chapter also discusses the differences between the local and non-local individuals at El Rey, the carbonate values indicating that the non-local individuals adopted the local eating practices. The chapter concludes with a summary of the findings and how they might be enhanced by future research.

2   CULTURAL AND ENVIRONMENTAL CONTEXT

The sites of El Rey and San Miguelito are located on the Island of Cancun, in the northern Maya Lowlands (Andrews 2006). The northern Maya Lowlands are located in the Yucatan Peninsula, in the present-day Mexican states of Quintana Roo, Yucatan, and Campeche (Figure 2.1). Located on the Carrillo Puerto geological formation the area consists of limestone bedrock and a vast karst environment (QRSS 2001). The area was occupied by the Maya civilization from the Preclassic to the Postclassic (Demarest 2004). This chapter summarizes the environment of the Peninsula, the culture history of the major Maya periods, with special emphasis on the Postclassic, and then it discusses the sites of El Rey and San Miguelito.

2.1   Environment

The sites of El Rey and San Miguelito are located on the Island of Cancun off the east coast of the Yucatan Peninsula (Figure 2.1). The Peninsula is the exposed section of the Yucatan Platform (Luzzadder-Beach et al. 2012; QRSS 2001), which is part of the Carrillo Puerto geological formation (QRSS 2001). The Peninsula was once underwater and has only recently, geologically, been exposed. The Yucatan Platform consists mainly of limestone that formed around the Cenozoic era (White and Hood 2004) within the Miocene and Pliocene epochs (Meacham 2007; QRSS 2001). The area has a vast karst environment formed over time by very heavy rainfall mixed with carbon dioxide producing an acid that dissolved the permeable limestone bedrock. The karst environment contributes to the formation of cenotes, or water-filled sinkholes, that allow access to an underground aquifer. The karst environment contributes to a lack of rivers (Escolero Fuenter 2007; QRSS 2001; White and Hood 2004), with wetlands

forming over non-permeable limestone but there are few other water bodies (Escolero Fuenter 2007; QRSS 2001).

The Yucatan experiences abundant rainfall during the rainy season May to September, with rain accumulation ranging from 1400 mm and 2000 mm (Escolero Fuenter 2007; Luzzadder-Beach et al. 2012; QRSS 2001). The Yucatan is not only subject to heavy rainfall but is also impacted by tropical storms and hurricanes during the rainy season. The dry season lasts from October to May with about 30 cm of rain and cold fronts (*nortes*) (White and Hood 2004). Average temperatures range from 23°C in January to 28°C in May (Ward et al. 1985; White and Hood 2004).

Cancun is located at the northern tip of the Mesoamerican Barrier Reef. This reef is the largest reef in the Western Hemisphere, running the length the eastern coast of the Yucatan Peninsula, Belize, Guatemala, and Honduras. The reef spans approximately 700 miles. The reef provides habitat for a variety of marine fish, turtles, and sharks. Mangrove swamps can be found along the shoreline, providing habitats for birds and protect the area from damage from storms and hurricanes. These environments have been heavily impacted by global warming and tourism development (WWF 2017).

Figure 2.1 Lowland Maya Archaeological Sites mentioned in Text.
Sources: Data SIO, NOAA, U.S. Navy, NGA, GEBCO

2.2 **Maya Culture History**

Maya culture history is divided into roughly four periods before the arrival of the Spanish.

These include the Preclassic, Classic, Terminal Classic, and Postclassic (Table 2.1) (Demarest

2004). These divisions are based on various criteria including changes in ceramic assemblages,

stylistic elements, and architecture. The most defining features that denote the changes in

cultural periods are the extent of elite activity, trade, and population (Andrews and Castellanos

2004; Masson 2012).

Table 2.1 Maya Cultural Periods and Subdivisions.

Years (AD/BC)	Cultural Period	Subdivision
700 BC–200/250 AD	Preclassic	Middle Preclassic
		Late Preclassic
AD 200/250–900	Classic	Early Classic
		Late Classic

AD900–1100	Terminal Classic	-
AD1100–1521	Postclassic	Early Postclassic
		Late Postclassic

Source(s): Cucina et al. 2018; Ortega-Muñoz 2015b

2.2.1 *Middle Preclassic Period (200 BC to c. AD 200/250)*

The Middle Preclassic represents the earliest appearance of occupation of what is now the Yucatan and Quintana Roo (Andrews 1985; Andrews and Castellanos 2004; Glover et al 2012; Rissolo et al. 2005). During this period, developments occurred that were able to fuel growth into what would become the Classic period (e.g., Demarest 2004; Scarborough 1983). Elements critical to the divine-kingship of the Classic period developed during the Preclassic including the endowment of individuals with divine or supernatural power and that individual's contractual connection with other divine beings. The depiction of royal individuals on stelae with calendrical text and writing has its foundation in the Preclassic (Freidel and Schele 1988). Agricultural techniques developed during this time that would be able to support large populations including ridged fields, raised fields, terraced fields and location of canal networks. These techniques reduced the amount of slash and burn agriculture and help support a larger population that could not be supported with slash-and-burn agriculture alone (Scarborough 1983). An expanding population (Glover and Stanton 2010) and development of trade (Freidel and Schele 1988) lead to the emergence of elites and a hierarchical political structure (e.g., Glover and Stanton 2010; Freidel and Schele 1988).

The northern Maya Lowlands did not exhibit the same development as other areas in the Preclassic, but ceramic evidence indicates substantial occupation. A small number of small ball courts have been recorded in the Yucatan during the Preclassic (Anderson 2009; Andrews and Castellanos 2004). Ball courts were specialized spaces, formed with two parallel structures and usually had designated spaces for end zones or a small highly places ring on a wall. The game is

an important feature of the Maya world as a recreational sport, a form of public entertainment, and as part of ritual (Miller and Houston 1987). Other features found in the Maya area during the Preclassic, such as tombs and early writing systems have not been recorded in the area (Glover and Stanton 2010).

Depopulation during the end of the Preclassic (Andrews and Castellanos 2004) and the lack of large concentrations of people may have contributed to an absence of centralized power in Yucatan Peninsula at the end of the Preclassic (Glover and Stanton 2010). Between the Early Classic to the Postclassic, the area of the northern Maya lowlands was largely depopulated but not completely abandoned. Larger concentrations of people occurred in the central area, rather than those closer to the coast (Glover and Stanton 2010).

2.2.2 *Classic Period (AD 200 – 900)*

During the Classic period, settlements in the Yucatan Peninsula were densely located within the interior (Andrews 1985; Demarest 2004a; Glover and Stanton 2010). Populations grew along with increasing social hierarchy that began developing in the Preclassic and culminated with the divine-kingship political organization of the Classic (e.g., Baron 2016; Stuart 2005). The Classic Period having elaborate urban centers and widespread public architecture (Andrews 1985; Glover and Stanton 2010; Scarborough 1983). There was increase in long-distance trade (Sidrys 1976), use of polychrome ceramics, and the development of the Maya calendrical system (Andrews 1985)

Monumental architecture was a defining feature including civic buildings, residences, ball courts, ceremonial buildings, tombs (Andrews 1985; Glover and Stanton 2010), stelae, and causeways known as sacbes (Andrews 1985). Trade and economic connections formed throughout the Maya area (Andrews 1985) enabling the exchange of trade goods like obsidian

(Sidrays 1976). Polychrome and orange gloss ceramics are characteristic of the period (Andrews 1985; Glover and Stanton 2010). People were more densely populated in the interior (Andrews 1985), but people from inland sites near the coast would travel to the coast to fish, harvest salt, and participate in coastal trade (Andrews and Castellanos 2004).

Religion and political organization were tied tighter in the Classic period (Baron 2016), taking the form of the divine-kingship (Masson 2012; Freidel and Schele 1988). This type of rulership is a system tied to the ruler's authority and legitimacy to a divine power. This divine authority supported the highly stratified social hierarchy (Baron 2016). Eventually, the divine-king organizational structure was delegitimized (e.g., Andrews and Castellanos 2004). It has been suggested that this lack of confidence in the political and religious structures was caused by drought, lack of resources for a large population, among others (Amiers 2007). Many interior sites that were so heavily inhabited were depopulated and people moved to coastal areas (Amiers 2007; Masson 2012; McKillop 2010). This lead to the drastic political and social change marks the end of the Classic Maya period (e.g., Masson 2012).

2.2.3   *Terminal Classic (c. AD 600 – 1100)*

The Terminal Classic is marked by a significant social and political change. Often considered the fallout of the Classic period. The "collapse" during this time was not a complete loss of "civilization" but more a transitional period when social, political, and economic change from that of the Classic period over a long span of time (Luzzadder-Beach et al 2012). Depending on the severity of regional change, the Terminal Classic is either treated as its own period or lumped into the Postclassic (Aimers 2007).

Though there was great social change and decentralization, for a time, the site Chichen Itza rose to prominence and controlled various parts of the northern lowlands (Masson 2012)

developing long distance trade routes (Andrews 1990, 1993). However, the Terminal Classic is most notable for population decline in the southern lowlands (Andrews and Castellanos 2004) and the lack of elite activity, most notably the lack of construction of monumental architecture (Aimers 2007). Abandonment of sites occurred between the late 7th century AD and the early 10th century with a significant movement of people to the coast (McKillop 2010). Though the central part of the Peninsula was not totally abandoned (Amiers 2007; Andrews 1985; Andrews et al. 2003; Chase and Rice 1985; McKillop 2010; Masson 2012) the Postclassic period did not see a massive resettlement of the abandoned southern and central areas (Masson 2012).

2.2.4 *Postclassic (c. AD 1100 – 1521)*

The Postclassic has been described as a time of decline in both population and in aspects of the Classic period that had been previously glorified. Recently the trend in archaeology is to see the Postclassic as a time that has its own unique characteristics (Montañés 1986). Marked by the rise of the site of Mayapan that exerted a measure of political control over parts the Yucatan (Andrews 1985; Andrews et al. 2003; Glover et al. 2011; Lothrop 1934a), the period shows an increased use of marine resources and long-distance maritime trade in the wake of Chichen's decline (Andrews 1985).

During this period, population in the Maya Lowlands was concentrated in coastal areas (Andrews 1985; Andrews et al. 2003; Chase and Rice 1985; McKillop 2010) with very few population centers in the interior of the northern Yucatan and the region of the Petén lakes (Andrews 1987; Demarest 2004). The Maya relied heavily on marine resources (Andrews 1985) for food and use of the coast for long-distance maritime trade (Andrews 1985; Andrews 1990; Andrews et al. 2003; Chase and Rice 1985; Glover et al. 2011; McKillop 2010). This was in no small part due to the difficulty in growing maize on the coast (Roys 1957). Maritime trade

developed from the Preclassic to the Postclassic (Glover et al. 2011), but the Postclassic has the clearest evidence for extensive seafaring trade. The first instances of coastal trade appear with the sites on Isla Cancun, Cerros, among others on the east coast. Prominent trade goods were cacao, salt, cotton, and obsidian. Other trade items included shells, pottery, basalt, jade, greenstone, slaves, honey, and feathers. Coastal communities gained more autonomy during the Postclassic and the ability to make new alliances with the rising power Mayapan (McKillop 2010; Glover et al. 2011) and causing more local involvement in trade (Conner 1983).

Besides maritime trade, a distinctive style of architecture, known as the East Coast-style, appears on the east coast of the Yucatan (Andrews et al. 2003; Lothrope 1924b, 1924e; Montañés 1986). The architecture was smaller scale and made with rougher techniques than that of the previous time periods (Andrews 1993; Andrews and Andrews 1975) which created a large variety in appearance (Andrews 1993) (Figures 2.2 and 2.3). Types of architecture include temples, palaces, platform mounds, ball courts, shrines, altars, and benches, all of which were set on types of platforms or substructures (Andrews and Andrews 1975; Lothrop 1924b). Other notable characteristics are columns, some with serpents, flat and vaulted ceilings, and decorative moldings (Andrews and Andrews 1975; Lothrop 1924b). Artistic embellishments of architecture of the East Coast-style include Chacmool sculptures, sun-disks, speech-scrolls, feathered serpents, and groupings of warriors (Lothrop 1924c, 1924e). The East Coast-style extends from Vista Alegre to Chetumal (Conner 1983) and is found at sites including Xcaret, Tulum, Cozumel, El Rey and San Miguelito (Andrews and Andrews 1975; Vargas Pacheco 1978).

Figure 2.2 East Coast Architecture at Tulum, Quintana Roo, Mexico.

Figure 2.3 Example of Artistic Elements on Postclassic Architecture at Tulum, Quintana Roo, Mexico.

2.2.5   *Contact, Conquest and the Caste War (1511-1851)*

Ralph L. Roys in *The Political Geography of the Yucatan Maya* in 1957 describes the

political landscape of the Yucatan during the 16th century, as a one of split independent states that

occurred after the fall of Mayapan. The Island of Cancan and other sites located on the East coast

were located in the eastern province known as Ecab during the 16th century (Andrews 1985,

1993; Roys 1957). Named after the site of Ecab (Andrews 1985, 1993; Roys 1957), the

province's political organization was structured around the hereditary office of the *halach uinic*,

known as the *Ahau* or ruler who was the was the local head the town where he lived (Roys

1957). The *halach uinic* of Ecab presided over loosely connected populations centers (Andrews

1985) and local heads of other settlements offered him tribute (Roys 1957). However, based on

the size of these settlements, like Cancun, Tulum, and others, it is assumed that they retained

some measure of autonomy from the *halach uinic* of Ecab (Andrews 1985).

The "discovery" of the Yucatan Peninsula is attributed to Francisco Hernández de

Córdoba (Andrews 1985; Glover 2006) in 1517 (Andrews 1985). However, it is generally agreed

that the first European contact with the Yucatan Peninsula and the Maya happened with the

wreck of the *Valdivia* in 1511 near what is now Chetumal, Quintana Roo (Andrews 1985; Glover

2006; Lothrop 1924a). The two survivors of the Valdivia were Gonzalo de Guerrero and

Jerónimo de Aguilar, and they would lead different path in the wake of the Spanish Conquest.

Guerrero integrated into the local population, and was treated well, acquiring a spouse and

having children. Aguilar, however, did not fare so well. He was enslaved and after learning the

language, joined with Hernán Cortés and was influential in the eventual conquest of the Aztecs

as Cortés' translator. Guerrero, having assimilated, fought against the Spanish with the Maya.

After three campaigns, the Yucatan was finally conquered, and the city of Merida was established in 1542 by Montejo (Andrews 1985).

After the successful acquisition of the Yucatan, the Spanish instituted the *encomienda* system. This allowed the Spanish to demand tribute and forced labor form the Maya inhabitants, but the Maya did not go quietly. The Great Revolt occurred in 1546, but the revolt was put down by 1547 creating chaos in its wake. This was exacerbated by the population decline due to the introduction of European diseases among the Maya. The chaos, population decline, poverty, and general difficulty getting supplies to the eastern part of the Yucatan, lead the Spanish to decrease control of the area and eventually abandon it in the mid-17th century (Andrews 1985).

The Yucatan Peninsula remained in obscurity until the indigenous Maya, frustrated with the rule of Mexico, organized and revolted, beginning what is known as the Caste War. Governor Domingo Barret decreed that Carnival would not be held in Merida in the year of 1847 because of the fear of infiltration during the festivities; the fears were well founded as hostilities broke out that same year. The conflict caused heavy losses on both sides and raged until 1850, with the beginning of a stalemate. It would be the coming of a talking holy cross, translated through Juan de la Cruz, which would rally the indigenous Maya together to redouble their efforts to gain freedom from Mexican rule. Rallying at Chan Santa Cruz, the rebel Maya continued hostilities until 1855. At this point, with some indigenous Maya support waning, Mexican officials declared the Caste War over, leaving the indigenous Maya to their own devices. Throughout the succeeding years, smaller revolts take place, but were not connected to the Caste War rebellion (Reed 2001).

2.2.6   *Tourism (1974-2005)*

In the 1970s, Quintana Roo entered what is call the "tourist era" (Juarez 2002) due the expansion of tourism by the Mexican government with a major development project at Cancun (Baklanoff and Moseley 2008; Juarez 2002). The 50-million-dollar project was intended to develop Cancun, then a small fishing village, into a mecca for tourism along with the coast of Quintana Roo. This flourishing tourism lead to Quintana Roo becoming a state in 1974 (Baklanoff and Moseley 2008; Juarez 2002). There was a massive influx of tourist related services including hotels and restaurants. By the early 2000s, the economy was dominated by tourism, which accounts for over 50% of state income (Baklanoff and Moseley 2008). The development of tourism on the Island of Cancun lead to work of INAH archaeologists (Uribe 2005).

2.3   Cancun Island

Figure 2.4 Sites El Rey and San Miguelito, Island of Cancun.
Sources: Esri, HERE, Garmin, USGS, NGA, EPA, USDA

The sites of San Miguelito and El Rey are located on (Figure 2.4) the *Zona Hotelera* on

the Island of Cancun (Cucina et al. 2018). The Island of Cancun was previously called "Nizue"

in historic times (Andrews 2006). The name was associated with the largest prehispanic

community that was on the island. This community probably incorporated both the sites of El

Rey and San Miguelito (Andrews 2006) as they are only separated by two kilometers (Vargas

Pacheco 1978). There are at least 11 sites on the island, and most of them date to the Postclassic

period; however, there is no mention of a community inhabiting the island in Spanish accounts.

The name Cancun may have come from the word Kankun, which means seat or throne of the serpent. Serpent iconography is prominent at the sites (Andrews 2006; Vargas Pacheco 1978).

The first reports of El Rey come from an English Captain Richard Owens, he does not mention any pre-Hispanic settlements on the island but that there were freshwater wells. The first report of pre-Hispanic settlements on the island came from John Steven in 1842 who noted the presence of temples on the island and the similarity of the buildings to Tulum. Between 1877 and 1878, Augustus Le Plongeon and Alice Le Plongeon sailed the coast of Quintana Roo and described the ruins of Cancun, the ruins they notated as Nisucte probably refer to El Rey. William H. Homes visited the island and described, what was probably, San Miguelito noting columns and rooms. He also noted the presence of maize and coconuts on the island. The site was also visited by Channing Arnold and Fredrick J.T. Frost in 1909, drawing the first plan of El Rey with only the pyramid. Frost's map was very inadequate, but he did notate the similarity of the pottery to that of Tulum. The island was surveyed by Raymond Merwin in 1911. It is important to note that Vargas Pacheco mentions the lack of clarity presented by these individuals and that these previous authors were also citing other individuals, making the information even less reliable (Vargas Pacheco 1978).

In 1954, the first systematic excavation took place on the island conducted by William T. Sanders, but he did not publish any of the findings but did report that the ceramics were of the Tulum period. E. Wyllys Andrews IV and others excavated a shell midden on the island that dated to the Preclassic (Andrews IV 1974). Archaeological work was conducted by INAH on the Island of Cancun in response to related tourist construction (Uribe 2005). In 1975, archaeological work was conducted at El Rey by Pablo M. Mayer Guala of INAH who excavated and restored 60 structures. In 2009, Sandra Verónica Elizalde Rodarte excavated test pits at San Miguelito

due to the intended construction of a museum at the site. Maintenance on both El Rey and San Miguelito was conducted between 2010 and 2012 (Cucina et al. 2018).

The site of El Rey is divided into two sections; El Rey and Pinturas (Figure 2.5 and 2.6). There are seven structures in the site center of El Rey and 27 at Pinturas. Both sections of El Rey consist of two plazas one with a temple structure, platforms, and mural painting. The other plaza consists of two structures, two platforms, a palace structures, and an altar at the center. These sections of El Rey are bounded by residential structures (Cucina et al. 2018; Vargas Pacheco 1978).

INAH.
CENTRO REGIONAL DEL SURESTE.
PROYECTO CAN CUN.
QUINTANA ROO.
TOPOGRAFIA Y DIBUJO:
ERNESTO VARGAS PACHECO.
1976.
ESCALA:

CONJUNTO PINTURAS

Figure 2.5 El Rey Site Map (1 of 2) (Vargas Pacheco 1978:114).

Figure 2.6 El Rey Site Map (2 of 2) (Vargas 1978:114).

San Miguelito (Figures 2.7 and 2.8), like El Rey, is generally dated to the Postclassic, but a more detailed chronological examination must await future research. San Miguelito consists of three groups of structures, The Great Pyramid, The Group of the Dragons, and the Chaak group. The Great Pyramid group consists of a pyramid structure and is the most significant structure at the site as its construction is typical of ceremonial centers. Seven residential building and five palace-like structures, alters and mounds make up The Group of the Dragons. The dragons are a reference to the recovery of two serpent heads. The Chaak group consists of residential structures that were probably also used for economic or administrative purposes. It also has a large amount of carved stones, two representing the god Chaak (Cucina et al. 2018).

Figure 2.7 San Miguelito Site Map (1 of 2) (Vargas Pacheco 1978:113).

Figure 2.8 San Miguelito Site Map (2 of 2) (Vargas Pacheco 1978:113).

3 THEORY

Biological anthropology and its numerous subdisciplines have been critiqued for their lack of concern with broader political and economic processes, and how those shaped human biology. Bioanthropology still deals with the stain of racial studies of the past (Armelagos and Goodman 2001; Goodman and Leatherman 2001). The race concept was a prominent feature during the inception of anthropology and has dogged skeletal biology and bioarchaeology even to the present (Armelagos and van Gerven 2003; Zuckerman and Armelagos 2011). The theoretical frameworks since the 1960s have been driven by the need to distance the discipline from the historical legacy of racial classifications and descriptive analysis in skeletal biology (Agarwal and Glencross 2011).

Race as a natural concept was conceived out of pre-Darwinian ideas of the special creation of the earth and that all life was static. In this worldview, all beings were ranked on a divinely ordained ranking system, including humans. Various rankings were developed by figures like Carolus Linnaeus and Johann Friedrich Blumenbach. Racial differences were based on perceived biological differences (Armelagos and van Gerven 2003; Armelagos and Goodman 2001; Gould 1996).

The publication of Darwin's Origin of Species in 1859 and the introduction of Darwinian evolution and genetics should have begun reevaluating the biological validity of race, but Darwin's theories were instead used to justify race, racism, imperialism, and inequalities. Evolutionary concepts were used to search for racial "traits" through various means (Armelagos and Gaven 2003; Armelagos and Goodman 2001), including an obsession with cranial morphology (Armelagos and van Gerven 2003; Cucina and Tiesler 2005; Gould 1996). Individuals including Herbert Spencer, Taylor, and Morgan used Darwinian evolution to justify

assumptions in their analysis of culture. Cultural development was linked to moral progress and justified with a misrepresentation of evolutionary principles (Roseberry 2001). Skeletal studies stagnated into descriptive particularism (Armelagos and van Gerven 2003).

Until the 1960s, the only figure to go against this trend was Franz Boas by criticizing these racial typologies, and their usefulness in anthropological studies (Armelagos and Goodman 2001; Boas 1911). There wasn't a decline in the interest of racial studies until after World War II with the realization that biological race had been used to justify the Nazi's institutionalized genocide (Armelagos and Goodman 2001; Zuckerman and Armelagos 2011). This initial criticism focused on self-reflection, realizing the use of biological race categories implied naturalization and justified racism, and the misuse of data by racists. There was a reflection on the subjectivity of typological categories (Armelagos and Goodman 2001). During the 1950s, Sherwood L. Washburn proposed a "new physical anthropology" to go beyond description and frame investigations with hypothesis testing (Armelagos and van Gerven 2003). This would not be fully appreciated until the 1960's when combined with the influences of the "new archaeology" (Armelagos and van Gaven 2003; Zuckerman and Armelagos 2011)

Due to these criticisms, biological anthropology and skeletal biology began to move away from racial typologies as the framework for human and cultural variation (Agarwal and Glencross 2011; Armelagos and Goodman 2001). Subsequently, theory in skeletal biology and bioarchaeology, has strived to move away from this typological and descriptive past (Agarwal and Glencross 2011). The first efforts to theoretically engage with research were based around adaptive response to the environment (and cultural forces) and a population-based perspective (Agarwal and Glencross 2011). Influenced by the "New Archaeology" of the 1960s and the developing ecological approaches (Cucina and Tiesler 2005; Goodman and Leatherman 2001)

that focused on ecology and evolution as a means to explain human diversity (Goodman and Leatherman 2001), studies focused on ecology, adaptation, and emphasized concepts like health and nutrition, biodiversity, adaptations, and other interactions of cultural and environmental constraints (Cucina and Tiesler 2005).

A second paradigm shift saw research foci diverging into two areas. The first was the application of new and developing technologies, the use of isotopes for dietary (Tykot 2002, 2006; White 2012; White et al. 2006; Williams et al. 2005; Wright and Yoder 2003) and migration investigations (Schoeninger and Moore 1992; Sierra Sosa et al. 2014; Turner et al. 2009). These types of specialization focused studies have been critiqued for being too descriptive and lacking analytical and population-based focus (Agarwal and Glencross 2011; Armelagos and Van Gerven 2003; Goodman and Leatherman 2001). The second area of research is the focus on the nature of skeletal samples in the archaeological record. Early research in skeletal biology and forensic anthropology gave the impression that skeletons provided biological evidence that was unbiased (Agarwal and Glencross 2011; Wright and Yoder 2003). The publication of "The Osteological Paradox" by Wood et al. (1992) cataloged the challenges and biases of the skeletal record (Agarwal and Glencross 2011). The specific challenges brought up by Wood and others selective mortality and that the skeletal population does not actually represent the whole population and how this bias sampling affects studies (Wood et al. 1992). These challenges pushed researchers to investigate biological and cultural mechanisms of frailty (Agarwal and Glencross 2011; Jackes 2011; Knudson and Stojanowski 2008; Wright and Yoder 2003).

The third shift in theoretical engagement in bioarchaeology allowed for a greater contextualization of archaeological skeletal remains. Instead of only using archaeological context for mortuary practices, bioarchaeologists, like Buikstra and Beck (2006), emphasize the cross-

disciplinary use of archaeology, history, and other disciplines to contextualize bioarchaeological skeletal analyses of past lifeways. Bioarchaeology now emphasize the ethical reflections and the role of multiple interests in bioarchaeological analysis, most notably the descendants of the study population (Agarwal and Glencross 2011) and the reflection that the majority of previous scholarship has been done by foreigners (Cucina and Tiesler 2005)

The current goal of bioarchaeology, according to Agarwal and Glencross (2011:3), is to "transcend the skeletal body into the realm of lived experience and to make a significant contribution to our understanding of social processes and life in the past." However, based on articles by Armelagos and van Gerven (2003), Stojanowski and Buikstra, (2004), Buikstra (2006) and Zuckerman and Armelagos (2011) there is still debate on the use of specialized investigations. Armelagos and others indicate that these specialized studies run the risk of being too similar to the previous descriptive past of skeletal biology and bioarchaeology (Armelagos and van Gerven 2003; Zuckerman and Armelagos 2011) and are becoming more prevent in publications (Armelagos and van Gerven 2003). Others like Stojanowski and Buikstra (2004; 2005) disagree that these specialized investigations are a step backward and are more prevalent in recent scholarship. Stojanowski and Buikstra (2005) noted, based on an analysis of publications in the *American Journal of Physical Anthropology*, that researchers publish what Armelagos and van Gerven (2003) consider non-theory driven research in the beginning of their carriers but publish more analytical leaning publications later in their careers (Stojanowski and Buikstra 2005).

My own research mirrors these trends. My thesis incorporates the use of new technologies to understand the eating practices of the people on the Island of Cancun. This avenue of research does run the risk to be too descriptive, if I only stop at describing the diet of

El Rey and San Miguelito, this would not be considering any social context. This would mean that the only question I would ask is what were they eating, marine resources or maize? To move forward with this information, I incorporate the context of previous research at the site to look beyond what the two communities were eating and examine a broader social context. Where there difference based on age or sex? Based on previous research of biological affinity at both sites, El Rey and San Miguelito were not related (Cucina et al. 2018). Was this difference in biological affinity present in the isotopic data? Where they eating the same things or not? The two populations came from different context. The burial population from El Rey came from a ceremonial context and the San Miguelito population came from residential areas (Cucina et al. 2018). Do the isotopic data indicate status differences, given the different burial context? There were four individuals whose oxygen and strontium isotopic values indicated that they had come from other parts of the Maya area including the western part of the Yucatan, the central Maya area, Belize and the Petén lakes (Ortega et al. 2015). Did these individuals adapt the foodways of the locals or did they continue the dietary practices from where they had previously come? These questions follow in the previous trends of using specialized technology to understand a broader social context of the two communities of El Rey and San Miguelito. Chapter 4 details the theoretical background of isotopic analysis and Chapter 5 details the isotopic methods used for obtaining the isotopic values to answer these questions.

4   ISOTOPIC ANALYSIS METHODS

The human body is biological and cultural. This is the basis for the cultural interpretation of the human skeleton. Isotopic analysis of human skeletal remains can indicate changes in diet that may not only be related to survival, but the effect culture has on an individual's ability to have access to food resources. Trade between groups makes different foods available and hierarchical stratification can make those and other foods only available to a certain class of people. Access to food can be based on age, sex, religion, ethnicity, and other variables (e.g., Schoeninger and Moore 1992). Isotopic data from skeletal remains comes from isolated carbonate and collagen recovered from tooth and bone that indicate the amounts of proteins, carbohydrates, and lipids present in the diet of an individual. Given the values of these results, the types of foods consumed, like C_4 and C_3 plants and marine protein (Tykot 2004).

4.1   Development of Dietary Analysis

The use of isotopic analysis for investigation in past diet has its roots in the development of archaeological chemistry. Archaeological chemistry is a subfield of archaeology and involves the investigation of inorganic and organic structures found in archaeological remains. This includes analyses of elements, isotopes, molecules, and compounds. The original goals of archaeological chemistry were to authenticate and conserve archaeological materials by using chemical analyses to characterize and identify those artifacts (Pollard et al. 2007; Price and Burton 2011a). Important discoveries and developments in chemistry and archaeological chemistry eventually lead to the use of isotope analysis for dietary research in archaeological populations (Price and Burton 2011a).

During the 17th century, the first element, phosphorus (P), was described (Price and Burton 2011a). By 1860, 63 elements had been described. In the 19th century human artifacts

were discovered with extinct animals, leading to the acceptance of human kinds antiquity. This is important to the development of archaeological chemistry as early investigations using chemical analysis were conducted to resolve archaeological questions like chronology issues. In the mid-19th century, the origin of archaeological materials could be identified by their chemical composition (Price and Burton 2011a). The first isotopes were discovered in 1913, and by the mid-1930s most stable isotopes had been identified (Katzenberg 2008). In the 1930s, phosphorus was used to search for archaeological sites as high phosphorus levels were associated with ancient settlements. Fluorine absorption was used to uncover the forgery of Piltdown Man (Price and Burton 2011a). In 1942, the first commercial mass-spectrometer was used to analyze petroleum. After this, techniques with the use of a mass spectrometer advanced rapidly in chemistry, geochemistry, and biology allowing for more samples to be run at a more affordable cost. By the 1980s, new tools and instruments simplified the purification of samples (Katzenberg 2008).

A pivotal moment in archaeological chemistry was the discovery of radiocarbon by Willard Libby in 1955 (Price and Burton 2011a; Tykot 2006). Radiocarbon decays at a steady rate until all the ^{14}C is gone. Measuring this decay in wood and charcoal remains allowed archaeologists to be confident in the age of archaeological materials (Price and Burton 2011a). When Carbon-14 dating was used in dating archaeological materials, researchers noticed that there was variation in the radiocarbon dates when they came from human bones versus charcoal or maize. Carbon was the first isotope to be explored for dietary research due to archaeologists already being familiar with the radioisotope ^{14}C (Ambrose and Krigbaum 2003; Katzenberg 2008; Tykot 2004). The difference in radiocarbon dates in maize is due to maize fixing carbon

using a different pathway yielding a higher ratio of ^{13}C: ^{12}C ratio (Katzenberg 2008; Tykot 2004).

After analyzing stable carbon isotope ratios in dietary research, researchers began to expand using other elements to analyze diet. The most common elements used for dietary isotopic analysis are carbon and nitrogen, but strontium and oxygen are also used. The first applications of stable isotope analysis were during the 1990s and dealt with paleodiet. Later applications were for investigating duration of breastfeeding, residency and migration patterns, among others.

Maize played a key role in the subsistence of peoples throughout the Americas (Larsen 2002). Ethnohistoric, iconographic, and botanical analyses all supported the interpretation that maize was the dominant food staple of the Maya (White et al. 2001; White et al. 2006). Even the creation myth in the Popul Vuh recounts that humans were only successfully created from maize (White et al. 2006). Due to the ideology importance of maize, maize is assumed to have great importance as a food staple. Many of the first isotopic studies in Mexico focused investigating the importance of maize (see Tykot 2002). Most of these studies have been conducted in the Petén region, Belize, and Guatemala (Tykot 2002). The importance of maize ideologically and as a staple crop lead to the first paleodiet studies in the New World focused on the introduction of maize (Katzenberg 2008; Tykot 2004, 2006).

4.2   **Fundamentals of Dietary Isotopic Analysis**

The term isotope was first used by Fredrick Soddy, a Scottish chemist, to describe the observation that atoms with different atomic masses have the same chemical properties and are of the same periodic element (Price and Burton 2011b). Isotopes are atoms of the same element that have the same number of protons but a different number of neutrons within the nucleus

(Katzenberg 2008; Price and Burton 2011a; Schwarcz and Shoeninger 1991). The weight of an isotope is affected by the number of protons and neutrons. Due to the different number of protons and neutrons for each isotope, they have a different atomic weight. There are stable and radioactive isotopes. Carbon-14 (or ^{14}C) is a radioactive isotope, meaning it is unstable and decays over time. Isotopes like ^{13}C and ^{12}C are stable and do not deplete over time (Katzenberg 2008; Schwarcz and Shoeninger 1991). Stable isotopes important to dietary and environmental analysis are carbon, nitrogen, oxygen, hydrogen, and sulfur (Schwarcz and Shoeninger 1991).

The different weights of isotopes affect the rate of chemical reaction that takes place when converted. These different rates of chemical reaction create different ratios, or fractionation, of the isotope. Isotopic "fractionation" occurs because the different rates of chemical reactions when converted create different ratios of the isotopes. This fractionation is the basis for stable isotope variation in geochemical and biological systems (Katzenberg 2008; Schwarcz and Shoeninger 1991; Tykot 2004, 2006). Isotopic fractionation causes measurable differences in the ratio between the initial substance and the reaction product. An example would be the difference between atmospheric CO_2 and carbon fixation through photosynthesis. The CO_2 in the atmosphere will always be more abundant than the carbon found in plants after the plants have converted the carbon through photosynthesis (Schwarcz and Shoeninger 1991; Tykot 2006).

4.2.1 *Materials*

Human tissues are made up of atoms from various elements that include carbon, nitrogen, oxygen, etc. and can be used for dietary analysis (Schwarcz and Shoeninger 1991). The main tissues used in dietary analysis of human remains are bone and teeth. From these tissues collagen and carbonate are isolated for the measurement of various isotopic ratios, including carbon and

nitrogen (Katzenberg 2008) and are measured in the isolated components of tissue with a mass spectrometry (Price and Burton 2011b).

The amount of inorganic and organic tissues varies between the different tissues of bone, enamel, and dentine (Wang and Curling 1994). Bone is ~30% (proteins and lipids) and 70% inorganic (mineral matrix) (Katzenberg 2008; Wang and Curling 1994). The organic portion of the bone consists of protein, mainly collagen (up to 85 to 90%), and crystals of calcium carbonate (Katzenberg 2008; Schwarcz and Shoeninger 1991; Wang and Curling 1994). Enamel is almost completely inorganic, while dentine has less than 17% organic components and about 75% inorganic components (Wang and Curling 1994). The mineral fraction of bone and enamel incorporates carbon from the whole diet which included carbohydrates, protein, and fats (Katzenberg 2008; Tykot 2004, 2006), while the organic fraction typically represents a disproportionate amount of carbon from dietary protein, though this can vary depending on overall amounts of protein in the diet and various physiological factors (O'Connell et al. 2002).

One complication of this is that carbon in groundwater and soils can be exchanged for the carbon in the bone tissue (Schwarcz and Shoeninger 1991). Collagen can be well preserved for long periods of time after internment, which makes it ideal for isotopic analysis (Ambrose 1990). It contains both carbon and nitrogen that can be used to interpret protein intake (Ambrose 1990; Schwarcz and Shoeninger 1991; Tykot 2004, 2006). Even degraded bone can have collagen that can be isolated (Schwarcz and Shoeninger 1991; Tykot 2004, 2006). The use of both collagen and carbonate in the analysis creates a whole picture of the diet of an individual because of the use of both information about protein intake and whole diet (Katzenberg 2008; Price and Burton 2011b; Price and Burton 2011c). Tooth enamel crowns are inert once formed, and thus preserve dietary information from the time the of crown formation and maturation, typically during

infancy and childhood (Tykot 2004). However, bone experiences turnover throughout the life of the individual. Analysis of bone carbonate and collagen thus yields dietary information averaged over approximately the last decade of life, (Schwarcz and Schoeninger 1991; Tykot 2004, 2006). Therefore, comparing isotopic values in enamel carbonate to those in bone carbonate from the same individual allows researchers to reconstruct diet and compare it between early- and late-life (Sealy et al. 1995).

4.2.2 *Carbon*

Paleodiet research first focused on carbon because of familiarity with it due to carbon-14 dating (Katzenberg 2008). Carbon has two stable isotopes, ^{13}C and ^{12}C (Katzenberg 2008; Price and Burton 2011c; Schwarcz and Shoeninger 1991; Tykot 2004). Atmospheric CO2 is converted by plants into glucose and produces ^{13}C and ^{12}C in different ratios depending on the photosynthetic pathway that the plant uses to fix the carbon. The two different pathways are C_4 (or Hack-Slack) and the C_3 (or Calvin) photosynthetic pathway. The ability to distinguish between human consumption of either C_3 or C_4 plants is due to the inherent non-overlapping ranges of C_4 and C_3 plants (Katzenberg 2008; Schoening and Moore 1992; Schwarcz and Shoeninger 1991; Tykot 2004, 2006). Using carbon for dietary analysis begins in the atmosphere which has a δ ^{13}C ratio of -0.8‰. During photosynthesis the chemical reaction that takes place to fix carbon in the plants either attached four or three carbon atoms to form the carbon isotope. Plants, such as maize, sorghum, millet, amaranth, and sugarcane are C_4 plants. Plants such as squash and beans are C_3 plants. Bone collagen values of $\delta^{13}C$ for C_4 plants range from -9 to -14‰ and C_3 plants range from -20 to -35‰. There is a third pathway is known as CAM (crassulacean acid metabolism), which includes succulents, and has values that resemble both C_4 (Katzenberg 2008; Schwarcz and Shoeninger 1991; Tykot 2004, 2006), but these plants are

unlikely to be major dietary sources, compared to the abundance of C_4 and C_3 grasses and plants, and would not contribute as much to the overall nutrient values (Tykot 2002).

C_4 pathway plants metabolize carbon dioxide by converting a four-carbon compound, that incorporates more ^{13}C. Plants that use the C_3 pathways convert a three-carbon compound. The values in bone collagen reflect the differences because the values do not overlap (Price and Burton 2011c). Values of $\delta^{13}C$ bone collagen ranges from approximately -5‰ to -25‰. Less negative values indicate more marine foods and/or C_4 plants (Katzenberg 2008).

It is important to understand the diets of the animals that are consumed by humans because there is enrichment of isotopic values by trophic level, or with each step of the food chain (Katzenberg 2008). In controlled dietary studies, collagen was enriched by 5‰ relative to diet, and carbonate was enriched by 9.4‰. Enrichment remained constant in apatite even with changes in diet. Collagen enrichment did change with differences in protein consumption relative to diet (Katzenberg 2008; Price and Burton 2011c; Tykot 2004). Though this study does not have a comparative animal isotopic values, the issue of topic effect on the human isotopic values was taken into account.

4.2.3   *Nitrogen*

Nitrogen, like carbon, has two stable isotopes ^{15}N and ^{14}N (Katzenberg 2008; Price and Burton 2011c; Schoening and Moore 1992; Schwarcz and Shoeninger 1991; Tykot 2004, 2006). The use of nitrogen in dietary research is analyzed to evaluate marine protein (Katzenberg 2008; Schoeninger et al 1983; Tykot 2004, 2006), freshwater protein, and other meat protein intake within the diet (Price and Burton 2011b).

Nitrogen is greatly affected by trophic level and is enriched as it is moved from one organism to another up the food chain. Plants fix nitrogen in one of two ways. One is bacteria

that live in the roots of plants and fix the nitrogen, along with other elements, to make them available to the plant. Another method is that plants obtain nitrogen from decomposing material as the decomposition process breaks down ammonia (NH_3) or nitrate (NO_3). Legumes have been shown to cause increased nitrogen values (Katzenberg 2008). Natural levels of nitrogen range from -5 to -10‰ (Price and Burton 2011c).

Values are used to infer trophic level and, ideally, researchers would have a range of values from various animals and plants from the environment to analyze and compare to the human values. Herbivores and carnivores have nitrogen values ($\delta^{15}N$) of approximately 3‰ higher than nitrogen values of their diet (Katzenberg 2008). Values in human bone range from 5‰ to 10‰ (Price and Burton 2011b). Freshwater fish also exhibit trophic level effects in nitrogen and a slight increase in carbon. Water stress also enriches nitrogen in tissues. When an individual experiences protein stress, from lack of protein, the body breaks down and reuses tissues, causing an increase in the levels of nitrogen (Katzenberg 2008).

4.2.4 *Limitations of Isotopic Analysis*

Isotropic analysis can have its limitations due to the preservation and availability of individuals with sufficiently preserved tissues (Jackes 1993; Webster 1997; White 2012). In the tropical environment of the Maya area, hot, humid, and acidic soils rapidly degrade bone (Webster 1997; White 2012). Burial contaminants can lead to the loss or diagenetic alteration of isotopic ratios from the remains (Schwarcz and Shoeninger 1991). Human skeletal remains can become fragmentary and have been disregarded in past investigations (Webster 1997).

This selective practice and unsystematic recovery of remains in the past, creates a sampling problem in skeletal research, including isotopic dietary reconstruction. Maya burials are mostly found in architecture, whether they are in residential areas or site centers. The location of a burial

is not always easy to predict and makes recovery efforts difficult. Increasingly, human remains are systematically recovered when they are encountered. However, there are still problems with sampling and many researchers include curated collections of remains in their studies and this can be problematic. These individuals were recovered in completely different circumstances and for different research agendas and future researchers are only left with the individuals that were recovered in those past investigations (Webster 1997).

4.3   **Review of Methods**

Developing standardized methods to remove visual contaminants like dirt, as well as bacteria, and fungus is important to ensure the accuracy of results, as contaminants can affect the carbonate and collagen yields and isotopic values (Ambrose 1990). However, the methods to isolate the various substances, carbonate and collagen, are destructive in nature. To analyze the various tissues, samples must be ground and soaked in acids and bases of different amounts and concentrations. Various methods have been developed to isolate collagen and other components of tissues to analyze for dietary information. These methods are crucial for isolating the carbonate and collagen from the contaminating conditions that can occur in burial environment and yield inaccurate isotopic values (Ambrose 1990; Katzenberg 2008).

The use of carbonate was first proposed by Sullivan and Kruger (1981) but initially there were some reservations about its use (Ambrose and Krigbaum 2003). However, several studies indicated that carbonate was a viable and reliable substance for use in dietary analysis (Katzenberg 2008). Methods have been developed for isolating carbonate from bone mineral or tooth enamel (Lee-Thorp and van der Merwe 1991; Lee-Thorp et al. 1989). Bone tissue is ground and soaked in sodium hypochlorite, removing the organic material from the bone sample and isolating the carbonate portion. Contaminates from the burial environment are removed by

soaking the ground material in acidic acid and the samples are then exposed to phosphoric acid to release the carbonate.

The suggestion of demineralizing bone to improve collagen accuracy was first suggested by Hal Krueger in 1965 (Ambrose and Krigbaum 2003) There are typically three methods used for isolating collagen. The first method, described by Sealy (1986), consists of decalcifying small bone chunks in a hydrochloric acid solution with an additional soak in sodium hydroxide to remove burial contaminants. The samples are then freeze dried. The second method takes small chunks and demineralizes them in EDTA (ethylenediaminetetriacetic acid) and sodium salt to isolate the collagen (Bocherens et al. 1995; Tuross et al. 1988). The third method takes powdered bone and demineralizes it in an 8% hydrochloric acid solution for approximately 18 minutes. This is followed by a slow hydrolysis in water with a weak acid (Brown et al 1988; Katzenberg 2008; Longin 1971; Schoeninger and DeNiro 1984; Schwarcz and Shoeninger 1991).

A variety of natural processes occur in the burial environment and can leave trace amounts of fungus, dirt, and the absorption and loss of organic material (Schwarcz and Shoeninger 1991). To determine that the material that is being analyzed is collagen, researchers use the carbon-to-nitrogen ratio (Katzenberg 2008), which should range of 2.7‰ to 3.6‰ for collagen that would be preserved enough to contain usable isotopes for analysis (Katzenberg 2008; Schwarcz and Shoeninger 1991).

4.3.1 *Mass Spectrometer*

Laboratories use various instruments to describe different energies in terms of the electromagnetic spectrum that covers the range of electromagnetic radiation (Price and Burton 2011a). Mass spectrometers are able to measure ratios for specific elements and can measure atomic weights that differ by one atomic mass unit (AMU). The mass spectrometer separates the

atoms into a "mass spectrum" based on their atomic weights and counts the number of particles based on a known weight that corresponds to the element or particle being analyzed. The instrument puts the particles through an electric and/or magnetic field to sort the particles by their weight. Usually two or more isotopes are measured using gas or liquid chromatography and a mass spectrometer to identify the different molecules (Price and Burton 2011b).

Measurements of the instrument used in the analysis, precision, accuracy, and sensitivity are all relevant criteria, but the most important is precision. The accuracy of the instrument is the ability for the instrument to provide the correct reading. Sensitivity is the size of the smallest amount that the instrument can measure. Precision is the ability of the instrument can reproduce the same result, whether it is correct or not (Price and Burton 2011a). Instruments used for the analysis use an interface of a combustion furnace, gas analyzers, and a mass spectrometer. Elements, such as hydrogen (H), oxygen (O), nitrogen (N), and carbon (C), are introduced as gases (H_2, CO_2, N_2, and CO_2) (Katzenberg 2008).

The abundance of stable isotope ratios is reported relative to the international standard, National Bureau of Standards (NBS), material. The standard material is used so that values can be compared between labs (Katzenberg 2008; Schoening and Moore 1992; Tykot 2004, 2006). The standard for carbon is the PeeDee Belemnite (PDB) formation and values are reported as negative, because the ratios in biotic systems are lower than the standard material. The nitrogen standard is AIR, or rather the actual atmosphere which has a $\delta^{15}N$ value of 0‰ (DeNiro and Schoeninger 1983; Price and Burton 2011c; Schoening and Moore 1992; Tykot 2004, 2006). Isotopic values are reported permil (‰) as the ratio is multiplied by 1000 (DeNiro and Schoeninger 1983; Katzenberg 2008; Price and Burton 2011c; Schwarcz and Shoeninger 1991; Tykot 2004, 2006). Most mass spectrometers can measure carbon ($\delta^{13}C$) with an analytical

precision of +/- 0.1‰ and nitrogen (δ^{15}N) with an analytical precision of +/- 0.2‰ (Katzenberg 2008).

Dietary isotopic analysis has been used since the 1970s to reconstruct the diet of past individuals. Initially influenced by the differences in dates for materials like human remains and maize, the technology was first used to study the stable isotopes of carbon to distinguish between different plant that past groups were consuming. In the Americas, the introduction and importance of maize was the focus of these first studies. Eventually other isotopes were used in distinguish dietary marine protein with the use of nitrogen isotopes. The human tissues used in these analyses are teeth and bone which are processed to remove dirt, fungi and other burial contaminants that can yield inaccurate isotopic values. The teeth and bones are isolated for collagen, which indicates protein consumption, and carbonate, which yield values that incorporate the protein, carbohydrate, and fats consumed. This study included the processing of human bone and tooth enamel for isolation of bone collagen for nitrogen analysis and enamel carbonate for whole diet. The methods used to remove burial contaminants and isolate these substances are detailed in Chapter 4. The results of the analysis are found in Chapter 5.

5   RESEARCH DESIGN

Dietary reconstruction in the Maya area has been used to determine the importance of maize. The importance of maize ideologically along with other archaeobotanical remains suggested that maize was an important part of past diets, but it wasn't till the use of isotopic dietary reconstruction that were researchers able to gauge the amount of maize being consumed and by who (Tykot 2006; White et al. 2006; White 2012). Research in the Maya area has also centered on access to marine resources (Sierra Sosa et al. 2014; Williams et al. 2009). Based on several studies, El Rey and San Miguelito have the potential to have a maize heavy, or C_4 plant, diet with the possibility of C_3 plants, like squash and legumes (Coyston et al. 1999; Mansell et al. 2006; Sierra Sosa et al. 2014). However, based on the location of the Island of Cancun and the limited space available for the growing of maize, it would be presumed that the inhabitants would be using the marine resources (Williams et al. 2009) like shark, rays, grouper, snapper, and other reef fish (Götz 2008; Hamblin 1980).

Based on the findings of the researchers at Xcambo, an ancient Maya port site along the north coast of the Yucatan Peninsula, the carbonate results indicate that the people at the site were consuming a combination of C_4 and C_3 plants, most like maize, squash, and beans, which make up the core of the Maya diet. The Xcambo results indicated that the inhabitants were consuming largely C_4 plants, but this was amended to include at least 50% marine resources with the contribution of the collagen nitrogen results (Sierra Sosa et al. 2014). Isotopic data from Marco Gonzalez and San Pedro, Belize, conducted by Williams et al. (2009), revealed that the carbonate results have the potential to be enriched by the addition of marine protein. This gives the opportunity to understand the contribution of marine protein from carbonate results which

will be improved with the addition of the nitrogen collagen results when they return from the

University of Florida in Gainesville.

Figure 5.1 Comparative Maya Sites.
Sources: Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Previous research at the site of El Rey opens a unique line of inquiry. This work involved

a study of biological affinities of the site of El Rey with other sites (Ortega-Munoz 2015b;

Ortega-Munoz et al. 2015) along with a study of population movement using oxygen and

strontium isotopes. Using frequency of dental traits from permanent teeth, El Rey was found to

have similar comparable patterns in teeth as those found at El Meco, a coastal site just north of

Cancun (Figure 5.1). The authors found that El Rey was similar in biological affinity to El Meco

(Cucina et al. 2008). Dental morphological analysis of both El Rey and San Miguelito indicate

that the sites did not have a biological affinity which was unexpected, given the close

geographical proximity (Cucina et al. 2018). As I will discuss below, it is interesting to see if the

isotopic data will mirror this unexpected difference.

The oxygen and strontium isotopes (Table 5.1) indicated that four individuals were not

local to the island and had come from other parts of the Yucatan including coastal and inland

areas. The male individual from Burial 7 was from north coast of the Yucatan, possibly the area

of Xcambo. Individuals from inland location were Burial 23-1 and 32. The female individuals

from Burial 23-1 could have originated from northern Belize or northern Petén. The individual

from Burial 32, was a female and could be from the northern Lowland Maya region based on the

strontium isotopes, but the oxygen values indicate the Petén or Northern Petén region.

Table 5.1 El Rey Non-Local Burials Strontium and Oxygen Results.

ID	Burial	$^{87}Sr/^{86}Sr$	$\delta^{18}O$	Sex	Age
EDGSU4	7	0.7088	-1.2	Male	30.0
EDGSU13	23-1	0.7085	-1.5	Female	>30
EDGSU16	28	0.7081	-4.5	Adult	>30
EDGSU17	32	0.7090	-2.9	Female	Adult

Source: Ortega et al 2015.

The individual from Burial 28 was an adult individual older than 30 years and had both a

coast and inland origins, depending on the striatum or the oxygen value. The oxygen indicated

they could be from either near the central Maya Region, like Tikal, and the strontium indicated

the Gulf Coast as a place of origin (Ortega-Muñoz et al. 2015). Are there similarities in dietary

consumption between the local individuals and the non-local individuals from coastal areas? Are

there differences between the local individuals and the non-locals from inland area? Did the

non-local individuals adopt the floodways of the local populace or will the isotopic values

indicate that they continued their own food practices?

The population at El Rey was excavated from ceremonial areas; whereas, the San Miguelito individuals were excavated from residential areas (Cucina et al. 2018). It is a possibility that the differences between the sites are due to status, given that both sites were occupied during the Postclassic. Access to food is often tied to status and this is also evident in the Maya area (Williams et al. 2009). It is a possibility that the isotopic values will indicate the degree of stratification at the sites. Given this contextual information, the research questions featured in Chapter 1 allowed for a rich discussion of the results, rather than just a descriptive analysis of the diet of the two communities.

To estimate and interpret diet and dietary variation, individuals from both El Rey and San Miguelito were selected based on the availability of a tooth and a bone sample from the same individual. These samples taken from the individuals were a molar and a section of femur bone. These samples were processed using isotopic methods to isolate bone and tooth carbonate, and bone collagen. The isolated carbonate and collagen was analyzed using a mass spectrometer at the University of Florida in Gainesville. The bone and tooth carbon carbonate will indicate the whole diet of the individual (protein, carbohydrates, and lipids). The nitrogen collagen will be used in conjunction with the carbonate results to discern the marine protein utilized by the individuals on the island. The individuals selected for the study are described below in section 5.1.1 and the isotopic methodology is described in section 5.2.1.

5.1   Methodology

5.1.1   *Sample Selection*

The following paragraphs details the individuals chosen for isotopic diet analysis with burial contexts. Each individual was chosen because both a tooth and bone sample could be sampled for dietary analysis. The contextual information for El Rey comes from a database

provided by Allen Ortega-Muñoz of INAH. Information for San Miguelito is also found in

Informe de análisis osteológico macroscópico de los restos óseos provenienes del "Proyecto

Arqueológico San Miguelito, Cancún", Quintana Roo: Temporadas de excavación 2011-2012 by

Dr. Allan Ortega-Muñoz (2015a).

5.1.2 *El Rey Burial Sample*

A total of 48 individuals from the site of El Rey are housed at the Instituto Nacional de

Antropología e Historia (INAH) Quintana Roo facility in Chetumal, Quintana Roo, Mexico. The

individuals were excavated from ceremonial areas at the site (Cucina et al. 2018). Thirty of the

individuals from El Rey were selected for dietary reconstruction based on the availability of a

femur bone and enamel tooth sample (Table 5.2). There were 15 males, 12 females, two adults,

and one subadult. Out of the sexed individuals the males ranged in ages from 30 to 65-years-old.

The females ranged in age from 30 to 46-years-old. Neither the adult nor the subadult had age

estimations. The sample from El Rey is skewed toward adult individuals, with the greatest

number being male (Allan Ortega-Muñoz, personal communication 2015).

The individuals from both El Rey population will be described in numerical order by

excavation season beginning with the two burials from 2008 and then the remaining individuals

from the 1976 to 1978 seasons. The only deviation from this ordering occurs when burials were

recovered from the same structure or area. The individuals are referred to by their burial number,

and he individual's age and sex estimation and type of interment are reported. The location and

the grave goods will be described, if the information is available. If the individual was not local,

the information on their previous location within the Maya area will be provided.

Individuals from Burial 2, Individual A, and Burial 3 were excavated in 2008. Individual

A, was a male more than 30 years-old and was a primary direct interment with Navula Burdo,

Cehac-Hunacti Compound, and Payil red ceramics (all Postclassic types) and conch shell fragments. Burial 3 was a male, 30 years-old and was a primary direct interment with Navula Burdo and Payil red ceramics, and a Chen Mul effigy. Also recovered from the burial was a conch shell with two perforations.

The reaming 28 burials individuals were excavated from 1976-1978 and were another Burial 3 followed by Burials 6, 7, 10, 11, 12, 14, 18, 19, 21, 22, 23-1, 23-2, 23-3, 27, 28, 31, 32, 36, 37, 38, 39,40, 42, 43, 45, 46, and 50. The second individual counted as Burial 3 was a male, younger than 30 years old at time of death was located in rubble and was a primary direct interment. Artifacts recovered from the burial were ceramic fragments and a perforated conch shell. Burial 6 was a 30-year-old male but had no other contextual information. Burial 7 was a 30-year-old male and was a primary direct burial located in Structure 2 that served a ritual function. Materials recovered from the interment were a small jade plaque, a copper ax and pincers, deer antlers, ceramic pots, and a conch shell (Allan Ortega-Muñoz, personal communication 2015). Oxygen and strontium isotope analysis indicated that the individual of Burial 7 could have been from the north coast of the Yucatan, possibly the area of Xcambo (Ortega-Munoz et al. 2015). Burial 10 was a 30-year-old male and was recovered from rubble and was a primary direct interment. Materials recovered from the burial were an obsidian fragment, a fish vertebra, and turtle bones (Allan Ortega-Muñoz, personal communication 2015). Burial 11 contained a 30-year-old male in a primary direct interment with a stone cylinder under the cranium, turtle bones, and a caracol shell. Burial 12 was a female younger than 30 years-old in a primary direct burial recovered from rubble with carnivore teeth and turtle bones, ceramic fragments, and a conch shell.

Burials 14, 18, 19, 21, and 22 were all recovered from Structure 8B, which served a habitational function. The individual in Burial 14 is an adult less than 30 years-old from Structure 8B, a habitational structure, and was a primary direct interment with an obsidian flake, faunal bones, and a caracol shell. Burial 18 was female less than thirty years old and was a primary direct burial. Materials recovered from the interment was a jade bead, and fragments of concha shell and stucco. Burial 19 was a 33-year-old female, a primary indirect interment with an obsidian blade and a bead, and bird bones. Burial 21, a 30-year-old male was a primary direct burial recovered. Materials recovered from the interment were an obsidian flake, turtle bones, a shark tooth, ceramic fragments, and concha shells. Burial 22 is a 65 years-old female and was a primary indirect burial with an obsidian blade, fish vertebra, and fragments of ceramics and caracol shell (Allan Ortega-Muñoz, personal communication 2015).

Individuals from Burials 23-1, 23-2, and 27 were recovered from Structure 7 which served a religious and habitational function. Burial 23-1 was female less than thirty years old and was a secondary indirect burial recovered with faunal bones and a large concentration of ceramics (Allan Ortega-Muñoz, personal communication 2015). Previous migration research at the site of El Rey indicated that the Burial 23-1 individual could have originated from the north coast of Belize or northern Petén (Ortega et al. 2015). Burial 23-2, a female between 16 to 18 years-old, a secondary interment burial recovered with faunal remains and a large concentration of ceramics fragments. Burial 23-3 was a 28-year-old male but did not have any other contextual information. Burial 27 was a 33 years-old female and was a primary, indirect burial with a large concentration of ceramics and ash was found under the pelvis (Allan Ortega-Muñoz, personal communication 2015).

Burial 28 was an adult less than 30 years-old was a secondary indirect burial recovered from Structure 5 that served a ritual function (Allan Ortega-Muñoz, personal communication 2015). Strontium and oxygen migration values indicated the individual could be from either near the central Maya region, like Tikal, or from the Gulf Coast (Ortega et al. 2015). Burial 31 was a subadult with no age estimation, no other contextual information was (Allan Ortega-Muñoz, personal communication 2015).

Burial 32 was an adult with no age estimation recovered from the western side of Structure 9, a habitational structure. The burial was a primary direct interment (Allan Ortega-Muñoz, personal communication 2015) and the strontium isotope analysis indicated that the individual could be from the northern lowlands. However, the oxygen values indicate the Petén or Northern Petén region (Ortega et al. 2015).

Burials 36, 37, and 39 were all recovered from different wells at Structure 1-22, which served a habitational and ritual function. Burial 36 was a 36-year-old male and was a primary direct interment was recovered from Well 3, which served a ritual function. Materials recovered with the burial were snail shells (Allan Ortega-Muñoz, personal communication 2015). Burial 37 was primary indirect interment of an adult with no age estimation recovered from Well 2. A carbon sample was collected from associated ash. Burial 39 was a 42 years-old female and was a primary indirect burial recovered from Well 1, which served a ritual and habitational function. One shell was recovered with the burial (Allan Ortega-Muñoz, Personal communication 2015).

Individuals from Burial 40, 42, and 45, and 45 were recovered from the Pinturas area of el Rey. Burial 40 was a 36-year-old male, Burial 42 was a 33 years-old female, and Burial 45 was a 30 years-old female. There was no other burial information for these burials. The remaining individuals from burials 38, 43, 47, and 50 were not associated with any structures and

had no grave goods. Burial 38 was a 32-year-old female but had no other contextual information.

Burial 43 was a male with no age estimation, Burial 46 was a 30 years-old male, and Burial 50

was a 47 years-old male (Allan Ortega-Muñoz, personal communication 2015).

Table 5.2 El Rey Burial Context.

ID	Burial	Excavated	Structure/Function	Sex	Local vs. Non-local
EDGSU1	2 Individual A	2008	-	Male	Local
EDGSU2	3	1976-1978	Rubble	Male	Local
EDGSU3	3	2008	-	Male	Local
EDGSU4	7	1976-1978	Structure 2	Male	Non-local
EDGSU5	10	1976-1978	-	Male	Local
EDGSU6	11	1976-1978	-	Male	Local
EDGSU7	12	1976-1978	Rubble	Female	Local
EDGSU8	14	1976-1978	Structure 8B	Adult	Local
EDGSU9	18	1976-1978	Structure 8B	Female	Local
EDGSU10	19	1976-1978	Structure 8B	Female	Local
EDGSU11	21	1976-1978	Structure 8B	Male	Local
EDGSU12	22	1976-1978	Structure 8B	Female	Local
EDGSU13	23-1	1976-1978	Structure 7	Female	Non-local
EDGSU14	23-2	1976-1978	Structure 7	Female	Local
EDGSU15	27	1976-1978	Structure 7	Female	Local
EDGSU16	28	1976-1978	Structure 5	Adult	Non-local
EDGSU17	32	1976-1978	Structure 9, West Side	Female	Non-local
EDGSU18	36	1976-1978	Structure 1-22, Well 3	Male	Local
EDGSU19	37	1976-1978	Structure 1-22, Well 2	Male	Local
EDGSU20	39	1976-1978	Structure 1-22, Well 1	Female	Local
EDGSU21	6	1976-1978	-	Male	Local
EDGSU22	23-3	1976-1978	-	Male	Local
EDGSU23	31	1976-1978	-	Subadult	Local
EDGSU24	38	1976-1978	-	Female	Local
EDGSU25	40	1976-1978	-	Male	Local
EDGSU26	42	1976-1978	-	Female	Local
EDGSU27	43	1976-1978	-	Male	Local
EDGSU28	45	1976-1978	-	Female	Local
EDGSU29	46	1976-1978	-	Male	Local
EDGSU30	50	1976-1978	-	Male	Local

Source: Allen Ortega-Muñoz, Personal Communication 2015.

5.1.3 *San Miguelito Burial Sample*

A total of 39 individuals from the site of San Miguelito are housed at the INAH Quintana

Roo facility in Chetumal, Quintana Roo, Mexico. Out of these, 20 individuals were selected for

dietary reconstruction based on the criteria that the individuals had both a tooth and bone sample

available for extraction (Table 5.3). Of those individuals, two were female, five were male, and

13 were subadults, with ages ranging from two to six. Two individuals had no age estimation,

and the sexed individuals ranged from 20-60 years in age (Ortega-Muñoz 2015a).

The individuals from the San Miguelito population will be described in numerical order

by structure location. The individual's age, sex estimation, and type of interment. The location

recovered from the site and the grave goods will be described, if the information is available. If

the individual was not local, the information on their previous location within the Maya area will

be provided.

Individuals recovered from Structure 1 were in Burials 2, 13, and 22. Burial 2 was a 28 to

48-year-old male recovered with a shell fragment and faunal bones and teeth. Burial 13 was two-

year-old subadult recovered with a red shell with two drilled holes, a pottery sherd, and a

vertebra and mandible of a rodent. Burial 22 was a two-year-old subadult recovered with several

faunal bones, one bone with evidence of cremation, and a ceramic sherd (Ortega Muñoz 2015a).

Individuals from Burials 4, 5, 6, 7, 15, 18, 19,23, 25, 26 were recovered from Structure 3.

Burial 4 was a subadult two to three-years-old recovered with fish vertebra, faunal bones, two

shells, and charcoal fragments. Burial 5 was a six-years-old subadult recovered with ceramic

sherds, faunal bones and caracol shell fragments Burial 6 was a male approximately 25 years old

recovered with faunal bones fragments, shell fragments, ceramic sherds, obsidian blade

fragments, and a possible projectile point. Burial 7 was a subadult two years of age recovered

from Structure 3. Materials recovered with the burial were ceramic sherds, faunal bone fragments, and a crab claw (Ortega Muñoz 2015a).

Burial 15 was a 35 to 60-year-old male recovered with turtle bones and a red pot and coffee. Burial 18 was a 30 to 34-year-old male recovered with bird bones, a net weight, two awls made of bird bones, and a possible fan handle with incised decoration and two perforations at one end. Burial 18 also contained several manta ray tails with two having perforated holes. Burial 19 was a three-year-old subadult with no other contextual information. Burial 23 was a two-year-old subadult recovered with turtle bones, rat vertebras, and ceramic sherds. Burial 25 was a three-year-old subadult recovered with turtle bones and a coral fragment. Burial 26 was a five-year-old subadult recovered with a crab fragment, a faunal tooth, a snake vertebra, turtle bones, and a pottery sherd (Ortega Muñoz 2015a).

Individuals from burials 29 and 30 were both recovered from Structure 4. Burial 29 was a five-year-old subadult recovered with two white shell beads, the root of an animal tooth with a hole at one end, and a burned animal bone. Burial 30 was a 25 years old or older male recovered with a worked bone that was possibly a fan handle. Burial 41 was a 20 to 24-year-old female recovered from Structure 5 with no associated archaeological material. Burial 37 was a subadult with no estimation recovered from Structure 6. Associated materials were turtle bone fragments and a possible bone awl (Ortega Muñoz 2015a).

Burial 12b was a three-year-old subadult recovered from Structure XX. Materials recovered with the burial were a bird bone with cut marks, turtle bones, fish bones, caracol shells and one that was perforated, and a ceramic sherd. Burial 14 was a four-year-old subadult recovered from Structure XXX with faunal bones, ceramic sherds, a lithic fragment, and concha shells. Burial 42 was a female with no estimation recovered from Pavilion 2. Materials

associated with the internment was one bone fragment and ceramic sherds (Ortega Muñoz 2015a).

Table 5.3 San Miguelito Burial Context.

ID	Burial	Excavated	Structure/Function	Sex
EDGSU31	2	2011	Structure 1	Male
EDGSU32	4	2011	Structure 3	Subadult
EDGSU33	5	2011	Structure 3	Subadult
EDGSU34	6	2011	Structure 3	Male
EDGSU35	7	2011	Structure 3	Subadult
EDGSU36	12b	2011	Structure XX	Subadult
EDGSU37	13	2011	Structure 1	Subadult
EDGSU38	14	2011	Structure XXX	Subadult
EDGSU39	15	2011	Structure 3	Male
EDGSU40	18	2011	Structure 3	Male
EDGSU41	19	2011	Structure 3	Subadult
EDGSU42	22	2011	Structure 1	Subadult
EDGSU43	23	2011	Structure 3	Subadult
EDGSU44	25	2011	Structure 3	Subadult
EDGSU45	26	2011	Structure 3	Subadult
EDGSU46	29	2011	Structure 4	Subadult
EDGSU47	30	2011	Structure 4	Male
EDGSU48	37	2011	Structure 6	Subadult
EDGSU49	41	2011	Structure 5	Female
EDGSU50	42	2011	Pavilion 2	Female

Source: Ortega-Muñoz 2015

5.1.4 *Isotopic Methods*

Each individual from both El Rey and San Miguelito had bone and tooth enamel sample, and those samples were processed for the extraction of bone collagen, bone carbonate, and enamel carbonate. The methods for isolating carbonate have been adapted from van der Merwe et al. (1996), Ambrose (1993) and Schoeninger et al. (1989), as detailed in Turner et al. (2009). The results of the carbonate samples have been received and are presented in Chapter 6 and discussed in Chapter 7. The collagen isolation methods are detailed in Turner et al. (2010) to minimize burial contaminants modified from Linden et al. (1995) and Ambrose (1993). The

results for the collagen analysis are still pending, due to the inclusion of femoral cortical bone rather than ribs, and will be included in a future publication.

5.1.5 *Carbonate*

Carbonate was isolated from enamel and bone for carbon isotope classification. This was accomplished with the use of methods outlined in Turner et al. (2009). The enamel used for analysis was removed from each tooth with a Dremel cutter and abraded with an engraving cutter. After each sample was cut, the Dremel tool was cleaned with acetone to prevent cross-contamination. The enamel was then crushed into a fine powder using an agate mortar and pestle. The mortar and pestle were also cleaned after each sample to prevent contamination. The fine powder was then soaked for 72-hours in 2% NaOCl (bleach)/ddH2O solution until the chemical reaction in the solution had ceased. The samples were centrifuged, rinsed, and then diluted with ddH2O. This process was repeated until samples had a neutral pH. After being neutralized, each sample was soaked in 0.2% acetic acid solution for four hours at four degrees Celsius to remove any remaining contaminants in the samples (Turner et al. 2009).

The isolated carbonate samples were again centrifuged and diluted with ddH2O immediately after the four-hour soak until the sample had a neutral pH. This was done to prevent sample loss from the acetic acid solution. Samples were freeze-dried before being sent to the Department of Geological Sciences at the University of Florida, Gainesville. There the samples were digested in 100‰ phosphoric acid on an automated prep system at 50°C, interfacing with a VG prism mass spectrometer (Turner et al. 2009). Isotopic values are expressed as per mil (‰) in delta notation (δ) relative to the PeeDee Belemnite geological standard (vPDB).

This process was repeated for the bone samples for isolation of carbonate for carbon isotope analysis. Bone cuttings were taken from the small section of femur bone that had been

cut from the individuals for the isolation of carbonate and collagen. The only deviations from the above carbonate isolation methods were that the bone cuttings were washed and dried before being crushed with the agate mortar and pestle. The fine powder and small chunks of bone were separated with a sieve. The fine powder was separated from carbonate isolation using the above methods, and the bone chuck was separated for collagen isolation. Methods for collagen isolation are described below.

5.1.6   *Collagen*

Collagen was isolated from samples of a femur bone for analysis of nitrogen in hopes of determining the marine protein consumed by both archaeological populations. The isolation procedure has been adapted from Turner et al. (2010). The procedure for collagen isolation is designed to minimize contamination in smaller samples.

Bone samples separated from the sample to being isolated from carbonate isolation, after being crushed with a mortar and pestle. The samples were placed in a Soxhlet distillation apparatus for four hours and continually flushed with 10:5:1 solution of methanol, chloroform, and water to remove lipids. The samples were then air-dried for 48-hours at room temperature (Turner et al. 2010).

After lipid removal, the samples were placed in 15 ml annealed glass tubes with Teflon caps. Each sample was demineralized in 0.5 molar (M) HCl at 4 degrees Celsius until translucent. The HCl solution was pipetted out and replaced every 48-hour to renew the chemical reaction (Turner et al. 2010). Typically, bone collagen is isolated from rib cortical bone, which is much thinner than the dense, load-bearing cortex of the femoral diaphysis. Consequently, the femoral bone samples were relatively resistant to demineralization, and the methodology was adjusted during the demineralization process. The concentration of HCl solution was increased to

1M in samples that were not demineralizing, and the samples placed inside the fume hood at room temperature to facilitate the demineralization of the femur bone samples. According to experiments by Pestle (2014) and Tuross (2012) indicating that variation in HCl solution did not affect the isotopic values of the bone, I assumed the increase to 1M HCl solution would not affect the values from the collagen.

After the samples had been demineralized, the HCl solution was pipetted out and replaced with ddH2O until samples were neutral. The samples were then soaked in a solution of 0.1% KOH for 48 to 72 hours to remove humic acids and other organic contaminants. Samples were then diluted with ddH2O until neutral and then gelatinized in .05 HCl on a heating block at 93-97 degrees Celsius until the solution was reduced (Turner et al. 2010).

The gelatinized samples were filtered through the .045 μm Millipore syringe tips. The samples were filtered into 5 ml borosilicate tubes and freeze-dried for 3 hours under a vacuum. The freeze-dried samples were sent to the Center for Isotope Geoscience at the University of Florida, Gainesville to be analyzed on a Carlo Erba CNS analyzer connected stable isotope ratio mass spectrometer (Turner et al. 2010).

The samples processed for carbonate have been sent to the University of Florida in Gainesville, Florida and the carbon isotope results have been received. The results are presented in Chapter 6 and are discussed and interpreted in Chapter 7. The samples processed for collagen have been prepared and are ready to be sent to the University of Florida. However, because of this, these collagen data are not presented in this thesis. They will be included in a future publication where they will be analyzed and interpreted along with the carbonate values.

5.1.7 **Conclusions**

These isotopic methods and the setting of the coastal communities of the Island of

Cancun represent a unique investigative context. Given the importance of maize in previous

dietary research (see, Tykot 2002) and the importance of maize ideologically, it stands to reason

that despite the accessibility of marine resources, that the communities on the island might take

extreme measures to provide that staple. It is also possible, and far more likely, that the

individuals would have relied heavily on the marine resources available off the coast. Growing

maize on the coast was very difficult (Roys 1957) and it would have been far easier to fish than

to import maize. This means that there were three scenarios were possible on the island: reliance

on C_4 plants, in this case maize; a reliance on marine resources; or a mixture of C_4 and marine

resources. The bone and tooth sample from El Rey and San Miguelito were both processed using

the methods described above.

6   RESULTS

This chapter details the results of the isotopic analysis of the two populations of Cancun and a discussion of those results as they related to the research questions as stated in Chapter 7. The chapter details the burial populations of the two sites and the overall carbonate result from both San Miguelito and El Rey. The sites are discussed noting any clustering and associations of individuals as well as a discussion of how the sites compare to one another. As stated, the collagen results are not included in this thesis, as they have not been received from the laboratory facilities at the University of Florida. The collagen results will be included with the carbonate in a future publication. All carbonate values are ‰ (permil) relative to the PeeDee Belemite geological standard (vPDB).

7.1.1   *El Rey*

The individuals selected for isotopic analysis from the site from the site of El Rey (N=30) had a mean bone carbonate $\delta^{13}C$ value of -4.5+/-1.5‰ and a mean enamel carbonate $\delta^{13}C$ value of -1.6+/-1.1‰. The maximum bone carbonate value was -8.5‰, a male individual from Burial 3, who was older than 30 years of age. The minimum bone carbonate value was -2.7‰ from two females in Burials 12 and 39, a female greater than 30 years old and a 46-year-old female. The maximum enamel carbonate value was -4.6‰, was also from Burial 3, a male individual older than 30 years. The minimum enamel carbonate value was -0.3‰. This value was from the female individuals from Burial 12 who was older than 30 years old. The El Rey carbonate values can be found in Table 6.1 and the distribution of the carbonate results is depicted in Figure 6.1.

Table 6.1 El Rey Carbonate Results.

ID	Burial	Bone d^{13}C*	Enamel d^{13}C*	Sex	Age
EDGSU1	2, Individual A	-3.4	-0.9	Male	Adult

EDGSU2	3	-3.6	-0.6	Male	30.0
EDGSU3	3	-5.5	-4.6	Male	>30
EDGSU4	7	-4.7	-4.2	Male	30.0
EDGSU5	10	-3.0	-0.4	Male	30.0
EDGSU6	11	-3.6	-1.4	Male	30.0
EDGSU7	12	-2.7	-0.3	Female	>30
EDGSU8	14	-2.9	-1.0	Adult	>30
EDGSU9	18	-3.6	-1.2	Female	>30
EDGSU10	19	-3.2	-1.0	Female	33.0
EDGSU11	21	-3.5	-1.1	Male	30.0
EDGSU12	22	-5.8	-2.5	Female	65.0
EDGSU13	23-1	-5.3	-2.3	Female	>30
EDGSU14	23-2	-5.2	-1.4	Female	16-18
EDGSU15	27	-6.4	-1.4	Female	33
EDGSU16	28	-3.7	-2.3	Adult	>30
EDGSU17	32	-4.4	-2.5	Female	Adult
EDGSU18	36	-4.0	-3.9	Male	36
EDGSU19	37	-5.1	-1.2	Male	Adult
EDGSU20	39	-2.7	-0.9	Female	46
EDGSU21	6	-5.1	-3.0	Male	30
EDGSU22	23-3	-6.6	-1.4	Male	28.3
EDGSU23	31	-8.5	-2.5	Subadult	none
EDGSU24	38	-4.1	-1.1	Female	32
EDGSU25	40	-3.0	-0.5	Male	36
EDGSU26	42	-6.3	-1.0	Female	33
EDGSU27	43	-6.1	-0.8	Male	0
EDGSU28	45	-6.3	-1.1	Female	30
EDGSU29	46	-2.9	-0.5	Male	30
EDGSU30	50	-4.7	-1.7	Male	47

* Values in parts per mil (‰), vs VPDB

Figure 6.1 El Rey Carbonate Results.

When the results bone and enamel carbonate values are graphed, three distinct clusters of individuals are visible. These clusters have been noted using a green, red, and yellow circle in the El Rey graphs (Figures 6.1 through 6.3). Cluster I is distinguished by a green circle, Cluster II by orange, and Cluster III by a yellow circle.

Cluster I included the most individuals from the El Rey sample (n=21). This included individuals from Burials 2, Individual A, the 2008 Burial 3 and Burials 10, 11, 12, 14, 18, 19, 21, 23-2, 23-3, 27, 37, 38, 39,40, 42, 43, 45, 46, and 50. Of these individuals, 11 were male, nine females, and one adult with no sex estimation. The male individuals were from Burials 2, individual A, the 2008 Burial 3, Burial 10, 11, 21, 23-3, 37, 40, 43, 46, and 50. Burial 2, Individual A, 37, and 43 had no specific age estimation. The male individuals from Burials 3, 10, 11, 21, and 46 were all 30-years-old. The male individuals from Burials 23-3, 40, and 50 were

28.3, 36, and 47-years-old, respectively. The male bone carbonate values ranged from -2.9‰ to -6.6‰ and the enamel values ranged from -0.4‰ to -4.6‰, see Table 6.1 for specific values.

The nine females were from Burials 12, 18, 19, 23-2, 27, 38, 39, 42, and 45. Beginning with the youngest estimated age, Burial 23-2 was estimated to be 16 to 18-years-old. Burial 45 was 30-years-old. the individuals from Burials 12 and 18 were estimated to be older the 30 years. The female individual from Burial 38 was 32-years-old and Burials 19, 27, and 42 were both 33-years-old. The female from Burial 39 was 46-years-old. The bone carbonate values of the female individuals ranged from -2.7‰ to -6.4‰ and the enamel values ranged from -0.3‰ to -2.5‰. For specific values, please see Table 6.1.

Cluster II included six individuals, including one male, three females, an adult with no sex estimation, and one subadult. These individuals included individuals from Burials 6, 22, 23-1, 28, 31, and 32. The male individual from Burial 6 was estimated to be 30-years-old. The three female individuals were form Burials 22, 23-1, and 32 that were estimated to be 65, older than 30-years-old, and an adult with no age estimation, respectively. Cluster II included three of the four non-local individuals Burials 23-1, 28 and 32. The individual from 23-1 was from northern Belize or northern Petén. Burial 28 was from the central Maya area, possibly Tikal and Burial 32 could be originally from the northern Lowland Maya region or from the Petén (Ortega et al. 2015).

Cluster III was a linear distribution of three male individuals from Burials 3, 7, and 36. The male individual from Burial 3 was greater than 30 years old, Burial 7 was 30 years old, and Burial 36 was 36 years old. Burial 7 was one of the four non-local individuals, from the western Yucatan, possibly the area of Xcambo (Ortega et al. 2015).

Figure 6.2 El Rey Carbonate Results by Sex Estimation.

Figure 6.3 El Rey Carbonate Results by Age Estimation.

7.1.2   *San Miguelito*

The enamel and bone values for the individuals from the study population at San

Miguelito (N=20) can be seen in Table 6.2 and are graphed in Figures 6.4 through 6.6. The mean

bone carbonate value was -4.4+/-1.1‰ and the mean enamel value was -2.7+/-1.8‰. An enamel

value for Burial 6 was not returned for the enamel carbonate. The bone carbonate value for this

burial is included in the average, but is not graphed due the lack of an enamel value. The

maximum bone carbonate value was -7.8‰ and was, also, Burial 25, a subadult three years old.

The minimum value was -2.9‰. This value was from Burial 22, a subadult two years old. The

maximum value for enamel was -6.6‰ and came from Burial 25, a subadult three years old. The

minimum value was -0.3‰ from Burial 12b, a subadult 3 years old. A complete distribution of

the carbonate results is depicted in Figures 6.4 through 6.6. El Rey had previous research that

indicates four individuals were not originally from the Island of Cancun. It should be noted that

the individuals from San Miguelito are assumed to be local, as the results of strontium and

oxygen data from Douglas Price are in the process of being published and so are not included in

this study (Allan Ortega, personal communication 2017).

Table 6.2 San Miguelito Carbonate Results.

ID	Burial	Bone d^{13}C*	Enamel d^{13}C*	Sex	Age
EDGSU31	2	-3.6	-2.0	Male	-
EDGSU32	4	-4.9	-3.3	Subadult	2
EDGSU33	5	-3.4	-5.5	Subadult	6
EDGSU34	6	-3.9	-	Male	-
EDGSU35	7	-4.1	-1.9	Subadult	2
EDGSU36	12b	-3.7	-0.3	Subadult	3
EDGSU37	13	-5.6	-1.8	Subadult	2
EDGSU38	14	-3.7	-3.5	Subadult	4
EDGSU39	15	-4.2	-1.1	Male	35-60
EDGSU40	18	-4.0	-1.1	Male	30-34
EDGSU41	19	-3.8	-0.9	Subadult	3
EDGSU42	22	-2.9	-4.3	Subadult	2
EDGSU43	23	-5.3	-3.6	Subadult	2
EDGSU44	25	-7.8	-6.6	Subadult	3
EDGSU45	26	-3.6	-2.4	Subadult	5
EDGSU46	29	-4.2	-2.8	Subadult	5
EDGSU47	30	-4.3	-1.0	Male	+25
EDGSU48	37	-5.3	-1.2	Subadult	-
EDGSU49	41	-5.7	-2.1	Female	20-24
EDGSU50	42	-4.7	-5.2	Female	-

* Values in parts per mil (‰), vs VPDB

Figure 6.4 San Miguelito Carbonate Results.

When graphed, the San Miguelito individuals bone and enamel carbonate values distribute into three distinct clusters and one outlier. These three clusters are distinguished with circles. Cluster I with a green circle, Cluster II with a red circle, Cluster III with a yellow, and the Outlier with a blue circle (Figures 6.4 through6.6). Cluster I consisted of six individuals from Burials 12b, 15, 18, 19, 30, and 37. This cluster had three males and three subadults. The three males were from Burials 15, 18, and 30; and they were 35-60, 30-34, and older than 25, respectively. The three subadult were from Burials 12b, 19, and 37. Subadult from 12b and 19 were three-years-old. The subadult from burial 37 had no age estimation. The bone carbonate values ranged from -3.7‰ to -5.3‰ and the enamel values ranged from -0.3‰ to -1.2‰.

Cluster II consisted of the majority of the San Miguelito individuals totaling ten from Burials 2, 4, 6, 7, 13, 14, 23, 26, 29, and 41. These burials included two were male, one was

female, and seven were subadult. The two males were from Burials 2 and 6 and both had no age estimations. The female individuals was from Burial 41 and was estimated to be 20 to 24-year-old. The remaining seven subadults were from Burials 4, 7, 13, 14, 23, 26, and 29. Subadults from Burials 4, 7, 13, and 23 were estimated to be two-years-old. Burial 14 was estimated to be four-years-old and Burials 26 and 29 were five-years-old. The bone carbonate values ranged from -3.6‰ to -5.7‰ and the enamel carbonate values ranged from -1.8‰ to -3.6‰, for specific values see Table 6.2.

Cluster II consisted of three individuals from Burials 5, 22, and 42. One of the individual was a female and the remaining two were subadults. The female was from Burial 42 and had no age estimation. The two subadult were from Burials 5 and 22 and were six and two-years-old. Burials 5, 22, and 42 had bone carbonate values of -3.4‰, -2.9‰, and -4.7‰. The enamel values were -5.5‰, -4.3‰, and -5.2‰. The remaining individual in the San Miguelito study population was a subadult from Burial 25 with an age estimation of four-year-old. This individual did not cluster with any of the others, with a bone carbonate value of -7.8‰ and an enamel value of -6.6‰.

Figure 6.5 San Miguelito Carbonate Results by Sex Estimation.

Figure 6.6 San Miguelito Carbonate Results by Age Estimation.

The individual results from El Rey, when graphed, presented three separate clusters. As mentioned, Cluster I had the largest number of individuals (N= 21), Cluster II and III had significantly less individuals with six and three, respectfully. Cluster I and II were a combination of sexes and age estimations. Only Cluster III consisted of only males who were 30-years-old or older. Clusters II had three of the non-local burials and Cluster III had one. The carbonate results from San Miguelito, when graphed, depicted three clusters and one outlier. Cluster I consisted of six individuals, Cluster II with nine, and Cluster III with three. Cluster I had a majority of adult, all of which were male. Cluster II has the majority of individuals numbering nine, with a majority of subadults. Cluster III, totaling three individuals, had a majority of subadult. The outlier was a subadult and had the most negative values out of the San Miguelito population.

These results will be discussed and interpreted within the context of the study research questions in Chapter 7.

7 DISCUSSION AND CONCLUSIONS

Using the previous Maya dietary research presented in Chapter 5 as a contextual framework, a central objective of this thesis is to evaluate three possible scenarios that the isotopic data from the sites of El Rey and San Miguelito could represent. The communities could have been dependent on maize, as it was so ideologically important and critical to population growth. Alternatively, the communities could have been taking advantage of the marine resources that were readily available off the coast. Finally, there could have been a combination of both. A second objective is to evaluate whether there were differences between the study samples from the two sites, and whether there were there differences within the sample from either site. In interpreting the bone and enamel carbonate $\delta^{13}C$ results generated in this study, it is worthwhile to revisit the central questions posed in Chapter 1:

1. Do the isotopic data indicate that communities of El Rey and San Miguelito were utilizing the marine resources that were so readily available or were they reliant on maize like the majority of the inland Maya communities? What does the data show about the types of marine resources begun utilized?

2. Do the isotopic values within each site indicate differential access to food resources based on sex and age? In comparing the sites of El Rey and San Miguelito, are there similarities and differences? Do these differences indicate significant differences in food access?

3. Given the presence of four non-local individuals in the burial population at El Rey, and based on what we know about Contact coastal sites being multiethnic places, did these

non-local people bring with them their own foodways or did they adapt to the local

foodways? Also, do the dietary results indicate anything about the status of these

individuals relative to the rest of the population?

7.1   Regional Context

1. Do the isotopic values indicate that communities of El Rey and San Miguelito were

    utilizing the marine resources that were so readily available or were they reliant on

    maize like the majority of the inland Maya communities? What do the isotopic values

    show about the types of marine resources begun utilized?

This first objective of this study is not as simple as it may first appear, as the following

discussion will illustrate. Based on previous dietary isotopic investigations in the Maya area,

there are three possible scenarios for the communities at El Rey and San Miguelito, the first is a

diet relying heavily on C_4 plants, in this case maize, the second scenario of heavy reliance on

marine resources, or the populace could have been consuming a combination of both. Due to the

proximity to marine resources (Figure 7.1), the assumption is that the two communities on

Cancun Island would have relied heavily on marine resources like fish rather than having to rely

on maize. Maize was difficult to grow on the coast (Roys 1957), but it is not inconceivable that

maize could have been imported from the mainland. However, it would have been much more

convenient to utilize the marine resources located in the estuary to the west and the

Mesoamerican Barrier Reef to the east.

To determine the dietary scenario most likely used by the people from El Rey and San Miguelito, the carbonate results were compared to isotope values at the sites of Xcambo, Yaxuná, Chunchucmil, Lamanai, Marco Gonzalez and San Pedro. The site of Xcambo, Lamanai, Marco Gonzalez and San Pedro provide a coastal comparison and Yaxuná and Chunchucmil provide an inland context. Xcambo is located in close proximity to the northern Yucatan coast, having access to the Gulf of Mexico (Sierra Sosa et al. 2014). The site of Lamanai has riverine access to Chetumal Bay (Coyston et al. 1999). The sites of Marco Gonzalez and San Pedro have access to the Mesoamerican Barrier Reef (Williams et al. 2009). Chunchucmil is located inland but with access to the coast and Yaxuná is an inland site (Mansell et al. 2006). The El Rey and San Miguelito carbonate results are discussed within the context of the coastal sites of Xcambo, Lamanai, Marco Gonzalez and San Pedro and then with the inland context sites of Yaxuná and Chunchucmil.

Figure 7.1 Comparative Lowland Maya Sites.
Sources: Data SIO, NOAA, U.S. Navy, NGA, GEBCO

7.1.1 *Coastal Context*

The site of Xcambo is located on the northern coast of the Yucatan. The Xcambo

individuals' bone carbonate values ranged from -2.4‰ to -6.9‰. The researchers (Sierra Sosa et

al. 2014) conclude that the carbonate values indicated a diet high in maize content, about 60 to

80 percent. The δ^{13}C carbonate values from the individuals at Xcambo are not in the regional

distribution in Figure 7.2 due to the lack of enamel values. In comparison with the El Rey

individuals, all the individuals from El Rey were within the range of Xcambo except for Burial

31, which was more negative value of -8.5‰. The San Miguelito bone carbonate values were

also within the range of values present at Xcambo except for Burial 25, which was also more negative than the Xcambo population with a value of -7.8‰.

The site of Lamanai is a coastal site in northeast Belize. The study included individuals from the Preclassic to the Historic period (Coyston et al. 1999), but I only used the Postclassic individuals from the study for comparison. The site of Lamanai had values that ranged from -4.35‰ to -10.66‰. Coyston et al. 1999 stated that these ranges were indicative of a diet with a mixture of C_4 and C_3 plants (1999). The $\delta^{13}C$ carbonate values from the individuals at Lamanai are not in the regional distribution in Figure 7.2 due to the lack of enamel values. El Rey had more individuals (N=16) with more positive values, and the remaining (N=13) were within the Lamanai range. The majority of the San Miguelito individuals (N=13) were more positive than the Lamanai values with the remaining (N=7) falling within the values at Lamanai. The more positive bone carbonate values could indicate higher protein consumption (Tykot 2004, 2006) than the individuals at Lamanai, whereas the individuals with values falling within the Lamanai range could have similar C_4 and C_3 plant consumption.

The site of Marco Gonzalez is located on the Ambergris Caye off the coast of Belize with Chetumal Bay to the west and the Caribbean Sea to the east. The people of Marco Gonzalez would have had access to Chetumal Bay and the Mesoamerican Barrier Reef to the east for marine resources. The bone carbonate values for the site range from -4.4‰ to -8.8‰ from a total of 37 individuals. Williams and colleagues state that this values along with other dietary indicators of $\delta^{13}C$ and $\delta^{15}N$ collagen, indicate the diet of the population at Marco Gonzalez was primarily based on marine protein, but that some of the individuals may have consumed deer and maize (William et al. 2009). These values are not represented in the regional comparison in Figure 7.2, because of the lack of enamel carbonate values. The El Rey individuals were split
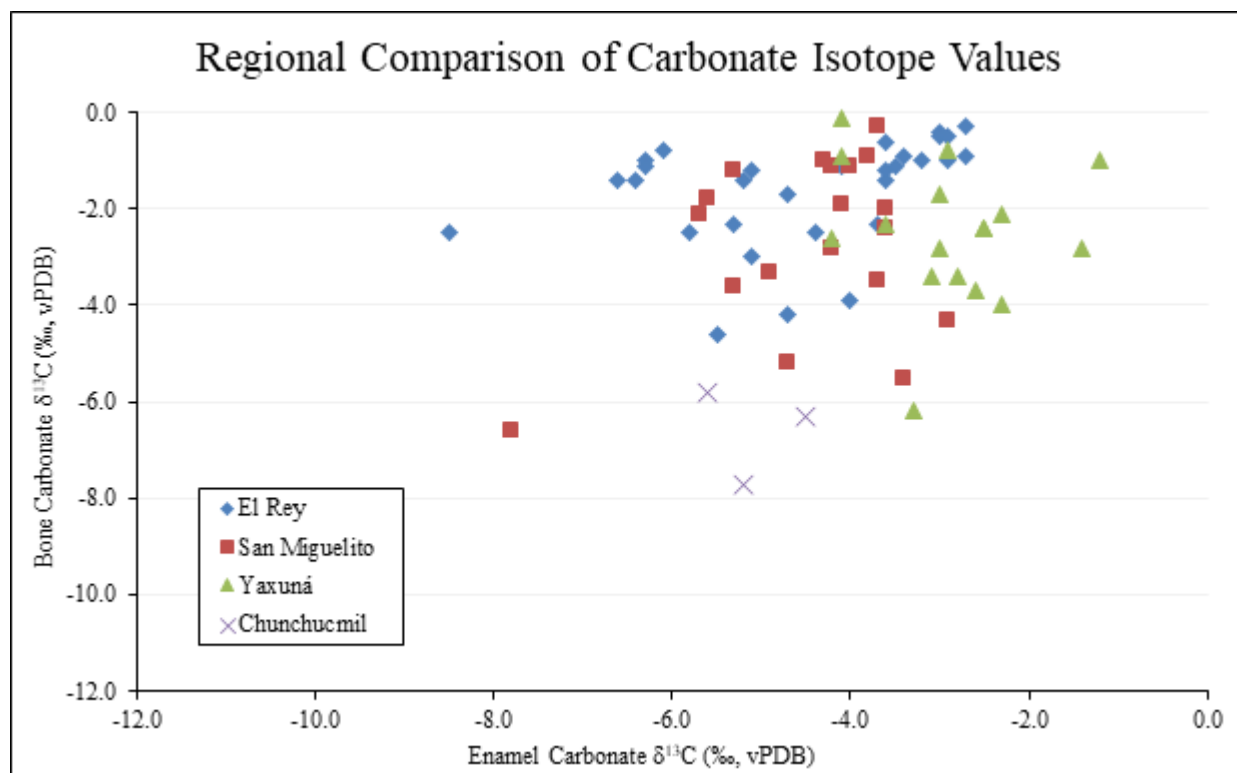
50/50, with half (N=15) falling within the bone carbonate range for Marco Gonzalez. The remaining individuals (N=15) had more positive in isotropic values.

The site of San Pedro is also located on the Ambergris Caye off the coast of Belize and also has the Chetumal Bay to the west and the Caribbean Sea to the east and would have had the same access, geographically, to the marine resources in Chetumal Bay and the Caribbean Sea. The individuals (N=29) from San Pedro had $\delta^{13}C$ a bone carbonate range of -2.0‰ to -6.9‰. The carbonate results combined with $\delta^{13}C$ and $\delta^{15}N$ collagen, the population relied heavily on marine resources (Williams et al. 2009). These values are not represented in the regional comparison in Figure 7.2 because there were not enamel carbonate values for comparison among the study sample at San Pedro. The vast majority of the individuals (N=29) from El Rey fell within the range of values at San Pedro, except for the individual from Burial 31 who had a more negative value than those from San Pedro. The majority of individuals from San Miguelito were also within the range of the San Pedro population, except for the individual from Burial 25 who was more negative $\delta^{13}C$ carbonate value of -7.8. ‰.

7.1.2 *Inland Context*

The site of Yaxuná is located in the middle of the Yucatan Peninsula. The individuals analyzed from the site of Yaxuná consisted of individuals (N=12) from a tomb dating to the Early Classic (AD 250–550 or 600) and burials from nonelite contexts (N=10) dating to the Late-Terminal Classic period (AD 550/600–1000). The site of Yaxuná had both bone carbonate and enamel values for comparison (Figure 7.2). The bone carbonate values (N=22) ranged from -1.2‰ to -8.1‰. According to E.B. Mansell and others, the diet of Yaxuná was very dependent on maize, about 60 to 70 percent (Mansell et al. 2006). All the El Rey individuals fell within this range except Burial 31 with a value of -8.5‰. All the San Miguelito bone carbonate values were

also within the range. The enamel values from Yaxuná ranged from -0.1‰ to -6.2‰. Of the El

Rey enamel values, all were within this range except Burial 25 with a value of -6.6‰. All of the

San Miguelito burials fell within those values.

Figure 7.2 Regional Comparisons of Carbonate Isotopes.

The site of Chunchucmil is located on a coastal plain and the individuals (N=5), dating to

the Late-Terminal Classic period (AD 550 or 600–1000), bone carbonate values ranged from

-3.4‰ to -8.2‰ (Figure 7.2), indicating individuals relied less on maize or maize-feeders

compared to Yaxuná. There is no indication from the isotopic results that the individuals

substituted protein for the lack of maize. Instead the individuals had a greater diversity of diet

including C_3 plants like squash and beans (Mansell et al. 2006). At the site of El Rey, the

individuals from Burials 10, 12, 14, 19, 39, 40, and 36 with more positive values than those at

Chunchucmil ranging from -0.3‰ to -3.9‰. El Rey Burial 31 had a more negative value of

-8.5‰ and the remaining individuals (N=22) were within the range of carbonate values from Chunchucmil. All the San Miguelito individuals fell within that range except for Burial 22 with a more positive value of -2.9‰. The site of Chunchucmil individuals also have enamel sample for comparison ranging from -5.8‰ to -6.3‰ (Figure 7.2). All the El Rey individuals had more positive enamel carbonate values than those at Chunchucmil. Most of the enamel values at San Miguelito (N=19) were more positive than those at Chunchucmil ranging from -0.3‰ to -5.5‰. Burial 25 was within the range with a value of -6.6‰.

Based on the contextualizing of the carbonate results from El Rey and San Miguelito with coastal and inland sites, the populations on the Island of Cancun had similar isotopic values to the sites of Xcambo, Marco Gonzalez, and San Pedro. The bone carbonate values indicated that the individuals from Xcambo were relying on C_4 plants with some C_3 but when combined with $\delta^{15}N$ collagen data, the population was relying equally on both marine and terrestrial resources (Sierra Sosa et al. 2014). The populations at the sites of Marco Gonzalez and San Pedro were relying heavily on marine resources, though Marco Gonzalez was consuming more terrestrial resources like deer and maize than San Pedro. The carbonate values from these sites were enriched by the consumption of the marine resources, giving them more positive $\delta^{13}C$ carbonate values (Williams et al. 2009).

The results from Marco Gonzalez and San Pedro underscore the complexity of coastal marine food webs and the effect those webs have on isotopic data. Nitrogen isotopic results are enriched based on trophic level; with each trophic-level shift in a foodweb there is a stepwise enrichment in $\delta^{15}N$ of approximately +3‰ due to fractionation. Based on the work of Winemiller et al. (2011), there are differences in the degree of $\delta^{15}N$ enrichment based on the location of marine resources, whereby lagoon, riverine, and ocean resources will exhibit varying degrees of

enrichment. According to Williams and colleagues (2009), the closer marine resources are to the coast, the more enrichment of ^{13}C collagen takes place. This enrichment, if the communities on the Island of Cancun were consuming marine protein, would raise their isotopic values, even in the $\delta^{13}C$ carbonate (Williams et al. 2009).

Since the populations at El Rey and San Miguelito are very similar to these two sites and Xcambo, it would stand to reason that the communities on Cancun Island had similar diets. Like Marco Gonzalez and San Pedro, the island offers easy access to an estuary to the west and the Mesoamerican Barrier Reef to the east, making marine resources more accessible. Out of the previously mentioned three scenarios, the two most likely are either heavy reliance on marine resources or a mix of marine and C_4 resources. However, with the addition of the pending $\delta^{15}N$ collagen sample for the sites of El Rey and San Miguelito, a clearer picture will be available of how much the people from the sites were relying on marine verses maize and other terrestrial resources.

7.2   **El Rey and San Miguelito Comparison**

2. Do the isotopic values within each site indicate differential access to food resources based on sex and age? In comparing the sites of El Rey and San Miguelito, are there similarities and differences? Do these differences indicate significant differences in food access?

The individuals at the site of El Rey distributed into three distinct clusters presented in Chapter 6. The distribution did not show any stark difference based on sex or age estimation. The sample population for this study from the site of El Rey was biased towards adult individuals, with only one subadult. Cluster I had a mix of males (N=11) and females (N=9) and included

one of the two adults with no sex estimation. The majority of these individuals were either 30-years-old or older. Cluster II also had a mix of individuals with one male, three females, an adult and the only subadult in the El Rey sample population. The male and female individuals were 30-years-old or older and the remaining two had no age estimation. Cluster III was unique as it consisted of only males and they were 30-year-old or older. Overall there appear, despite the clustering of individuals, no clear-cut differences based on sex or estimated age at death were prevalent.

As discussed in Chapter 6, the individuals from San Miguelito clustered into three different groups with one individual who did not group with any others. The majority of the individuals from the sample population at San Miguelito were subadults (N=13). The remaining individuals were five males and two females. Cluster I had six individuals with an even split between males and subadults. The male individuals' ages ranged from greater than 25- to 60-years-old. Two of the subadults were both three-years-old, and the third had no age estimation. Cluster II had the most individuals (N=10). This group had a majority of subadult (N=7), two male and one female. The subadults ranged in age from two- to five-years-old, one female had no age estimation and the other was between 20 to 24-years-old. Cluster III also had a majority of subadults (N=2) and one female. The subadults were six- and two-years old and the female had not age estimation. San Miguelito, like El Rey, also did not display distinct differences based on sex and age estimation.

Figure 7.3 Comparison of El Rey and San Miguelito Carbonate Results

When the individuals from the sites of El Rey and San Miguelito were graphed (Figure 7.3), there were also distinct clusters but with no distinct patterns related to sex or age estimation. Cluster I, noted by the green ellipse, consisted of the most individual with 21 individuals form El Rey and six from San Miguelito. The El Rey individuals were all adults, a mix of males (N=11) and females (N=9) and one adult individual. There were two females less than 30-years-old and the remaining individuals were 30-years-old or older. The San Miguelito (N=6) were three male and three subadults. The males were older than 25-years-old and the subadults were three-years old. Cluster II, noted by the circle, consisted of six individuals form El Rey and six from San Miguelito. The El Rey individuals consisted of one male, three females, and one adult with ages older than 30-years-old. Cluster II, noted by a yellow circle, had a

majority of individuals from San Miguelito (N=4) and three from El Rey. The San Miguelito

individuals were subadults, ranging in age from two to four-years-old. The El Rey individuals

were all males 30-years-old or older. Cluster IV, noted by the blue circle, consisted of a female,

with no age estimation, and subadult, six-years-old, both from San Miguelito. There were two

individuals that did not group with the others. One from El Rey was a subadult with no age

estimation and the San Miguelito individual was also a subadult three-years-old.

The above descriptions of similarities and differences within and between illustrate the

lack of distinguishable patterns of similar isotopic values. Within each site, the clusters of

individuals did not demonstrate stark differences between sex or age estimation. Even with the

cluster of three males from El Rey, they were not associated with other males of similar ages at

the site. This lack of distinct differences, indicates that the sample population at El Rey and San

Miguelito, indicates that there was not strict control of resources based on sex or age. Food

access has been linked to age, sex, or class restrictions (White 1999). The clusters of individuals

at the sites were mixed in age and sex indicating that the groups were not practicing food

restrictions based on age and sex estimation. Keeping in mind that the El Rey population was

excavated from ceremonial areas and the San Miguelito population was excavated from

residential areas (Cucina et al. 2018), this could also indicate that there was no strict restrictions

or special access to food resources on the island.

7.3   **Foreigner and Local Diet Comparison**

3.   Given the presence of four non-local individuals in the burial population at El Rey, and

based on what we know about Contact coastal sites being multiethnic places, did these

non-local people bring with them their own foodways or did they adapt to the local

foodways? Also, do the dietary results indicate anything about the status of these

individuals relative to the rest of the population?

The third research objective of this study was to compare and investigate the dietary

difference of the local and non-local individuals at the site of El Rey. Ortega et al. (2015)

performed strontium and oxygen isotope analysis on individuals from El Meco, Tulum, and El

Rey to investigate migration patterns. he theoretical principles are that the diet of tooth enamel

reflects the diet of childhood, and will yield oxygen and strontium isotopes from the area where

the individual was when the tooth developed. If the tooth enamel value indicates a different area

than where the individual was recovered, it is a safe assumption that the individual moved from

one location to the one of internment as some point in their life (Ortega et al. 2015). With the

dietary isotopic data, any similarities or differences between the local and on-local individuals

can be discussed. Soon to be published data by Douglas Price and colleagues on the oxygen and

strontium analysis of individuals from San Miguelito (Allan Ortega-Munoz, personal

communication 2017) is a potential avenue of future inquiry.

The oxygen and strontium isotopes from four individuals indicate that they were not local

to the island and had come from other parts of the Yucatan including coastal and inland areas.

The male individual from Burial 7 was from north coast of the Yucatan, possibly the area of

Xcambo. Individuals from inland location were Burial 23-1 and 32. The female individuals from

Burial 23-1 could have originated from northern Belize or northern Petén. The individual from

Burial 32, was a female and could be from the northern Lowland Maya region based on the

strontium isotopes, but the oxygen values indicate the Petén or Northern Petén region. The

individual from Burial 28 was an adult older than 30 years and had both a coast and inland

origins, depending on the striatum or the oxygen value. The oxygen indicated they could be from either near the central Maya Region, like Tikal, and the strontium indicated the Gulf Coast as a place of origin (Ortega-Muñoz et al. 2015).

Figure 7.4 El Rey Diet Local vs. Non-local (categories defined by Ortega et al. 2015).

It was assumed that the non-local individuals would have a similar diet to the rest of El Rey's population. This assumption was based on the accessibility of marine resources and the difficulty of cultivating and importing maize to the coast (Williams et al. 2009). Figure 7.4 shows the distribution of the enamel and bone carbonate results, noting the specific non-local individuals and the distinct group clusters. Based on the graph, the non-local burials did not cluster with most of the local individuals (N=27), noted by the green circle. This is mainly due to the distribution of the enamel values along the x-axis. Enamel values, representing the diet of the mother and food supplements during weaning, enrich the values through another trophic step

(Williams et al. 2005). Given that the non-local individuals were located in other areas during early childhood; this would be a natural place to see a difference in diet.

None of the non-local individual clustered with the local, however; this is probably due to the more positive enamel values of the local population, if the non-local individuals adopted the local foodways of El Rey. I propose that they did. There is no extreme difference in their bone carbonate values, falling within the ranges of the rest of the site. Like both the communities of Marco Gonzalez and San Pedro, the non-local individuals once they moved to El Rey, were consuming a diet that was either heavily reliant on marine protein or a mix of marine protein and C_4 plants. The differences occur when one looks at the enamel carbonate values, which reflect early childhood and would be a combination of the mother's diet and food supplement to the child (Williams et al. 2005). The addition of $\delta^{15}N$ collagen values will enhance these conclusions by teasing out the marine protein contribution from the C_4 plants.

7.4   **Conclusions**

Due to the importance of maize to the Maya, both as a staple crop and its interweaving with ideology, the communities at El Rey and San Miguelito had the potential to resort to more extreme measures to supply maize to the populace. Given the unsuitable soil for cultivation maize (Roys 1957), they would have to had to rely on trade connections to obtain it. They could have also relied on plants like squash and legumes (Coyston et al. 1999; Mansell et al. 2006; Sierra Sosa et al. 2014). The communities, being in such close proximity to the coast, would have had much easier access to marine resources (Williams et al. 2009) including fish associated with the nearby Mesoamerican Barrier reef, like sharks, grouper, and rays (Götz 2008; Hamblin 1980). The close proximity of these resources would have made them more easily accessible. Individuals from the sites of El Rey and San Miguelito were selected and their tooth enamel and

bone were processed to isolate carbonate and collagen to investigate what resources they were relying on, maize or marine resources.

Due to the unexpected delays in the processing the collagen results, those data are not presented in this thesis. Even though nitrogen isotope values are used to evaluate the extent to which people were consuming marine resources (Katzenburg 2008), this did not inhibit the evaluation of marine protein consumption in the current thesis. In fact, despite the carbonate carbon isotope values indicating that the communities of El Rey and San Miguelito were either consuming a mix of marine resources along with C_4 and C_3 plants, maize and possible squash and legumes (Sierra Sosa et al. 2014) or reflect a heavy reliance on marine resource consumption (Williams et al. 2009). However, this will be better understood with the addition of the pending $\delta^{15}N$ collagen values.

Previous research at El Rey and San Miguelito indicated that four the El Rey individuals were not originally from the island. The carbonate values of these non-local individuals did not cluster with the rest of the El Rey population, however, this was due to the enamel values on the x-axis of the graph. When looking at the ranges of bone carbonate, these individuals fell well within the range of the rest of the El Rey population, indicating that these foreigners had adopted the local food practices and were eating the same resources. It will be interesting to see the results of the soon to be published data from an isotopic migration study of San Miguelito burial population (Allan Ortega-Muñoz, personal communication 2017), and it will be interesting to see if those results enhance the understanding of this interpretation.

A study of biological affinity between El Rey and San Miguelito indicated that the two populations were not related. This was unexpected due to their geographical proximity (Cucina et al. 2018). However, there were no obvious differences between the two populations based on

the carbonate data and there was no obvious sex estimation or age differences, this not including the sample bias of El Rey towards adult and San Miguelito towards subadults. This indicated that both communities had the same access to resources, and that any social status there may have been, did not extend to the control of available foods.

Based on the carbonate data, the communities of El Rey and San Miguelito were taking advantage of the marine resources that were readily accessible. The carbonate values did not show a discrete distinction between El Rey and San Miguelito. Though the El Rey individuals were from ceremonial areas of the site and the San Miguelito population was from residential areas (Cucina et al. 2018), any status differences between the sites and indicated by burial location were not present in the isotopic data. This, along with the fact that there were not stark separations based on sex estimation and age, indicated that the inhabitants of the island were all able to consume the same foods, regardless of any hierarchical social organization. The data also indicated that the non-local individuals from El Rey had adopted the local food selections into their diet.

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