NON-SPECIFIC INFECTION IN A LATE CLASSIC URBAN RESIDENCE AT COPAN, HONDURAS

A Thesis

Presented to

The Faculty of the Department

Of Comparative Cultural Studies

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Stephanie M. Holsworth

December, 2013

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ABSTRACT

The aim of this research is to examine the distribution and severity of non-specific infection within the elite residential group 8N-11 of Copan, Honduras. Given the evidence of intra-group social ranking within elite Copan lineages, the aim of this study was to examine if social status could affect the distribution and severity of infection within a Copan residential compound. Results of analysis found no differential distribution of non-specific infection in any manner. Although intra-group ranking was evident, it could not be detected via indicators of health. Results of analysis did conform to previous research of the Copan elite population, as a high frequency of infection was present throughout the sample. This result suggests that the Copan urban core was facing considerable stress during the Terminal Classic period in a non-discriminatory fashion, possibly as the result of environmental degradation affecting both nutritional quality and disease transmission.

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Chapter One

Introduction

Paleopathology, the study of disease in prehistoric populations, enables us to explore the impact of the physical and cultural environment on patterns of health and disease in the past through the analysis of human skeletal remains.

Paleopathology is an important field of research as it allows us to explore how cultural adaptation can impact human health (Ortner 2011). The physical and cultural environment can affect the patterns of health within any population. The regional climate and the available natural resources can affect the local diet, while social organization and residential patterns can affect the distribution of resources and the transmission of disease. For example, a high population density can increase the rates of human contact, which exacerbates disease transmission and possibly increasing the rate of mortality (Storey 2006; Betsinger 2007).

The interpretation of health relies on the presence of physical indicators of stress, those pathological conditions that leave evidence of their occurrence on the human skeleton. In archaeological samples, one of the most commonly encountered pathological conditions is periosteal reactions (Ortner 2003; Shuler 2011). Periosteal reactions are areas of new bone growth on the periosteum, the outer surface of the bone. These reactions typically indicate the presence of infection or trauma, but determining specific etiology is difficult. Given this limitation, periosteal reactions are referred to as indicators of non-specific infection and are used as general indicators of stress. Although it is difficult to determine which specific pathogens may have affected a population, the distribution of non-specific infection allows us to analyze how the physical and cultural environment may have contributed to the transmission of disease in the past (Whittington 1989; Goodman and Martin 2002; Storey 2005b). Understanding the relationships that occur between the cultural and physical environment is essential to interpretation, allowing us to address which factors may have mitigated or exacerbated health, disease and mortality in past populations (Lallo 1973; Whittington 1989; Roberts and Manchester 1995; Ortner 2003; Ortner 2011). This study will aim to address how the cultural and physical environment contributed to the transmission and progression of disease within the urban core of the Classic Maya polity of Copan.

Copan

Copan was regional center in the Maya lowlands that flourished during the Classic period (A.D. 250-900). Established shortly after A.D. 400, Copan was located on the southeastern border of the Maya lowlands in a small river valley located in modern Western Honduras (Figure 1).

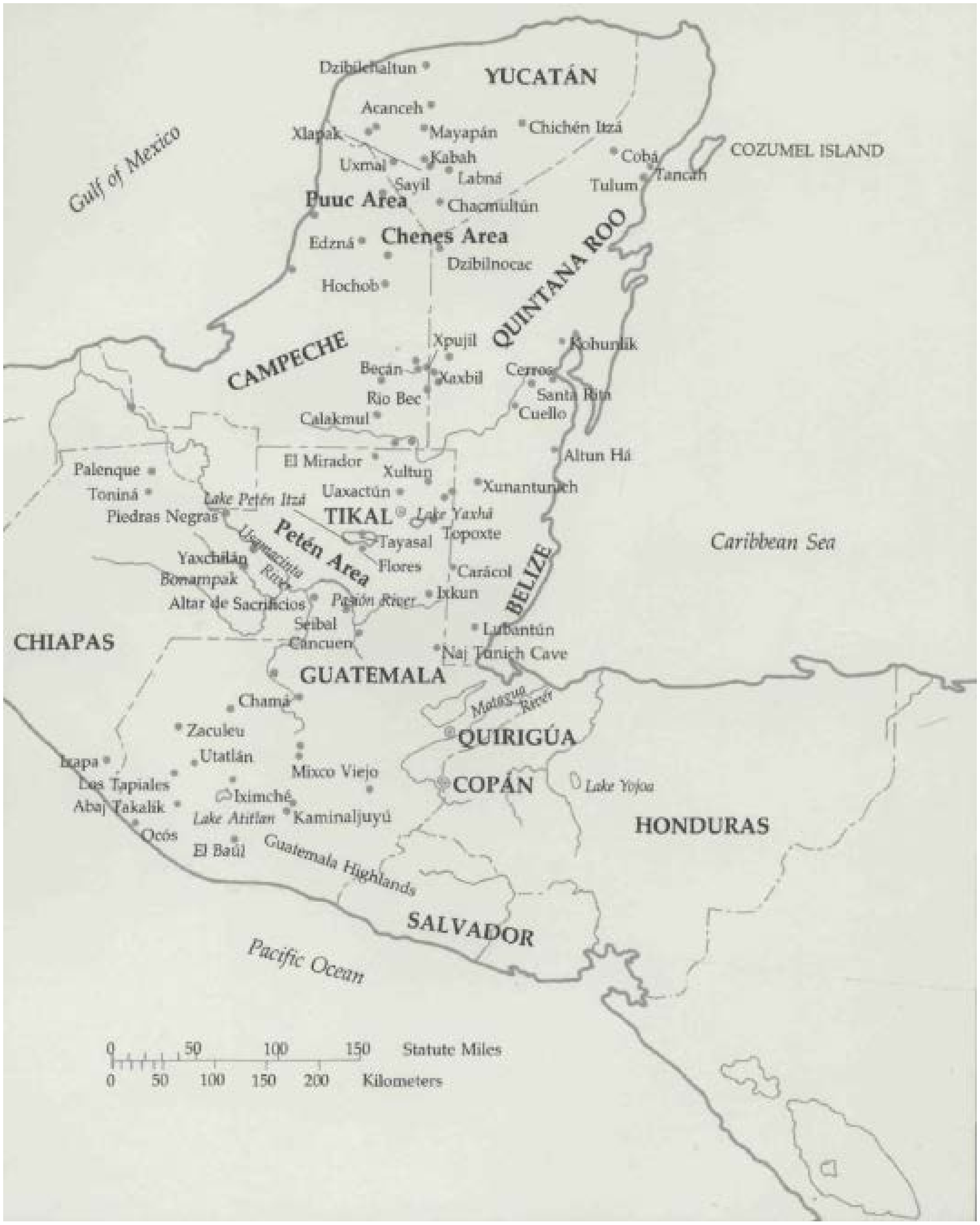

Figure 1 Map of Mesoamerica with Copan (Adapted from Ferguson and Royce 1984)

Copan is located in a valley, or pocket, off the Rio Copan system, in the mountainous region of western Honduras. The central settlement was centered on the lower alluvial terrace of the pocket, with the civic-ceremonial site of the Main Group located on the northern banks of the Copan River. Although the central site is relatively small in comparison to other great Maya centers, covering an area of .12 square kilometers, the large concentrations of sculpture and inscription have made the site a particular draw for archaeologists (Webster 1999; Webster et al 2000; Gerry 1993). The majority of the visible architecture represents the peak of the settlement, and was mostly constructed after A.D. 700 during a period of rapid population growth.

The Main Group (Figure 2) housed the temples and palaces of the royal establishment, including the Great Plaza, the Temple of the Hieroglyphic Stairway and the Acropolis, an elevated zone which include the royal residential compound (Webster et al. 2000).

Figure 2 The Main Group, Copan (Adapted from Ferguson and Royce 1984)

Surrounding the Main Group was the urban core, a structurally dense area composed of two elite wards which formed the rest of the central community; El Bosque towards the west and Las Sepulturas towards the east (Figure 3). These high status areas were linked to the Main Group with raised causeways, and were thought to house sub-royal elite administrators and ritual practitioners (Gerry 1993). The urban core had a very high population density, and is believed to have had the highest structural density of any Maya center (Webster et al. 2000). The ward of Las Sepulturas is thought to have has as many 1400-1800 buildings at one time, all within an area of one square kilometer. Population estimates for Copan places the peak population of the valley at approximately 28,000 individuals at the turn of the ninth century, with the elite communities of the urban core estimated at a peak of 11,600 individuals (Webster 1999).

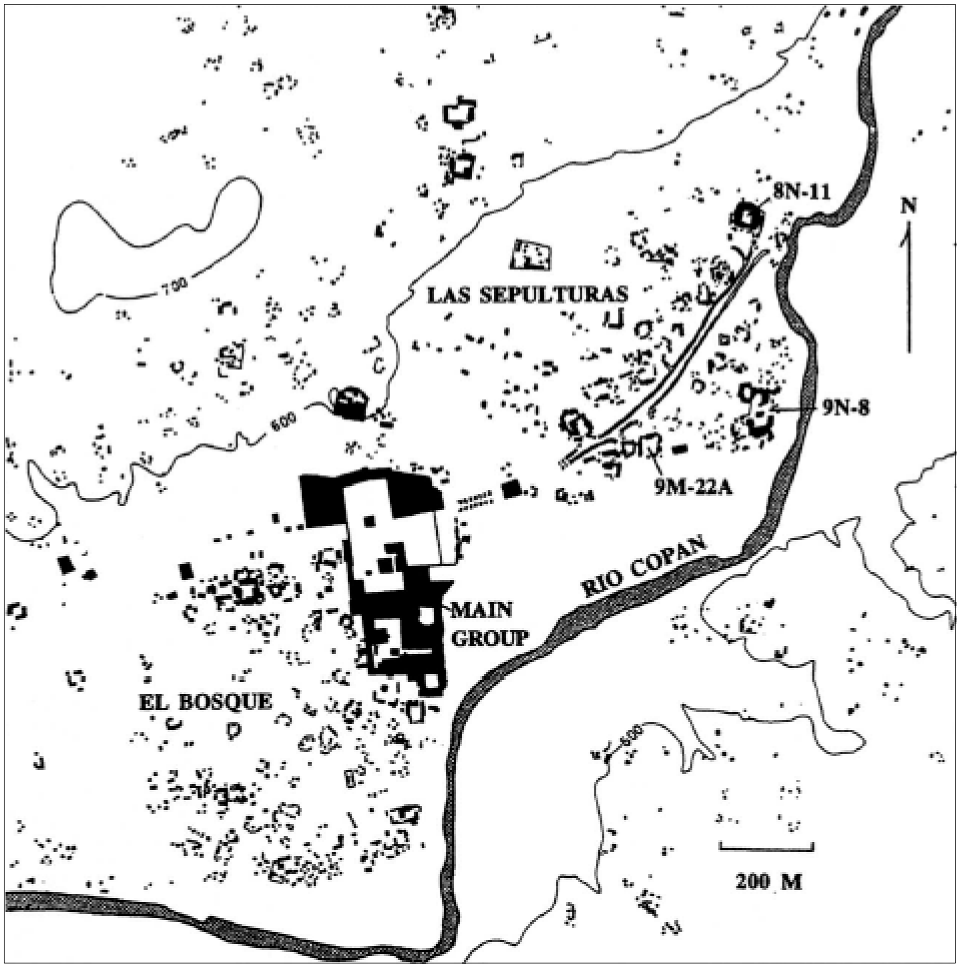

Figure 3 The Urban Core (Adapted from Webster 1999)

Copan prospered for over four centuries, however faced dynastic decline early in the ninth century (Weeks 1993; Webster 1999; Webster et al. 2000), which many attribute to the combined effects of political decentralization and environmental degradation (Fash and Sharer 1991). No formal monuments were raised in the city after A.D. 822 and a gradual decline of the population occurred in the century following with no known effective elite presence after A.D. 1050 (Webster 1999).

Copan has been subject to archaeological investigations for over a century, providing detailed information regarding its cultural history and physical environment (Webster et al 2000). Given the existing wealth of knowledge regarding the political, cultural, and physical environments, Copan is a particularly valuable source of information regarding the transmission and progression of disease in prehistoric populations.

Statement of Problem

The aim of this research is to determine how cultural factors, such as high population density, urban sanitation, and intra-group social status, affect health in the elite Maya population of Late Classic Copan. This will be accomplished through the analysis of the distribution and severity of non-specific infection within an elite residential compound in the urban core. Located in a small valley off the Copan River system, Copan flourished as a Maya center for a 400 year period until collapse of the political dynasty at approximately A.D. 822. With a high population density contained within the small urban core of the settlement, it has long been interpreted that the population faced considerable physiological stress in the period leading up to political collapse. Previous research at Copan has shown an overall decline in health as the population increased in the latter centuries of Copan's occupation, with evidence of lowered fertility, increased mortality, extensive malnutrition and overall poor health across the population (Webster 1999; Storey 2005). Non-specific infection has previously been used to address the distribution of infection and the state of overall health for all portions of the Copan population, with the urban core particularly facing high rates of infection (Whittington 1989). Population density seems to have affected the health of the community as patterns of infection severity differed significantly between the urban and rural populations, regardless of social status (Padgett 1996). These results indicated that the population of the urban core was facing considerable stress, which was exacerbated by a high population density. However, in these previous studies social status was assigned within the sample based on residential patterns, all urban residents within the sample were associated with elite status. However, given the social structure of Copan, there is strong evidence for intra-group social ranking within elite residential groups of the urban core.

It remains unclear how status and differential access to resources affected health within the residential compounds of extended families. The aim of this research is twofold, to first examine the general state of health within an elite residential compound of Late Classic Copan, and secondly, to examine how the distribution and severity of non-specific infection may manifest differentially within the extended family due to intra-group ranking. These problems will be addressed through the analysis of non-specific infection amongst the population of Group 8N-11, an elite residential compound in the Las Sepulturas ward of the urban core of Copan.

Specific Expectations

Hypothesis One: Non-specific infection at 8N-11 will occur at a high rate, greater than 50%, due to the effects of high population density within the urban core

The aim of this hypothesis is to test how health at 8N-11 compares with other Copan populations. Previous research at Copan has found a high rate of infection present throughout the population, regardless of social status, residence, age or sex (Whittington 1989; Padgett 1996). The null hypothesis states that no significant difference exists between group 8N-11 and other Copan samples, as reported by Padgett (1996) and Whittington

(1989), in regards to distribution of infection. Previous results have attributed the high rates of infection, ranging between 40 and 69.7% to the effects of population density. If the null hypothesis is rejected due to lower than expected rates of infection, this may suggest that the individuals from 8N-11 were protected from their environment and other factors contributed to the rates of infection on the greater population.

Hypothesis Two: Infant mortality at 8N-11 will occur at a high frequency, greater than 40%, as infants and young children of weaning age were affected by the transmission of disease due to high population density

This hypothesis is an extension of the first hypothesis, how group 8N-11 compares with other Copan populations. Previous research has found a high frequency of infants and young children included within the burial sample of another elite Copan compound, Group 9N-8, with 46% of that sample represented by sub-adults (Storey 2005). Infants and young children of weaning age are particularly susceptible to infection and previous findings suggest that elite children within the urban core were not buffered from the environment. The null hypothesis states that no significant difference exists between group 8N-11 and group 9N-8 in regards to mortality in children under the age of five. If the null hypothesis is rejected due to a lower than expected frequency of infant mortality, this may suggest that the juvenile residents of 8N-11 were somehow protected from their environment and other factors contributed to the rates of infection on the greater population.

Hypothesis Three: Severity of infection will manifest differentially within the 8N-11 sample; burials associated with the unelaborate, lower status residential buildings within the compound will present with increased severity of infection.

The second aim of this research is to assess how the distribution and severity of infection may answer questions regarding intra-group social ranking. Previous research comparing elite and non-elite individuals of the Copan population found a significant difference in the severity of infection present in the sample. Significantly higher rates of severe periosteal reactions were present in the elite sample from group 9N-8, despite the overall distribution of infection showing no significant difference between elite and non-elite individuals (Padgett 1996). However, in this previous study, the elite and non-elite samples were also separated physically, representing different residential locations. Considering the evidence that suggests elite residential groups at Copan were internally ranked (Hendon 1991; Gerry 1993; Webster 1997; Kintz 2004), as well as the synergistic relationship between malnutrition and infection, this research aims to determine if social status could influence the severity of infection within an elite group as the result of differential access to resources. If the null hypothesis is rejected, it will be expected that those burials associated with the non-elite residential structures of 8N-11 will display a higher severity of infection, due to a differential access to resources and the contributions of malnutrition to the exacerbation of infection.

Summary

This research aims to understand the state of health in a Late Classic residential compound in Copan, Honduras. The literature has shown that periosteal reactions, or non-specific infections, are a valuable indicator of a population's general health, and that Copan in general faced considerably stress during the Late Classic period. The following chapters will further detail the use of non-specific infection in addressing health in prehistoric populations, the cultural environment of Copan, the methods and results of data analysis, and will conclude with the discussion and interpretation of the results.

Chapter Two

Paleopathology

Through the examination of biological remains, paleopathology explores the impact of the cultural and biological environment on patterns of disease in human society and how human behaviors contribute to disease transmission and progression (Lallo 1973; Huss-Ashmore et al. 1982; Inhorn and Brown 1990; Ortner 2011). There is a synergistic relationship between culture and the health of its population. Human behaviors can affect how a disease may manifest and spread throughout a community (Lallo 1973), while in turn, the impact of disease can affect the development of a culture (Ortner 2011).

One of the ways in which to address the health of prehistoric populations is by assessing the patterns of distribution of skeletal indicators of stress as it manifests on the skeleton. Stress, in this sense, refers to those factors occurring in an individual's environment that cause physiological disruption (Huss-Ashmore et al. 1992; Larsen 1997). How stress manifests itself depends on the dynamic relationship between environmental constraints, cultural systems, and host resistance (Inhorn and Brown 1990; Larsen 1997), meaning that the stresses facing a population can either be mitigated or exacerbated by the cultural and behavioral processes of that population.

Stress can be detected in prehistoric populations through the analysis of human remains; a number of skeletal defects can provide evidence of a period of stress during an individual's life. The human skeleton is a direct link to the health of past populations; it can provide information on diet and nutrition, disease and infection, exposure to stress, and even labor practices (Padgett 1996; Storey 2005). Disturbances of growth and evidence of repair can be detected in human bone, and these disturbances can be indicative of a pathological condition. These defects include porotic hyperostosis, enamel hypoplasia, and periosteal reactions.

Porotic Hyperostosis

Porotic Hyperostosis is the term given to skeletal lesions of abnormal surface porosity that appear on the cranial vault (Ubelaker 2003). Porotic hyperostosis can be a symptom of multiple disease etiologies; however it is most often associated with iron deficiency anemia, which can develop from both malnutrition and infection (Ortner 2003). Iron deficiency is a critical factor for the growth and development of infants and young children as iron is required for active growth. For this reason porotic hyperostosis is more likely to develop in children, the presence of porotic hyperostosis in adults typically represents a healed lesion that developed during childhood (Mays 2010).

Diets low in iron or that affect iron absorption can lead to iron deficiency anemia, while prolonged breastfeeding and poor weaning diets can also contribute (Wright and Chew, 1998; Zorola 2009). Additionally, infection can cause or exacerbate iron deficiencies. Hookworm infection can cause intestinal bleeding, raising iron requirements for an individual, while other parasites such as roundworm can diminish the intestinal absorption of iron (Wright and White 1996; Wright and Chew 1998).

Porotic Hyperostosis is found in high frequencies in many Maya population samples. Wright and White (1996) found that 77% of subadults and 65% of adults presented with porotic hyperostosis across a range of Maya samples while Copan follows this trend with a similar frequency of 66.7% of Subadults and 62.5% of adults presenting with porotic hyperostosis (Whittington 1989). It has been interpreted that these rates can represent both the effects of malnutrition and infection, as similar rates have been observed in cultures not dependent on maize and modern cases of anemia in modern Guatemala are found to be most associated with hookworm infection (Wright and White 1996).

Enamel Hypoplasia

Enamel hypoplasia is a dental defect that is the physical result of a period of stress, which impeded the development of enamel as the tooth crown was forming (Roberts and Manchester, 1995; Wright 1997; Storey 2005). Periods of malnutrition or disease can lead to a thinning of the enamel that is being deposited on a developing tooth crown. These defects can only form during a period of enamel formation, and are thus indicative of specific periods of stress during childhood. Since deciduous teeth begin to form during gestation, these defects can also represent periods of maternal stress. A range of disease and dietary deficiencies can cause hypoplasias to form, including gastro-intestinal infections, diarrhea, vitamin deficiencies and general malnutrition (Mays 2010).

At Copan, enamel hypoplasias have been observed across the population. However there was variability in how enamel hypoplasias were manifesting within the sub-adult population. Whittington (1989) found a low frequency of hypoplasia in deciduous teeth of low status individuals, while Storey (2005) found that 76% of the subadult sample at the elite Group 9N-8 included hypoplasia or hypo-calcifications, including defects that formed in utero or infancy. Enamel defects in deciduous teeth can represent maternal health, and the occurrence of hypoplasia in the deciduous teeth of group 9N-8 suggests that prenatal stress was occurring in the urban core population at Copan.

Non-Specific Infection

Amongst the most common skeletal indicators of pathology are periosteal reactions, which are lesions on the bone that indicate an inflammatory response to either infection of trauma. These lesions are the physical response of bone to infectious disease and trauma, and as such can be a valuable indicator of the stresses facing an individual or greater community (Lallo 1973; Whittington 1989; Larsen 1997; Goodman 2002; Ortner 2003; Storey 2005).

Periosteal reactions are the result of abnormal bone growth in reaction to pathological changes in the underlying bone. The process begins as a response to inflammation caused by either infection or trauma, and results in the production of new woven bone on the surface of the existing bone, which often appears porous and disorganized. As the individual recovers from the infection or trauma that stimulated the response, the periosteal bone repairs and heals, remodeling into lamellar bone which has a more organized appearance (Ortner 2003; Weston 2008; Ortner 2011). When infection occurs as the result of trauma, the periosteal reaction will often present as a smaller more localized lesion, while infections resulting from disease will be more generalized and destructive, affecting multiple bones (Goodman 2002). Thus it is not uncommon to observe a high frequency of localized periosteal reactions on the tibia, where the surface of the bone is very close to the surface of the skin (Ortner 2003).

Skeletal tissue responds to disease in a few limited ways, as the process of periosteal new bone formation can be instigated by a number of factors, including infection and any trauma that affects the periosteum (Weston 2008). Exact diagnosis is often difficult, even with a complete skeleton with known contexts. Weston (2008; 2009) found that periosteal reactions cannot be used to infer disease etiology. Weston's sample was composed of museum specimens with known pathological conditions, yet she found no specific patterning of lesion characteristics that would clearly correspond to specific diseases. Given this unspecific nature, periosteal reactions are commonly referred to as evidence of Non-Specific Infection. Periosteal reactions are one of the most commonly encountered skeletal abnormalities in archaeological samples (Ortner 2003; Weston 2008), and as such are often used to address patterns of infection and general health in prehistoric communities.

The analysis of periosteal reactions is helpful in determining the presence of infection in a community; although etiology is often difficult to interpret (Betsinger 2007) the presence of any infection can be indicative of a general health problem (Ortner 2003). The distribution of infection throughout a community can help one infer what cultural and ecological factors protect a community from infection, or what factors cause or exacerbate health and disease (Lallo 1973; Ortner 2003). Beyond assessing the presence of non-specific infection, we must also address the severity of infection within populations. The severity of infection is an important factor in determining how infection is distributed throughout a population. Differences in health and disease transmission may not be reflected in distribution of infection, but may be observed in the distribution of infection severity. Addressing the distribution and variation of infection severity can reflect how differences in systemic stress are manifested within a population (Betsinger 2007), allowing inferences to be made regarding what stresses were affecting the population and what sub-groups may have been more exposed or protected.

Non-Specific Infection at Copan

Non-Specific infection and other patterns of skeletal pathology have been used to investigate the relationship between human behavior and the environment and to reconstruct health patterns for a number of archaeological populations. Powell (1988) used non-specific infection to investigate the effect of status on health, Larsen (1997) demonstrated how the prevalence of non-specific infection shows the effects of stress, and Lallo (1973) demonstrated how frequency and severity of infection increased in populations as they increased in population density, became more sedentary, and intensified trade.

Specific to Mesoamerican populations, non-specific infection has been observed at high frequencies and used to address patterns of health in these communities, especially at Copan. Many studies have found Maya populations to have been particularly stressed in regards to health and nutrition, and Copan is no exception. The cultural environment of Copan was characterized by a number of features that could have negative effects on health for the population, including a maize intensive diet, which can contribute to malnutrition, and high urban density, which can facilitate disease transmission and affect sanitation and hygiene practices. High rates of non-specific infection have been recorded within the Copan skeletal samples, with little discrimination by age, sex, or social status.

Osteological studies at Copan have shown that the population was highly stressed, with high frequencies of infection, as measured through periosteal reactions, and nutritionally related stress, as measured through enamel hypoplasia, found throughout the population regardless of social status (Whittington 1989; Padgett 1996). Whittington (1989), in assessing disease and demography within the lowest socioeconomic level of the Copan population found a highly stressed population overall. There were no significant differences detectable by age, sex, social status or residential location (urban or rural). The frequency and distribution of pathological lesions in Whittington's sample suggested that the population as a whole faced recurring periods of chronic stress, with little difference in nutritionally related stress between the urban and rural populations. However, the frequency of infection was significantly greater for the urban population, suggesting that infection in the urban core was more closely related to the effects of population density and sanitation on infection transmission.

The higher rates of infection among the population of the urban core have been noted in other samples as well. Padgett (1996) also examined patterns of health at Copan, specifically comparing urban and rural populations to determine how social status and residence affected distribution of infection. In this assessment, status was assigned based on residential patterns, specifically the urban core representing the elite sample and rural representing the non-elite sample. Results of frequency and distribution of infection were similar to Whittington's conclusions; over half the population presented with systemic periosteal infection, regardless of social status, and no significant differences were found between the urban core and rural samples (Padgett 1996). However, there was a significant difference detected between the urban core and rural populations in terms of infection severity. The urban core sample, representing the elite population, presented with a greater severity of infection and was more likely to be suffering from active infections at the time of death. The rural population presented with more moderate infections and was more likely to have healed lesions at the time of death. The increased severity of infection in the urban sample, as well as the increased likelihood of having an active infection, suggested that the differences in health between the two populations were a matter of the residential environment; high population densities, poor sanitation, and poor hygiene were contributing to an environment of chronic exposure to disease and infection.

Limitations to Non-Specific Infection

There are limitations to the use of infection in assessing health in prehistoric populations, both around the limitations of skeletal samples in general as well as limitations to identifying the presence of infection and determining its meaning. The first limitation is not limited to non-specific infection but to all osteological research. No skeletal sample can be fully representative of its living population and there are clear limitations to what interpretations can be made regarding the health of a population (Ortner 2003; Ortner 2011). Additionally, those individuals within a sample displaying skeletal evidence of pathology will not be the only individuals who suffered from disease and infection, as not everyone will manifest skeletal evidence of disease and incomplete skeletons can further limit the ability to determine presence of pathology (Ortner 2003).

Another limitation in assessing the health of a population is in the interpretation of the absence and presence of skeletal lesions. The absence of skeletal disease does not necessarily indicate that an individual was free of disease; an individual could die while ill, but prior to any effects appearing on the skeletal system (Ortner 2003). In contrast, neither does the presence of infection necessarily indicate poor health; some find that it can actually provide evidence of a strong immune response, with the individual surviving the infection and living long enough for evidence to appear on the skeleton (Goodman and Armelagos 1989; Wood et al. 1992; Betsinger 2007).

When assessing health in prehistoric populations it is important to consider these limitations, because when relying on skeletal indicators alone one cannot infer much regarding a populations health patterns. It is necessary to incorporate the cultural processes of the population in analysis, as they are a significant factor interpreting health (Goodman and Armelagos 1989; Goodman 1993). The following chapter will further explore the cultural and environmental factors that could have affected health within Late Classic Copan.

Chapter Three

The Biocultural Approach

An important factor in addressing health in prehistoric communities is recognizing the interplay that occurs between the biological and cultural environments. Cultural behaviors are developed in a relationship with the environment. Cultural behaviors develop to provide a protective buffer from stress and enable a population to extract and produce resources from the environment (Larsen 1997; Whittington 1989; Goodman and Armelagos 1989). However, certain cultural behaviors and characteristics can also increase the biological and environmental stresses a population may face, especially under conditions of population growth and high population density (Whittington 1989; Larsen 1997). Populations under stress often show an increasing frequency of non-specific infection due to a number of factors, including low resistance to disease due to malnutrition and the exacerbation of disease transmission due to the effects of elevated population densities (Lallo 1973; Whittington 1989; Larsen 1997; Goodman 2002; Storey 2005; Betsinger 2007). This chapter will examine the physical and cultural environments of Copan, and how cultural processes could contribute to the transmission of disease within a community.

The Physical Environment

Copan is located in a warm, humid, agriculturally rich valley, or pocket, located on the Copan River. The Copan pocket has high agricultural potential due to the climate, seasonal flooding of the river and the presence of river terraces for subsistence crops (Fash 1983; Gerry 1993; Webster 1999). The lower alluvial terrace of the pocket is agriculturally rich and is surrounded by a foothill zone of mixed tropical deciduous vegetation, which then merges with the upland forest zone dominated by Pine (Abrams and Rue 1988). Apart from the river, five smaller tributaries issue onto the floodplain, meandering through the settlement before emptying into the river. Seasonal rainfall in the valley is high, often causing the streams to overflow, creating a water rich environment (Davis-Salazar 2006). The climatic conditions of the region are conducive to traditional pre-Columbian agriculture, which would have included the staples of maize and beans, but the landscape was variable in its productivity. The lower alluvial terrace was the preferred area for cultivation as the soils of the upland hills were more susceptible to erosion, however agriculture expanded to this area as the population of the valley increased (Webster et al. 2000).

Deforestation and intensive agriculture can affect the local environment and the health of a community. As a population grows, agricultural production must expand to meet the needs of the community. At Copan, this expansion occurred into the foothill zone of the pocket, where soil and pollen analysis has shown evidence of forest clearance, soil erosion and nutrient depletion during the Late Classic period (Abrams and Rue 1988; Wingard 1992). The combination of deforestation and intensive agriculture can create problems with soil erosion, which reduces soil productivity through the loss of topsoil and reduces soil infiltration. Reduction in soil infiltration can affect soil run- off. Precipitation that does not infiltrate the soil detaches the topsoil particles, and transports more sediment which often accumulating in valley bottoms or water sources (Van der Perk, 2006). Increasing soil run-off leads to higher turbidity in rivers and reservoirs, increases sediment deposition, reduces water storage capacity, and alters the aquatic ecosystem (Morris and Fan 1998). The topsoil located at the surface is the most susceptible to erosion and also contains the majority of contaminants exposed to the soil, serving as a reservoir for fecal material. As the run-off due to erosion increases, the sediment increases the amount of contaminants, including fecal material, flowing into water sources (Crabill et al 1999; Van der Perk 2006).

Fecal material is a primary source of disease transmission; most known water-borne diseases are caused by microorganisms found in the intestinal tracts of human and other animals (Hoyle 2008). Water –borne pathogens, including campylobacter, salmonella, shigella, and Escherichia coli (E.coli) are especially prevalent in warm and moist tropical climates. All of these pathogens can result in severe diarrhea and dehydration (Barzilay et al. 1999), which can cause or exacerbate malnutrition. As agriculture expanded into the upland hills of the Copan pocket, soil erosion could have affected both agricultural production and water sanitation. The quantity and quality of agricultural resources would have been stressed, contributing to an elevation of nutritional stress within the population (Wright and White 1996). In turn, soil erosion could have increased the amount of sediment and contaminants entering the local water supply, contributing to the spread of infectious pathogens throughout the community.

The effect of soil erosion on the water supply could have been significant given the environment of the valley. A warm, humid environment is especially conducive to pathogenic growth and the high population could affect the levels of pollution entering the river and any water retention features (Davis-Salazar 2001; 2003; 2006). Given the need for water management and access to a daily source of water, it is not surprising that there is ample evidence of water management within Copan. Both elite urban wards, Las Sepulturas and El Bosque, display a number of water management features, including large reservoirs for water collection and flood control features built into the architecture (Davis-Salazar 2003; 2006).

An important component of water management was ensuring the quality of stored water; this was accomplished through community participation in the maintenance of water reservoirs as well as the inclusion of certain plants, and their associated bacteria, in still water features to help purify the water (Lucero et al 2011). The water lily is a plant that grows only in clean water, contributes to the quality of water by reducing evaporation, recycles organic waste, and produces dissolved oxygen (Davis-Salazar 2003). Given these properties, the water lily is often used as symbol of clean, fresh water. Interestingly, the water lily is also utilized as a royal symbol in many Maya contexts and appears in a number of elite contexts at Copan. This inclusion of water lily imagery at elite residences is thought by some to represent the ability of community leaders to provide clean water to the Copan wards (Davis-Salazar 2003; Fash 2005; Lucero et al 2011).

The physical environment is an important factor to consider in addressing the transmission of disease in late Classic Copan. Both water management and environmental degradation can have significant impacts on the spread of disease in areas of high population density. Water-borne disease are particular a concern for young children and infants, who have yet to develop the immunities necessary to protect from gastro-intestinal disease, leading to dehydration and diarrhea. Environmental degradation can further exacerbate the problem, with erosion increasing the amount of contaminants and sediment carried into still water sources (Davis-Salazar 2001; 2003).

The Cultural Environment

In addition to the physical environment, the cultural environment can also have a profound impact on the spread and progression of disease within a community. The following sections will review how population density, social structure, and diet can affect health in prehistoric populations.

Population Density

Population density is another factor to consider in the transmission of disease, as high population densities increase daily human contact and affect public sanitation. Higher levels of social contact and the effect of large populations on sanitation increase the likelihood of exposure and transmission of infectious disease (Lallo 1973; Whittington 1989; Larsen 1997; Storey 2006; Betsinger 2007; Rautanen 2010). The large population of the urban core, with an estimated 12,000 individuals within an area that covered less than 1 square kilometer, could have been accompanied with an increase in the transmission and spread of infectious disease.

Population density can have a strong impact on overall health, affecting growth, physiological stress and disease transmission (Betsinger 2007). High population densities and poor sanitation can increase the rate of disease transmission and the severity of disease progression. Large populations living in close proximity to one another creates breeding grounds for infectious disease, as rates of transmission increase and cycle throughout the community. The increased exposure allows chronic infection to become established within the population, increasing infection severity and affecting the healing process (Lallo 1973; Larsen 1997; Storey 2006).

Additionally, a high population density can affect the quality of public sanitation. The pollution of the water supply increases with the population, further exacerbating the presence and spread of communicable diseases (Fash 2005; Storey 2006; Betsinger 2007; Rautanen 2010). Contaminated water due to poor sanitation is known to facilitate the transmission of multiple bacterial and viral diseases, including cholera, dysentery and even polio (Fash 2005; Rautanen 2010). Although cholera and polio are modern examples, dysentery and other bacterial and viral infections, including species of staphylococcus and streptococcus, were present in pre-Columbian Mesoamerica and could have occurred in prehistoric populations (Roberts and Manchester 1995; Grob 2002). As reviewed in the previous section, Copan was located in a water rich valley, with a water management system designed to provide a constant water supply as well as to manage water flow from rainfall and the Copan River's tributaries (Davis-Salazar 2001; 2003; 2006). Freshwater is an essential component of daily life, and urban water management systems are the primary component in ensuring proper sanitation in any water rich environment (Rautanen 2010; Lucero et al. 2011). The combined effects of environmental degradation and elevated population densities could have affected the water supply significantly, increasing contamination from both soil erosion and trash accumulation. Although it is difficult to assess the extent of maintenance that would have occurred, it can be inferred that the high population densities could have affected the quality of the water supply, further exacerbating the transmission of disease within the community.

Sociopolitical Organization

Social organization is an additional component to consider when assessing how health and disease are distributed throughout a community. This section will review the social organization of the Copan community to better understand how social organization can affect health. Like much of the classic Maya world, Copan was a stratified society, comprised of three tiers: the Royal Dynasty, a high status elite class representing the heads of expanded lineages, and then the rest of the population, primarily composed of agricultural producers (Sanders and Webster 1988; Sanders 1989). Elite power was based in the control of the agricultural resources of production as it was structured through descent groups, or lineages (Sanders 1989; Hendon 1991; Kintz 2004). Much of the interpretations regarding social status at Copan have been the result of analysis of architectural characteristics.

The architecture at Copan has been extensively researched to demonstrate demographic patterns and sociopolitical organization, with the large number of residential sites of varying complexity and size suggesting a hierarchical population (Hendon 1987; Abrams 1989; Webster 1989). Architectural characteristics have been used to rank Copan residential sites by type, which has since been often used as a proxy for social status (Table 1).

Harvard Project Site Classification	
Type 4	Complex groupings of mounds, sometimes 40 or more, around one or more commonly multiple plazas. Construction includes high quality dressed stone and vaulted ceilings; sculpture is associated with some of the buildings
Type 3	Mounds may be as high as 4.75 meters and define one or more plazas. Dressed stone is abundantly used for construction
Type 2	One or more plazas with six to eight mounds, the largest of which are about 2.5-3 meters high. Although usually built of rubble and undressed blocks, they may also include cut-stone construction
Type 1	Two or more buildings (usually three to five) grouped around one or more plazas. Buildings on the surface appear as low mounds no more than 1.25 meters high, and are constructed of earthen fill and rough stone retaining walls

Table 1 Harvard Project Site Classification (Adapted from Webster et al 2000)

Sites are ranked based on the number and size of structures in patio groups, beginning with Type 1, simple groupings around a single patio and progressing in number to Type 4, representing elaborate and elite residential groups (Willey et al 1978; Abrams 1989; Webster 1989; Sanders 1989).

In addition to site typology, other methods have been used to associate architecture with social status within Copan, such as the cost of labor. Abrams (1989) calculated the labor costs that would be associated with the residences of the different tiers of Copan society, finding that rural and commoner residences would have required between 50-100 person days, masonry elite residences between 1,000-5,000 person days and the royal palace roughly 30,000 person days. The cost of labor shows a highly stratified society, reflecting differential access to resources within the greater population in the large difference in labor costs required between commoner residences and elite residences. However the great range of labor costs within the elite community also highlights a range of social power within the elite class, suggesting internal stratification as well.

Many of the elite groups of Copan were located in the urban core, within the El Bosque and Las Sepulturas communities. Although these communities contained a range of site types, they are considered as elite settlements for their proximity to the Main Group, which included formal linkages via the causeways. This close proximity to the Main Group was advantageous as it placed elite families near the royal court as well as allowing economic advantage in dominating the valley floor (Webster 1989). The high quality of residential construction also suggests strong elite presence (Webster 1989). Within the urban core even lower ranked site types were constructed of a considerable higher quality than their rural counterparts (Reed 1998; Gerry 1993).

The architectural design of the city has been interpreted as deliberate plans designed to mirror and reinforce the social structure by guiding daily interactions (Richards-Rissetto 2010). Using GIS to quantify social interaction, Richards-Rissetto (2010) found that the cultural and physical environment shaped and represented social structure within Copan society. In her analysis, results showed that by far the most accessible site at Copan was the Great Plaza, because from any location in the valley it had greatest ease of access. This was followed by Las Sepulturas as the second most accessible location in Copan. The suggestion is that movement was specifically channeled to the Great Plaza as well as by Type 4 sites, possibly to facilitate interaction between the elite and the rest of the community (Richards-Rissetto 2010). Residential construction at Copan seems to have been heavily integrated with social status, to the extent that the very design of the city reinforced the existing social hierarchy.

Within the population, social status and power was structured around the lineage. At Copan, lineages acted as cooperative groups, holding the economic and agricultural resources of the extended family (Sanders 1989; Kintz 2004). Lineages formed an extended household that occupied patio groups; compounds of multiple buildings surrounding formal courtyards, in which the extended families shared ritual activities and residence (Sanders 1989; Hendon 1991). These residential units were somewhat different from other Late Classic Maya households, as many of the residential groups at Copan contained more than a single patio. This suggested that extended families often remained together as a social group rather than establish their own household (Fash 1983), in fact, isolated nuclear families were very rare at Copan (Sanders 1989). These social groups formed the basis of Copan society; social status and power were structured around the social group of the lineage; however variation in status also existed within the extended family.

The lineage and household were internally ranked, with a differential access to resources observed within the patio groups, as determined by residential architectural characteristics, decoration, and mortuary offerings (Hendon 1991; Gerry 1993; Webster 1997; Kintz 2004). These differences in architecture were evident because residents of the extended family were divided into separate domestic units. Basic domestic activities, such as food preparation, would occur in several locations in each patio (Hendon 1991), representing the different individual family units that formed the greater group.

Despite the evidence of within group variation, there is no clear pattern of physical organization based on status within the patio groups. Lower status and higher status families could reside side by side or share the same patio; there has been no identification of any clear social segregation based on intra-group ranking. Social status, as determined from mortuary characteristics and residence site type, shows an overlap in physical distribution throughout the residential groups of Copan. This lack of segregation based on status reinforces the conclusions that residential groups were made up of lineages and extended families, and not contracted servants or retainers (Webster 1985; Sanders and Webster 1988; Hendon 1991; Diamanti 1991; Gerry 1993). Although there may have been social differences regarding daily activities, possibly including service to the head of the group, they were included within the family based on descent not on service (Hendon 1991).

Despite those conclusions, there is also the likelihood that full-time craft specialists may have also been included within elite households, albeit on a limited basis. Amongst the wide spread low-level craft production evident throughout Copan (Abrams 1989), there is some evidence of full-time craft specialization, specifically at the elite group 9N-8 in Las Sepulturas (Sanders 1989), which is thought to be representative of patronage. Lacking a market economy, specialist's goods would not have been readily available on an immediate basis to the Copan elite. It has been suggested that to ensure access to some goods, an elite household could retaining a craft specialist and absorb them into the household (Diamanti 1991). However their membership in the household would have been based solely on their ability to provide a service. In contrast to lower ranking family members, their residences within the group may have been more secluded or otherwise differentiated from the rest of the extended family. This is supported by the archaeology; in research utilizing GIS analysis of space and access, Richards-Rissetto (2010), found that some lower type plazas within the 9N-8 compound, specifically those mentioned above with evidence of craft specialization, were placed in a more restricted location within the group. Her conclusions found that this separation signified some sort of restricted or controlled access to the rest of the compound, allowing the greater household to monitor and/or control the movement of these particular residents. Richards-Rissetto's interpretations found this to be evidence of servants or specialists employed by the lineage head. Although the possibility remains that controlled access may have also applied to lower ranking family members as well, the control of movement suggests the presence of internal stratification with Copan residential compounds.

Variations in social status across Copan society, as well as within the lineage or extended family, are important factors to consider when assessing health and disease. Differential access to resources can lead to different manifestations of health and disease as they may be affected by nutritional quality. Social power can increase resource access and ensure a more nutritionally diverse diet (Gummerman 1997; White et al. 1993). Given that the Maya elite had significant control on the modes of production, the organization of labor, land use and redistribution of goods; it is thought that this would have allowed for elite classes to express their status through a greater degree of food choice and variation (Reed 1998; Danforth 1999; White et al 2001). Previous paleoethnobotanical research has shown that social elites within Maya communities had greater access to fruits and animal protein in comparison to the rest of the population (Lentz 1991; Gummerman 1997). How disease and health manifest across social status, even within the extended family, could shed light on the particular environment and what factors were contributing to the states of health and disease within Copan.

Diet and Malnutrition

The previous sections reviewed the physical and social factors that can affect health in prehistoric populations; a key component of these factors is understanding the nutritional quality of the local diet. Diet is an essential component in assessing health within a community, given the strong relationship between malnutrition and infectious disease. A community's diet is affected both by the physical and cultural environments, as the physical environment can affect the quantity and quality of production while social structure can determine how those produced goods and other resources are distributed. This section will discuss what is known about diet at Copan, and how this diet can contribute to patterns of health and disease within the population.

Malnutrition not only affects the growth and development of a population, but can also affect the transmission and development of disease. This strong synergistic relationship between malnutrition and infection is an important factor to consider when addressing health in past populations, as both stresses can contribute to the presence and progression of the other. Malnutrition exacerbates the spread of disease as dietary deficiencies can compromise the immune system and lower resistance to pathogens, increasing an individual's vulnerability to bacterial infections (Santley and Rose 1979; Danforth 1999). However, infection can also worsen nutritional status and contribute to malnutrition. Gastro-intestinal and upper respiratory infections can both affect the appetite, causing a reduction in calories consumed, as well as limit the ability of the intestines to absorb nutrients (Whittington 1989; Wright and White 1996; Larsen 1997; Danforth 1999; Betsinger 2007).

Research has repeatedly shown that maize was by far the most significant component of the Maya diet, through both paleoethnobotanical and stable isotopic methods, which include the analysis of stable carbon and nitrogen isotopes. Carbon isotopes can reflect the type of plants consumed, including maize, and nitrogen isotopes can reflect if resources were marine or terrestrial in origin (Danforth 1999). The remainder of the diet was composed of beans and squash, with some varieties of fruits and vegetables, and limited animal protein depending on the site and region (Whittington 1989; Gerry 1993; Padgett 1996; Zorola 2009). At Copan, Maize was the principle component of the diet, ranging between 62-78% of the diet, and was heavily supplemented with beans (Reed 1998); any animal protein would have been sourced primarily from deer and dog (Webster et al 2000).

In general, the Copan diet in was somewhat different from other Mesoamerican samples. Om comparison to other lowland Maya sites, the Copan diet was less diverse, lacked animal protein, and had an increased reliance on maize. Reed (1998) attributes these differences to the large, dense population which required a consistent staple crop to support the population. The intense cultivation of maize required to support the population would have limited the diversity of the diet and could have contributed to the nutritional stress facing the population.

The maize heavy diet of the Maya was deficient in the amount of nutrition it could provide the population, providing only moderate amounts of protein and lacking certain essential amino acids (Santley and Rose 1979; Reed 1998). This effect may have been intensified at Copan, with its greater intensity in maize cultivation. Diet is an essential component of growth and development, and contributes to health and disease progression. Diets lacking in diversity can lead to malnutrition, which can affect growth, lower resistance to infection, and even effect reproduction (Santley and Rose, 1979; Whittington 1989; Lentz 1991). Furthermore, diets can also have negative effects on dental health; diets heavy in carbohydrates can increase the occurrence of dental caries (Whittington 1989).

A strong reliance on maize could have a detrimental effect on a population. The lack of diversity due to the intensification of maize cultivation limits the nutritional quality of the diet, as resource diversity is an essential component of dietary quality. Additionally, the nutritional components of maize are rather limited, and thus the reliance on the crop would have created a nutritionally deficient diet that was already suffering due to a lack of diversity. However, there were cultural processes in place to increase the nutritional quality of maize; the process of Nixtamalization, treating the maize with lime, would enhance the nutritional quality of the grain (Santley and Rose 1979; Huss-Ashmore et al 1982; Wright and White 1996; Reed 1998; Zorola 2009).

However it should be noted, Nixtamalization would only make the diet nutritionally adequate for portions of the population, as the quality would still not be sufficient for those groups in need of additional nutrition, specifically pregnant and lactating women and young children (Santley and Rose 1979; Wright and White 1996; Reed 1998). For young children, some of the nutritional deficiencies may have been addressed with an elongated period of breastfeeding; it has been thought that the Copan population weaned young children at a late age, estimated between 3.5 and 4.5 years of age (Whittington 1989). While this may have provided additional nutrition to the child, it could also exacerbate other issues, such as increasing rates of anemia for both the child and mother, and also decreasing female fertility (Whittington 1989).

Diet and nutrition can have a strong effect on health and disease, and the maize heavy diet of Copan could have certainly contributed to incidences of malnutrition and infection. The limited nutritional quality of the diet would be especially concerning for the young children of the population, as it would not have provided the nutrients needed for ideal growth and development (Santley and Rose, 1979; Williams et al 2005). Breast milk would have remained as a significant contributor for protein, but extended periods of weaning in which breastfeeding continued could have led to an increase in iron deficiency among the sub-adult population (Herring et al, 1998; Williams et al, 2005). The weaning period is a particularly stressful time for young children, partly due to the diet employed; however it is a period in which young children are also exposed to infection and disease.

Weaning

One population particularly at risk for malnutrition and disease are young children. Infants and young children have complex biological requirements necessary for proper growth and development, as well as an underdeveloped immune system. For these reasons, infants rely on the immunities provided through breast milk for protection from infection. However the process of weaning and the introduction of food, which is necessary for proper growth in young children, can also lead to increasing exposure to pathogens at a time when their immune system is still vulnerable.

The weaning process can have a significant impact on nutritional quality and infant survival within a population. The high nutritional requirements of children may often not be met with the weaning diet provided, while pathogen exposure increases with the addition of food and water to their diet (Goodman and Armelagos, 1989; Santley and Rose 1979). The weaning process refers to both the cessation of breastfeeding and the introduction of other foods to young children; however this process varies greatly across populations, as the ability to provide supplementary food is highly dependent on resource availability and distribution (Santley and Rose, 1979; Herring et al 1998). Often the process begins with a slow introduction to foods other than breast milk, followed by an extended and gradual change in breast feeding (Katzenberg et al, 1996; Herring et al, 1998; Wright 2013; Burt 2013). The period of weaning can cause considerable physiological stress to a child. The introduction of food and water introduces external pathogens to the infant, causing chronic diarrhea, infection, and malnutrition, at a time when the immunity provided by breast milk begins to decline (Goodman and Armelagos 1989; Katzenberg et al 1996).

Breast milk contains immunoglobulin, staphylococcus, and lymphocytes which provide antibodies to protect the infant from infection and disease, especially gastrointestinal disease; however the benefits of passive immunity begin to diminish after 6 months of age with the decline in immunoglobulin (Wright 1997; Herring et al, 1998; Williams et al, 2005; Newburg 2005). At the time this passive immunity is beginning to decline, infants are also faced with a surge in growth requiring nutrients beyond what is provided in breast milk (Wright 1997). This is a time when many children are introduced to supplementary foods and the process of weaning begins. The combination of gastrointestinal disease and the exposure to other contagious pathogens due to both contaminated food and water and declining passive immunity can impart a severe amount of physiological stress on infants and toddlers (Katzenberg et al, 1996). Given this stress, it is not uncommon to see a significant increase in infant mortality corresponding to the period of weaning. An increase in gastro-intestinal and upper respiratory infections amongst children of weaning age have been observed in contemporary Maya populations, with infection having a negative effect on a child's growth due to the effect of acute diarrhea on food intake and absorption (Mata et al. 1976).

Literature on the Maya indicates the process of weaning began with the introduction of supplementary foods around 12 months of age with gradual cessation of breastfeeding up until sometime between 3-4 years of age. These interpretations have been confirmed in some specific Maya populations with isotopic analysis, including Belize and Guatemalan samples (Williams et al. 2005; Wright 2013). At Copan, no studies have specifically addressed the weaning through isotopic analysis; however Whittington (1989) found through examining the association between linear enamel hypoplasia and age at death, that weaning may have occurred between 3 and 4 ½ years of age, fitting with other interpretations of when breast feeding cessation would have occurred amongst the Maya.

Given this relationship, a high frequency of infant mortality or a high infant mortality rate (the ratio of infant deaths per 1000 live births) can be a sign of inadequate nutrition or infection in the subadult population (Whittington 1989; Danforth 1999). This strong synergistic relationship between malnutrition and infection is an important factor to consider when addressing health in past populations, as both stresses can contribute to the presence and progression of the other.

Late Classic Maya Collapse at Copan

The previous sections have discussed the various physical and social components of Copan and how they may have affected the health of the population. This last section will review the particular period of Copan's history in which both political and environmental factors initiated a process of decline and depopulation. This period is worth review as many factors may have contributed to a decline in health for the population during this process.

During the ninth and tenth centuries, many Maya sites were abandoned in the south-central Maya region, with many attributing the cause to the increasing population density of the Classic period in conjunction with accompanying environmental degradation of the valley (Abrams and Rue 1988). No single factor can be responsible for the complex process of political collapse and population decline, but the increasing population density of the polity is believed to have played a significant role, as it may have severely affected the local environment (Abrams and Rue 1988). Although located in an agriculturally productive valley, environmental degradation due in part to overpopulation is believed to have played a significant role in the population abandonment of the site. A number of cultural factors related to the expanding population contributed to the overall situation of degradation, especially the expansion of maize cultivation into the foothill zone, the deforestation of the upland forest zone in supplying wood for fuel, and the impact of urban growth (Abrams and Rue 1988). The daily recruitment of wood for fuel was high given the size of the local population, and Abrams and Rue (1988) calculated that the amount needed was significantly higher that what was needed for lime plaster production and house construction (Abrams and Rue 1988; Lentz 1991). In turn, urban growth intensified exploitation of the forest, exacerbating soils and nutrient loss and further contributing to the reduced agricultural productivity.

However, not all of the data agrees with these assessments. McNeil et al (2010), with analysis of a sediment core taken from the same location utilized in Abrams and Rue's research, produced a different result. McNeil's pollen profile did produce data that suggested a number of deforestations in the area; however they did not correspond with the period of the Late Classic collapse. The data produced showed a stable ratio between arboreal pollen and herb pollen, suggesting more controlled ecological management by the population. Possible resource preservation is also noted in the material culture through thinner layers of stucco on sculptured buildings, supporting this interpretation of the data (McNeil et al 2010). Additionally, this data also suggested a more abrupt collapse in regards to population decline, with a marked decrease in herb pollen indicated a dramatically reduced human population. This would not correspond to previous conclusions regarding a protracted population decline over time; however other research also supports this slower population loss.

Not all agree that environmental degradation would have been the sole cause of the large population displacement that occurred at Copan, even if the environment was under stress. Rather, many believe the state of the environment would have merely been a contributing factor further exacerbating an already destabilized political system in the process of decline (Fash and Sharer 1991). Manahan (2003 and 2004), in his assessment of construction in post-collapse Copan, found that the lack of continuity between the Coner and Ejar ceramic phases (with the Ejar phase commencing around AD 950) to be indicative of a more abrupt and complete depopulation after dynastic collapse. These conclusions have two important implications for interpretations regarding the classic collapse at Copan. Firstly, it does not support the ecological degradation model as a significant cause for collapse, and secondly, it reassesses the post-collapse appearance of individuals within the urban core. In finding abandonment to be more abrupt, Manahan (2004) found that the ecological degradation model would not be applicable; his interpretation being that environmental stress would cause gradual depopulation of the region as families would slowly abandon their lands due to increasingly reduced production. With a more abrupt depopulation however, Manahan concluded that the cause of collapse would have come from a more severe source, such as a possible sociopolitical or environmental catastrophe. Although there is evidence of droughts throughout the lowland region during the Terminal Classic (Medina-Elizalde et al 2010), the location of the polity on a flowing river, as well as the additional water management infrastructure, would have lessened the impact. Thus he suggests that the Collapse was possibly sociopolitical in nature. To support this interpretation Manahan refers to evidence of destruction and fortification within the principal group around the estimated time of collapse. Manahan found that evidence of extensive burning at the residential group of the final dynastic ruler, burning at other elite compounds in Las Sepulturas, and the construction of fortifications in the acropolis, all corresponded with the estimated time of collapse (Manahan 2004; Fash et al 2004).

Additionally, evidence of decentralization of the political system further supports this line of thought. Some research has suggested a period of decentralization in the political authority of the valley during the eighth century, based primarily on architectural evidence. A distinguishing feature of Copan has been the number and diversity of inscribed monuments outside of the Main Group (Fash et al 2004), which is believed to be representative of waning royal power. Hieroglyphic benches found in type four elite households are thought to be important status indicators detailing ritual and lineage ties (Fash 1983; Diamanti 1991). Three of the benches include historical inscriptions indicating that they were dedicated during the reign of Yax Pasah, the final ruler of Copan. Additionally, Structure 10L-22A, located on the Acropolis, constructed during the reign of Ruler 14 (Fash and Agurcia 2005), is thought to be a council house, in which community leaders would have been included, in some level, in the management of the polity. The imagery of the building is thought to explicitly portray representatives of different wards or lineages, and was built in the years following the defeat of the 13th King, 18 Rabbit, at Quirigua. Barbara Fash (2005) concluded that council house members would have been representatives of water hole groups, as the toponym glyphs located on the structure often contained a reference to a water course, cave, or black hole. These conclusions suggest that community leaders, possible representing water hole groups, were taking an active part in the Copan political environment.

With this connection to the council house, water management infrastructure has also been used to suggest decentralization within Copan. Interestingly, the water management infrastructure of the two wards, Las Sepulturas and El Bosque, supports this. Water management infrastructure was organized and managed differentially between the two elite communities (Davis-Salazar 2006). This could suggest a decentralization of infrastructural management within Copan, although it would be difficult to determine if this was due to decentralization or delegation. The process of water management may have provided a centralized source of authority for the elite population of each ward, controlling the water access for their own community (Davis-Salazar 2003). The use of the water lily motif is also thought to be indicative of this regional or community level management. The water lily is both a symbol of royalty and clean, still water, but the water lily motif began to appear outside of royal contexts toward the end of the Late Classic period, suggesting an increase of power in the non-royal elite (Davis- Salazar 2003; Fash 2005; Lucero et al 2011).

Taken all together, the evidence of heighted participation by lineage heads, decentralization of infrastructural management, and use of royal symbolism outside of the Main Group suggests that Copan during the eighth century was an increasingly decentralized state, with the lineage heads or representatives increasingly participating in the management of the polity (Fash et al 2004; Fash 2005). This evidence has been suggestive of a more significant political component to the collapse of the polity, in direct contrast to other hypotheses centered on environmental degradation.

The clear disagreement regarding the particular circumstances of the Late Classic collapse at Copan is important to the study of health within the population, as the different circumstances provide the context for understanding how health and stress were affecting the community. Theories focused on environmental degradation support that declining agricultural productivity was having a heightened effect on nutrition, while theories around decentralization provide the possibility that the collapse of water management, as a result of dynastic and elite collapse, would have increased the transmission of disease. However it should be mentioned that these factors are by no means mutually exclusive. Environmental degradation and political decentralization may have occurred concomitantly, exacerbating issues of disease transmission throughout the community through a combination of malnutrition, soil erosion affecting production and water contamination, and decentralization affecting community water management.

There is no disagreement that Copan faced decline and depopulation during the ninth century, and despite the differing interpretations, it is clear that the population of Copan was facing an increasing amount of stress across the board, be it sociopolitical or environmental or a combination of multiple factors, in addition to the stresses of an exceedingly dense population. This research aims to further understand how disease and infection were manifesting within the Copan urban core during the Late Classic and into the Terminal Classic period by examining the distribution and severity of infection of an elite residential group located in Las Sepulturas, group 8N-11.

Summary

As reviewed above, many factors contribute to the state of health in prehistoric populations. The physical environment, large population densities, social stratification, and political decline can all affect the transmission of disease and the quality of the local diet. Non-specific infection can be used to address those processes that may have significantly affected health within the urban core population, and have previously been used to investigate health at Copan. The primary cause of any infection will always be exposure to the pathogen, but paleopathology allows us to address how the physical and cultural environment can affect the development and progression of infection across a population. This study will examine the distribution and severity of non-specific infection to address how these factors may have been contributing to the state of health within the elite community of Copan.

Chapter Four

The Sample: Group 8N-11

The sample used in analysis represents all the burials recovered from Group 8N-11, also called the Skyband Group, an elite residential compound on the northeastern end of Las Sepulturas, at the end of the eastern causeway extending from the Main Group (Figure 4).

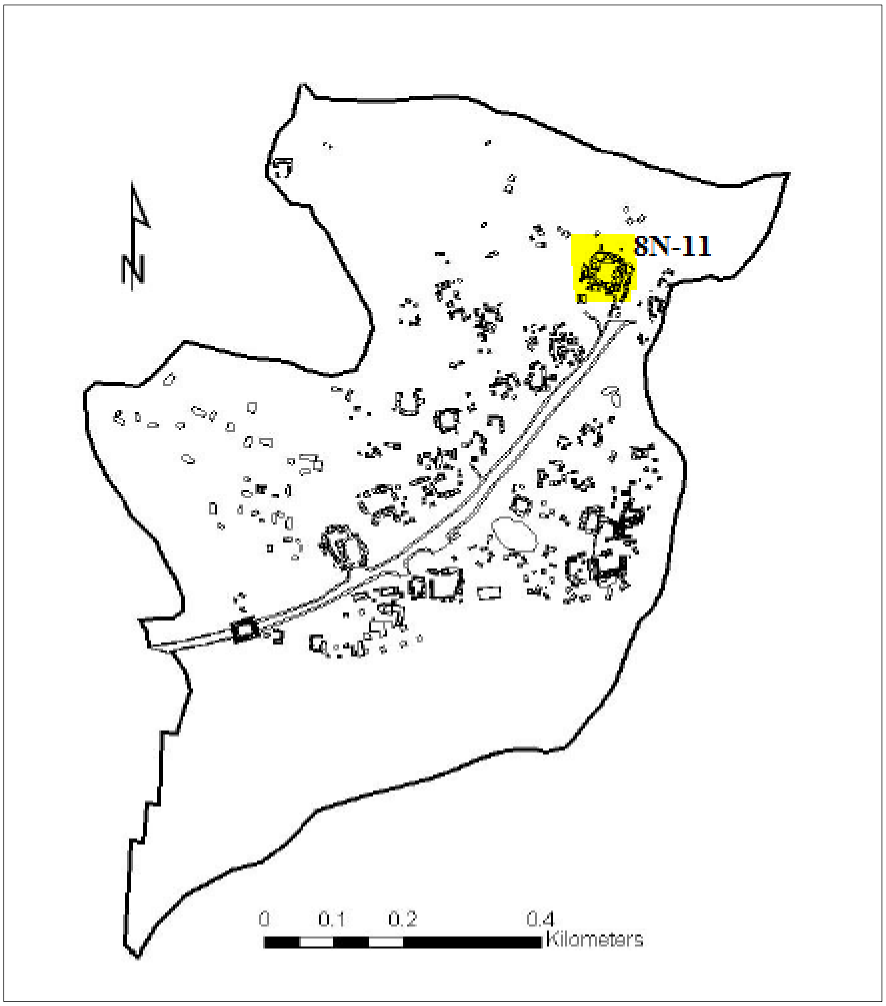

Figure 4 Las Sepulturas and Group 8N-11 (Adapted from Richards-Rissetto 2008)

Although the complex includes 24 associated buildings (Figure 5), this sample represents the excavations of only five buildings within the compound, the three buildings of the 66 Complex, which formed the eastern side of the patio, and two ancillary buildings, structures 50 and 51, which were located behind the 66 Complex.

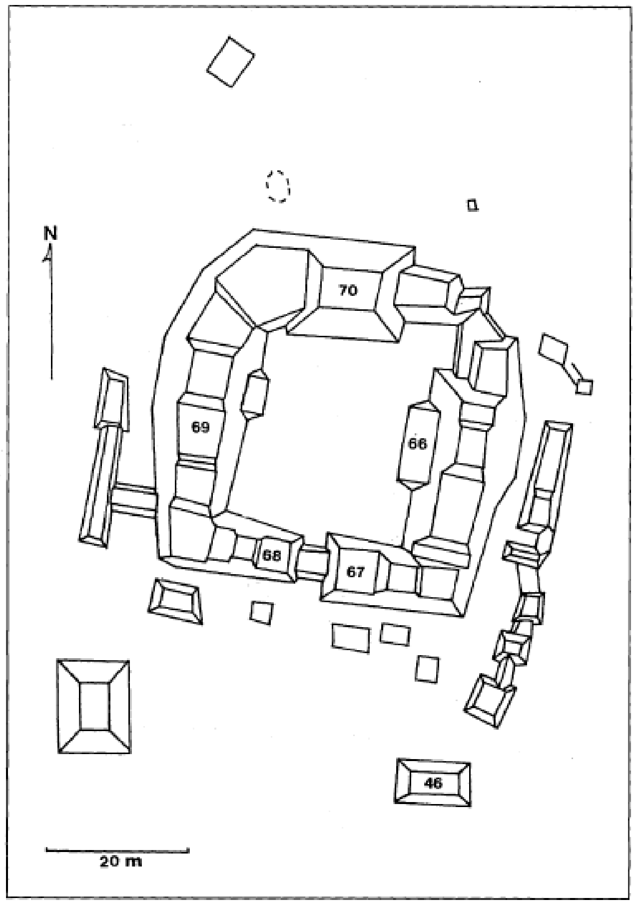

Figure 5 Map of Group 8N-11 (Adapted from Webster et al. 1998)

Group 8N-11 was an elite compound built rather late in the chronology of the Copan site, as determined by the ceramic assemblage, the architectural style and obsidian hydration dating (Webster et al 1998). The ceramic assemblage placed the site well into the Coner phase, which first commenced around A.D. 600, indicating primary residence of the site well into the Late Classic period. The architectural style of the site also placed the group within that time frame, given the elaborate construction and use of sculpture was most prevalent after A.D. 738, during the period of decentralization that occurred after the defeat of 18 Rabbit at Quirigua. During that time, elaborate construction increased outside of the Main Group, including sculptural hieroglyphic benches at a number of elite sites in Las Sepulturas. Lastly, obsidian hydration dating further confirms a late construction and occupation, with over half the obsidian hydration dates taken occurring after A.D. 800 (Webster et al. 1998).

The group was determined to be representative of an elite site for a number of reasons, including both the quality of the architecture and sculpture of the main buildings of the 66 complex. The architectural quality of the main structures was high, significant expenditures of energy would have been required to complete all three buildings of the 66 complex, and have been estimated at around 9,674 person days for 66C, the most elaborate of the structures (Webster et al. 1998). This fell above the range estimated for typical elite structures, which Abrams (1989) has estimated most elite structures to fall within a range of 1,000-5000 person days. Both 66N and 66S, the other two buildings of this complex, fall within that range, but 66C far exceeds it. This high cost of construction, in addition to the high quality sculpture included on the facades of the buildings, indicate that the leader of the group had the ability to exploit a high level of labor (Webster et al. 1998), further indicating the high status of the group.

The high quality sculpture also indicated a high status as well as connections to the royal dynasty through the imagery included in the 66 complex. The carved bench located in

66C included imagery associated with royalty and the quality was comparable to sculpture found in the Main Group (Webster et al. 1998) and there were also shared iconographic themes between the 66 complex and other instances of sculpture at the Main Group. Structure 66S shared stylistic features with Structure 10L-32, the principle building of Group 10L-2, the royal residence attached to the Acropolis. 10L-32 dates to the late eight century and its images include water lily motifs (Webster 1999). Structure 66S shares these similar themes around fertility and agricultural sustenance, including the use of water lily imagery. Meanwhile structure 66C also shares features with another building in the Main Group. This imagery on this structure included symbols of human sacrifice and images of Sun Gods with three stranded captive knots around their necks (Webster et al. 1998). These images, specifically the knots, are also found in the Main Group, in the sculpture of 10L-22, thought the be the Council House. The combination of water lily imagery and the connection to the Council House give evidence that the lord of this group was not only of a high status, but had an active political or leadership role in the community. The water lily motif, while a symbol of royalty, is also interpreted as a symbol of water management, of which there is strong evidence of in Las Sepulturas.

Additionally, Fash (2005) has interpreted the glyphs located on the Council House to be representative of more than just lineage heads, but representatives of water hole groups. 8N-11 not only shares imagery with the Council House and themes of water management, but the location of the compound is near two known water control features evident today, the causeway, which is thought to double as a water control feature allowing the catchment of runoff, and the Sepulturas reservoir located near Group 9N-8 (Davis-Salazar 2006). The use of water management imagery, the similarities to Main Group sculpture, and the connection to the Council House all imply the importance of 8N-11 within the community at some level. Especially when considering the main occupation and construction of the sit occurring during a period of increased decentralization and the evidence post-dynastic activity in the compound, the evidence points to the lord or leader of this compound to be of significant importance to his community.

Like other Copan residential compounds, the architecture of the buildings and the variation of mortuary characteristics suggest intra-group ranking within the extended family that occupied 8N-11. Of the buildings excavated, there are clear architectural differences between two groups of buildings, the 66 complex and the 50/51 complex (Figure 6).

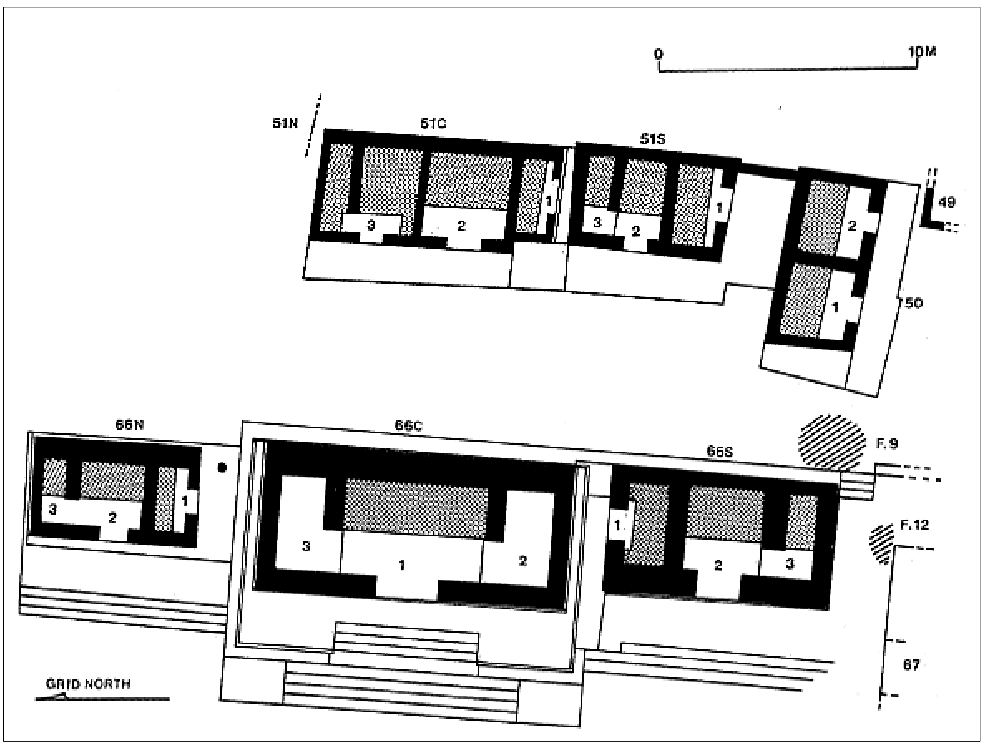

Figure 6 Plan of the 8N-11 Structures (Adapted from Webster et al. 1998)

The three buildings of the 66 complex formed the eastern side of the patio, and included two of the more impressive buildings of the compound, including 66C which contained the Skyband Bench. The inclusion of benches in all rooms of this complex clearly indicated a residential function, but the quality of the sculpture on the facades of 66C and 66S, as mentioned above, indicated an elite status of the residents. However in contrast, the buildings behind the 66 complex, 50/51 were ancillary structures of a much lower status. These buildings were unusual in that they were not included with the main patio group; they were located behind the 66 Complex, separated by a narrow corridor. At other Copan sites, while intra-group social ranking is evident, it does not often result in segregation; lower status residents will still be included in the patio group. But in the case of 8N-11, the 50/51 complex was segregated from the rest of the group in terms of placement; it was very close, but not included in the greater patio group. At first, due to its placement, it was thought to be a workshop or some other type of specialized building (Webster et al. 1998). However, artifact distribution and the presence of interior benches in all the rooms indicated that the buildings were residential in function and no unusual features that would otherwise indicate specialization were recognized (Webster et al. 1998).

Although the site as whole is considered a type 4 elite site, it is important to note that had the structures of 50/51 been taken apart from the greater group, they would have been designated a type one site, the lowest level on the scale of site ranking at Copan. Although it was built of a higher quality stone than most rural type one sites, this is not atypical; type 1 sites in the urban core were often of better quality then their rural counterparts (Abrams 1989; Gerry 1993). Additionally, the artifact distribution was statistically similar to a type 1 rural domestic site (Webster et al. 1998), further confirming the likelihood of it representing a lower status residence.

Given this difference in structural characteristics between the two groups of building within the residential compound, the burials of 8N-11 will be analyzed to determine if a relationship exists between their associated structural location and the presence and severity of infection. The overall aim will be to determine if differences in mortuary characteristics can show patterns of health and disease within the elite population of Copan to determine if intra-group social ranking affected resource distribution and health.

Data Analysis

All data for the sample was collected by Dr. Rebecca Storey of the University of Houston and has been provided for analysis. Severity will be assigned to all incidences of infection in the sample using a combination of the data provided as well as photographic images of the pathologies. To analyze the data, Statistical Analysis using SPSS v. 22 will be used to determine the distribution of all variables among the sample and to analyze the relationships between the biological and cultural variables. The chi-square test of association will be used to determine if relationships existed between the individuals and the distribution of pathology and infection. Given the small sample size and the missing data for some variables, Fisher's exact probability test will also be included in analysis, as it does not require large expected frequencies to be valid.

Analysis was conducted to determine if any distinctions in social status could be observed in the distribution of the burials. To begin addressing this question, the data was first assessed to determine if any significant relationships existed between the mortuary characteristics of the burials including: grave location, grave type, and grave goods. This will be followed by addressing the relationships between the cultural variables and pathology. Chi-square analysis will be used to determine if a relationship exists between the cultural variables and the occurrence of any pathology, the occurrence of infection, and more specifically the relationship between the cultural variables and infection severity, infection type, and state of healing.

The total sample originally include 28 individuals, however three were removed from analysis due to the lack of associated data: two individuals could not be examined for pathology due either to large portions of the skeleton missing or overly eroded surfaces, and a third individual was removed as all mortuary data (including grave location and grave type) were missing. This chapter will provided a description of the resulting data analysis that focused on the remaining 25 individuals. Interpretations of the results will be presented in the following chapter.

Variables

Variables for analysis will include both pathological data and cultural data to determine if patterns of health and infection exist within the group. Age and sex, as assigned by Dr. Rebecca Storey using the standards of Buikstra and Ubelaker (1994), will be analyzed for associations with all variables to determine how social status and health may have been distributed by age and/or sex.

Variables to be used to social status will include grave type, grave location (assigned by structural association), and grave goods. These variables will be used to represent social status, as the range in the energy and resources devoted to both construction and mortuary treatment can be indicative of social differences.

The grave type variables will include the six categories of grave type as taken from Reed (1998) and Diamanti (1991): simple pit, cobblestone, capstone, cist, rough stone tomb, and dressed stone tomb. As mentioned above, the range in the energy required to construct graves can be suggestive of social differences. Simple pits are those graves that lack any evidence of elaboration; they are simply placed in the ground and filled, and are the simplest form of grave. Cobblestone graves are those that are somehow formed using river cobbles, be it as a covering or rough walls, and is the simplest form of a constructed grave. Capstone burials are those graves that have either a partial or whole covering of dressed masonry stones laid over the top of the grave. Cists are burials with two or more walls of stone; cobbles, rough stone and dressed stone can be used in forming the walls and the burial may or may not be covered with a capstone. Rough stone tombs are similar to cists; however they have four walls, are larger, may have a stone floor, and are generally covered with a capstone. Dressed stone tombs are the most elaborate graves, well-dressed tuff blocks were used, and the tombs often had stone floors, wall niches and large capstones.

Location will be assigned to all burials based on structural association within the compound. This variable will also be used as a proxy for social status, given the architectural differences between the 66 complex buildings and the 50/51 buildings. As reviewed above in discussion of the 8N-11 site, there were significant differences in architectural style and quality between these two groups of buildings. The buildings that formed the 66 Complex were of high architectural quality, included elaborate sculpture, and included an elaborate hieroglyphic bench within the 66C building. For these reasons it was believed to that the site was occupied by a high status, elite family. However, the structures located behind the 66 complex, buildings 50 and 51, contrasted with the high quality of the rest of the compound. These buildings were not included within the greater patio group, as they were located behind the structures that formed the main patio, and they were of simpler construction. For these reasons, it is alleged, for the purposes of this study, that the differences between the 8N-11 structures could be representative of intra-group social ranking. Given the small sample size available, the five structures of the compound used in this research will be condensed into a two category variable. Structures 66S, 66C, and 66N will form the 66 Complex, while structures 50 and 51 will together form the 50/51 complex.

The grave goods and furnishings associated with individual burials will also be used to determine associations between social status and health. The objects included within graves can be indicative of social differences, representing unequal access to resources within the lineage or group (Hendon 1991). The grave goods found in association with the burials of 8N-11 will be placed into one of two categories: obsidian and ceramic vessels/ornaments following the descriptions of Hendon (1991). Obsidian blades were a basic tool throughout Copan and access was not restricted. However obsidian could also be used as material for items of adornment or ornaments. The obsidian recovered with the 8N-11 burials lacks further description; as such it will all be placed in a single category and will not be included as ornaments. Ceramic vessels include ceramics of varying type and function, and their inclusion in burials suggests a ritual function. Ornaments refer to items of adornment, such as beads and jewelry that are made of greenstone (either jade or serpentine), obsidian, shell, or animal bone. The presence of ceramic pottery or ornamental items can be indicative of social status, as they are less common, while the most common grave goods recovered are ceramic beads and obsidian blades (Hendon 1991). Given the association between social status and both ceramic pottery and ornamental items, these categories were merged together to determine if associations exist between the presence of grave goods and health.

Pathological variables will include the presence of infection, porotic hyperostosis, enamel hypoplasia and other dental pathology. The primary analysis will focus on the distribution and severity of infection; porotic hyperostosis, enamel hypoplasia and dental pathology will be included for purposes of assessing general health, but will not be analyzed for severity. Dental pathology will represent carious lesions, abscesses, and tooth wear and loss. Enamel hypoplasia will not be included with the dental pathology variable, given that hypoplasias represent disruption in tooth development and are indicative of episodes of stress and malnutrition in childhood, while dental disease can occur throughout life and results from tooth decay . Infection severity will be determined for infection based on the methods utilized by Weston (2008), which is based on Lallo's (1973) method for prescribing severity to periosteal lesions (Table 2). Severity level will be scored based on the location and characteristics of the periosteal lesions.

Stages of Periosteal Lesion Severity		
Stage 1	Smooth and undamaged periosteal surface	Represents appearance of bone not yet afflicted by infection
Stage 2	Longitudinal striations begin to appear in at least three quarters, two of which must be continuous up and down	Initial stages of disease wherein periosteal damage and destruction is beginning
Stage 3	From 1 to 3 noncontinuous quarters with mild pitting and swelling	
Stage 4	At least 4 noncontinuous quarters with moderate pitting and swelling	
Stage 5	At least one local large swelling with moderate pitting in three quarters	From Stage 5 onward periosteal damage and destruction becomes more acute
Stage 6	Three or more noncontinuous quarters exhibit swelling or two continuous quarters (up and down) exhibit swelling or one zone may exhibit swelling and scaling	
Stage 7	Heavy pitting in at least one zone (zones may consist of noncontinuous quarters)	
Stage 8	Heavy pitting in at least two continuous quarters	Stages 8 and 9 represent extremely heavy periosteal destruction
Stage 9	Heavy pitting of periosteum over the entire area of three continuous quarters and part of the fourth	

Table 2 Periosteal Lesion Stages of Severity (Adapted from Weston 2008)

Additionally, other ways of scoring periosteal lesions will be used to assess infection severity. These variables will include the stage of healing and if the periosteal reaction represents a localized or systemic infection. Photographs of the lesions will be utilized to make these determinations; the observations made by Dr. Storey will be used for those reactions without photographic representation, which were scored following Buikstra and Ubelaker (1994).

The type of periosteal bone present, woven or lamellar, can indicate the stage of the lesion at the time of death. Woven bone indicates that the disease process causing the reaction was still active, while lamellar bone represents a healed lesion (Weston 2008). If both types of bone are observed, this may indicate that the lesion was in the process of healing at the time of death. Woven bone presents with a more porous, disorganized appearance, while lamellar bone will present with a more organized appearance, blending into the surrounding bone. These distinctions are important as they may indicate how the disease or infection affected the individual, although it cannot be determined if the disease causing the reaction was terminal (Weston 2008).

Each periosteal reaction will also be analyzed to determine if the lesion is representative of a localized or a systemic infection. This will be determined based on size and characteristics of the lesions as viewed through photographic representations. Clearly defined lesions with distinct boundaries often represent a localized reaction, as there is a distinct demarcation between the lesion and the underlying bone (Weston 2008). A diffuse lesion with obscured boundaries will blend in with the underlying bone, and often represent systemic reactions (Weston 2008).

Results of Analysis

Age Distribution

In regards to age, the sample was overwhelmingly juvenile, with 52% of the individuals represented determined to be under the age of 5; all others were adults, only 1 of which was considered a young adult. No children or adolescents over the age of 5 were recovered. Within the subadult population, infants under the age of 1, not including newborns, were the majority at 54% (7), followed by neonatal/preterm infants and toddlers/young children up to age 5 with 23% (3) of the subgroup each. Young children between the ages of 3-5 were included in the toddler group as only one was identified.

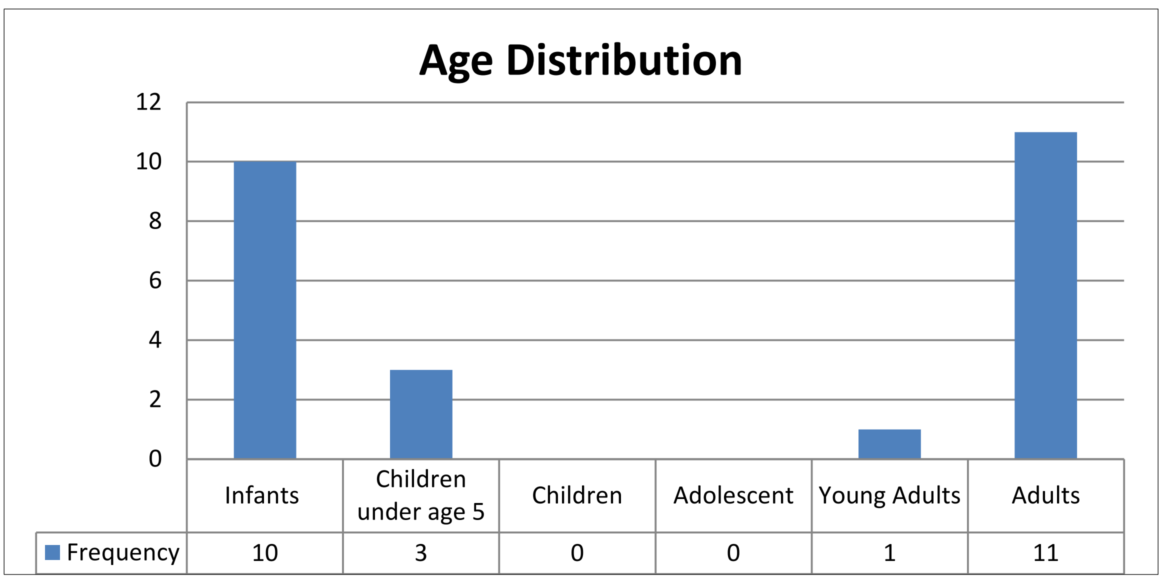

Table 3 Age Distribution

The distribution is age detailed in Table 3, above. The distribution does seem to follow the typical mortality distribution often recognized in research on demography.

Presenting with a high representation of infants in the first year of life, followed by a steep decline during childhood past weaning age and adolescence, followed by a slow increase through adult hood as degeneration and aging affect health and increase mortality (Kreger 2010).

Sex

Due to the high number of subadults in the sample, more than 50% of the individuals remain unsexed. Of the adults that remain, sex was determined for 50% of the sample through observation by Dr. Rebecca Storey at the University of Houston. Statistical analysis, specifically Discriminant Function, was used to determine possible sex for the remaining sample. The results of statistical analysis found that 42% of the sample was female, 50% male, and one individual remained unsexed. Assuming the analysis provided correct values, the sample was rather fairly distributed between the sexes.

Mortuary Characteristics

Mortuary characteristics varied through the sample, and included descriptions of location, grave type, and grave goods. In regards to burial location, 68% of the sample were associated with the 66 Complex while the remaining 32% were associated with the 50/51 buildings. For those buildings associated with the 66 complex, the majority were located around 66N (58%), and for the 50/51 group, the majority (75%) were associated with structure 50. Burial distribution can be seen below in Figure 7.

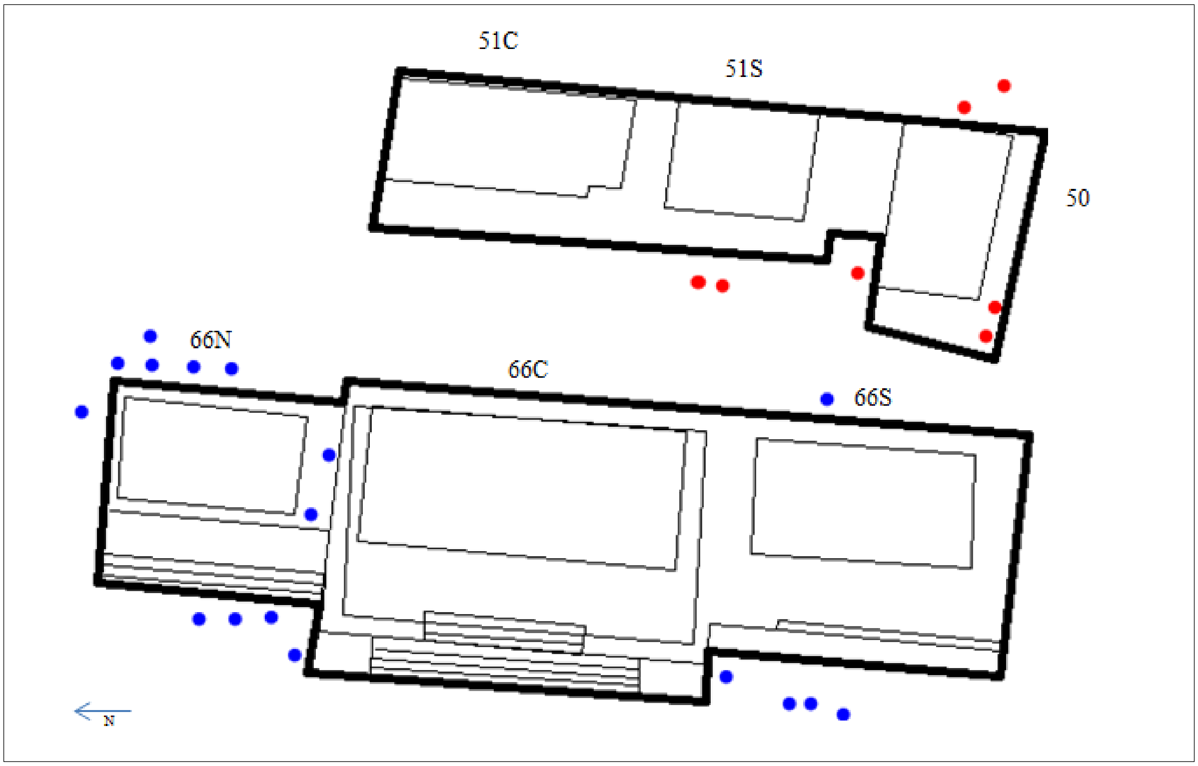

Figure 7 Location of Burials within 8N-11

Burial type was divided into six categories, as taken from Reed (1998) and Diamanti (1991). No elaborate tombs were recovered, and thus are not represented in this sample. Grave type distribution can be seen in Table 4 below. Pit and Cobblestone burials represent 64% of the sample, with eight individuals each, followed by 20% (five individuals) in Capstone burials, with the remaining split between Stone Tombs and Cists with two individuals each.

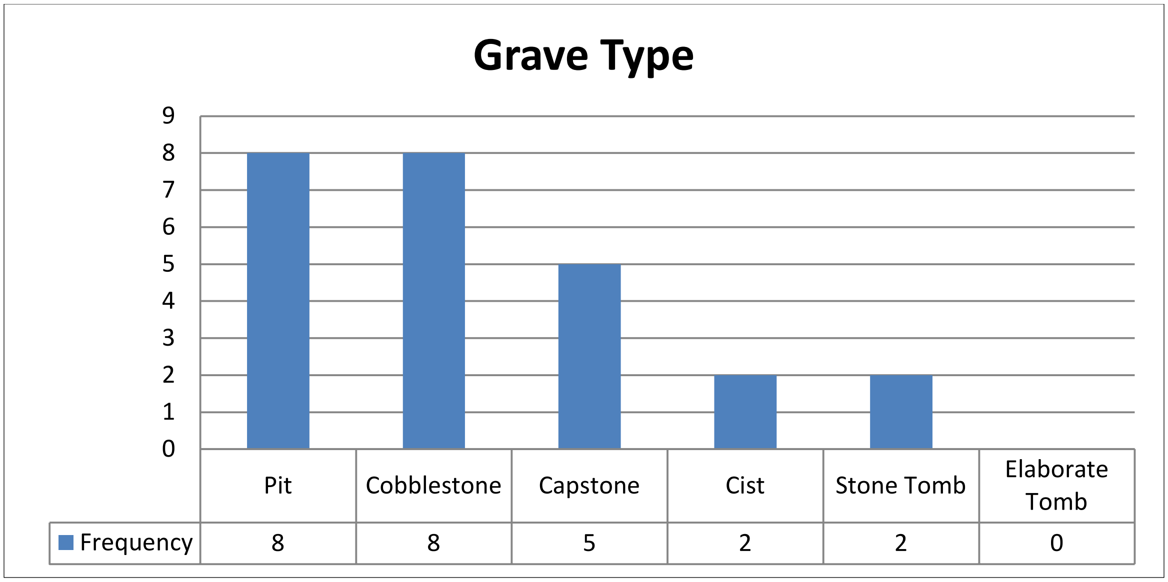

Table 4 Grave Type Distribution

Grave goods were present in the sample, but only occurred in six of the burials (24%), and all burials varied in the quantity and type of goods, including obsidian, ceramic vessels, varying ornaments, and one instance of jade in Burial 11. For those burials with grave goods included, obsidian represented 33% (2), ceramic vessels represented 16% (1), ornaments or items or adornment represented 16% (1), and a combination of ceramics and ornaments together were found in the remaining 33% (2).

Given the small sample size and the variability in assemblage amongst those with ceramics and ornaments, the three categories were reduced to a two category variable. Ceramic vessels and ornaments were combined together to form a single category while obsidian artifacts were left within their own category. When combined in this manner, the distribution resulted in ceramic vessels and ornaments together accounting for 66% of the burials, with the remaining 33% represented by those with obsidian goods only.

Pathology

In assessing pathology, it was found that 88% of the sample displayed evidence of some pathology, here including periostitis (non-specific infection), porotic hyperostosis, enamel hypoplasia and dental pathology. Of those with any type of pathology present, 45% displayed multiple pathologies, all including infection with only two exceptions. Dental pathology did not occur in any case alone, it was accompanied by non-specific infection in all cases. Porotic Hyperostosis also occurred most often with infection (75%); however it also occurred together with enamel hypoplasia in two cases. Enamel hypoplasia was present in 52% of the sample. Overall, infection occurred the most often with 72% of the sample. For those seven individuals with no evidence of infection, four individuals displayed enamel hypoplasia with two co-presenting with porotic hyperostosis. Only three individuals showed no evidence of any pathology, and all three were children under the age of five. No adults in the sample presented without any indicators of stress.

Infection Distribution

For those 18 individuals displaying evidence of infection, 55% (ten individuals) displayed infection in multiple areas of the body. Nine incidences of infection were located on the tibia, and all cases save for one had secondary locations of infection. Nine incidences of infection were also located on the femur; however, for 6 of these individuals this was secondary to infection on the tibia, and in three cases the infection was localized to the femur alone. Additionally, five cases included infection on unidentified long bones. It is possible they represent either the femur or tibia, but the exact bone was unable to be determined. Only one case of infection occurred independently from the lower limbs, with Burial 20 showing localized infections on the Clavicle and Rib All other cases of infection were either contained to the lower limbs or occurred in a secondary location within an individual with infection in the lower limbs.

Infection Severity

One of the aims of this research was to determine if infection severity could further highlight distribution of disease within a population beyond just assessing occurrence. In this sample, severity was determined for only a limited number of individuals, as observation was only possible through photographs of the infections. However, photographs were not available for all individuals; those cases without photographs were assessed a general severity based on the data available and observations previously made by Dr. Rebecca Storey of the University of Houston. Only those individuals with accompanying photographs were scored for severity based on Lallo's (1973) Criteria for Periosteal Reaction Severity. Severity was assessed in three ways: state of healing, general severity (local or systemic) and scored severity. The population was relatively split between healed (56%) and active (39%) infections, only one individual had an active infection in the process of healing at the time of the death. There was a similar distribution in regards to local or systemic infections; 45% of the sample displayed evidence of systemic infection while the remaining individuals had localized infections of varying severity. It was only possible to score severity based on the photographs and data for seven individuals in the sample, and more than half of this subgroup was scored at a moderate/severe level for infection. However, since so little of the sample was able to be scored for severity at this level, and given the limited data available to assess as specific level of severity for those individuals, a general severity description (light, moderate, severe) will be assigned to all cases to allow for analysis with the rest of the sample.

Chi-Square Analysis

Grave type and Grave location

The relationship between grave type and grave location was assessed to determine if any differences in social status could be evident based on either of these variables. Structural associations were condensed into a two category variable, combining all burials associated with the 66 Complex into one category and all burials associated with 50/51 into another. There was a significant relationship between burial type and structure, with a Pearson Chi-Square value of 9.835 and a Significance of p= .043, thus the null hypothesis is rejected.

The distribution of grave type by location can be seen in the Table 5 below. To confirm the significance of the association, the grave type variable was condensed into a two category variable, splitting the six categories into two groups. The significance in the association increased when the variables were condensed into a 2x2 table with a Pearson Chi-Square value of 6.946 and a significance of p=.008.

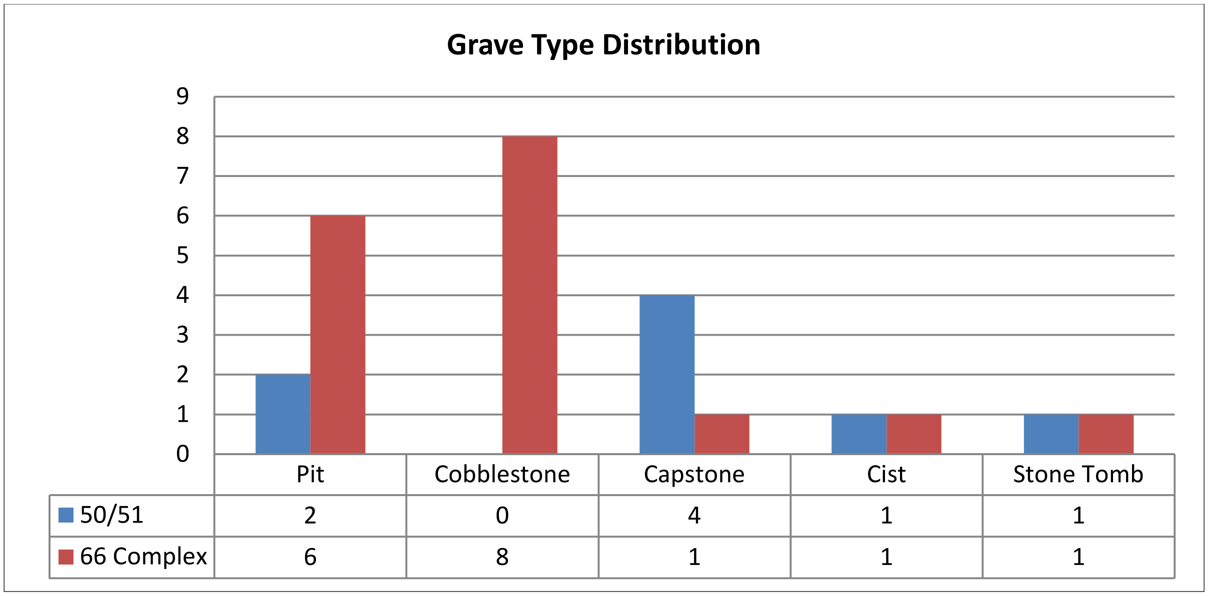

Table 5 Grave Type Distribution per Structural Association

Grave Goods

The remaining mortuary variable used to determine social status was the presence of grave goods. The presence of grave goods showed no significant relationship with either grave location or grave type. However, when analyzed by grave good type, significance did appear between grave goods and grave location.

The association between the presence grave goods and grave location resulted in a Pearson Chi-Square value of .006 with a significance level of p=.936. This shows an almost even distribution of grave goods relative to the sample location distribution. The association between the presence of grave goods and grave type resulted in a Pearson Chi-Square value of .111 with a significance level of p= .739. Accept the null hypothesis, there is no association between the presence of grave goods and either grave type or grave location.

The association between grave good type and grave type resulted in a Pearson Chi-Square value of 4.167 with a significance level of p = .384. Accept the null hypothesis; there is no association between grave good type and grave type.

The association between grave good type and grave location resulted in a Pearson Chi-Square value of 6.0 with a significance level of p = .050. Reject the null hypothesis, grave good type was associated with grave location. Despite the variation in grave goods, all ceramic vessels and items of personal adornment (such as jade, shell artifacts, and an amethyst crystal) were associated with the 66 Complex. The burials containing grave goods associated with the 50/51 structures only contained obsidian, no ornaments or ceramic vessels were included.

Age

Given the large representation of subadults in the sample, Chi-Square will be used to test if any association exists between age and the mortuary variables, as well as pathology.

The association between age and burial location resulted in a Pearson Chi-Square value of .949 and a significance of p=.814. The association between age and burial type resulted in a Pearson Chi-Square value of .019 and a significance of p= .891. The association between age and grave goods resulted in a Pearson Chi-Square value of 1.102 and a significance of .294. Results of analysis showed that age of the individual shows no significant association with grave location, grave type, or grave goods; must accept the null hypothesis that there is no association between age and social status as represented by these variables.

The association between age and presence of pathology in general resulted in a Pearson Chi-Square value of 3.147 and a significance of p=.076. The association between age and presence of infection resulted in a Pearson Chi-Square value of 1.470 and a significance of p=.225. The association between age and porotic hyperostosis resulted in a Pearson Chi-Square value of 3.436 and a significance of .064. The association between age and dental pathology resulted in a Pearson Chi-Square value of 2.564 and a significance of p= .109. The association between age and enamel hypoplasia resulted in a Pearson Chi-Square value of 2.036 and a significance of p = .154.

These results showed that age of the individual was not associated with the presence of any specific pathology when analyzed independently, must accept the null hypothesis that there is no association between age and specific pathology type. However, the association between age and the presence of porotic hyperostosis did come close to statistical significance. These results will be addressed in the discussions of the following chapter.

The association between age and type of pathology, when combined into a single variable, resulted in a Pearson Chi-Square value of 11.004 and a significance of p = .027. Reject the null hypothesis, there is an association between age the type of pathology. The specific association seems to be between age and the presence of multiple pathologies and can be seen below in Table 6. Infants and children under the age of five were more likely to present with infection without an accompanying presence of other pathologies, or no pathology at all, while adults were more likely to exhibit multiple pathologies. Given the majority of subadults were under the age of one year, this likely is the result of a short life span rather than the result of other social factors.

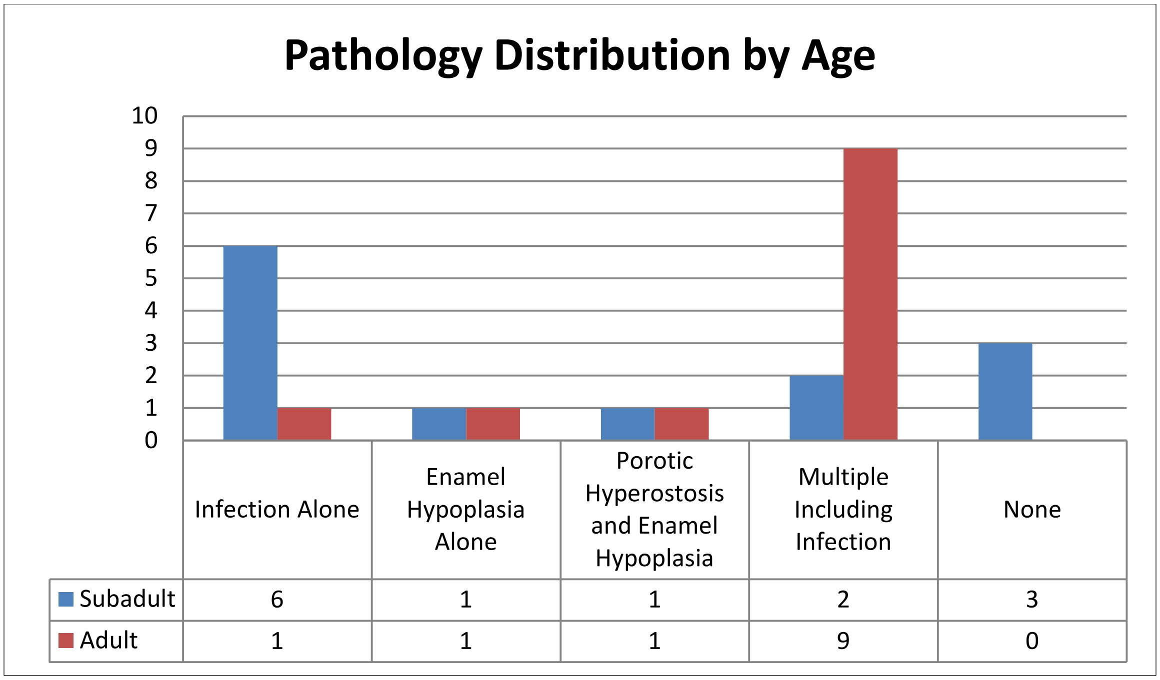

Table 6 Pathology Distribution by Age

Presence of Any Pathology

There were no significant relationships between the presence of pathology in general and social status as measured through grave location, grave type, or grave goods. The association between pathology presence and grave location resulted in a Pearson Chi-Square value of 1.883 and a significance of p = .170. The association between pathology presence and grave type resulted in a Pearson Chi-Square value of 3.220 and a significance of p = .522. The association between pathology presence and grave goods resulted in a Pearson Chi-Square value of 1.077 and a significance of p = .584.

Accept the null hypothesis of no significant association between the presence of any pathology and the mortuary variables of grave type, grave location and grave goods, thus suggesting no relationship between the presence of pathology and social status.

Presence of Porotic Hyperostosis

There were no significant relationships between the presence of Porotic Hyperostosis and grave location, grave type, or grave goods. The association between porotic hyperostosis and associated structure resulted in a Pearson Chi-Square value of .164 and a significance of p = .686. The association between Porotic Hyperostosis and grave type resulted in a Pearson Chi-Square value of 2.824 and a significance of p = .093. The association between porotic hyperostosis and grave goods resulted in a Pearson Chi-Square value of .006 and a significance of p = .936.

Accept the null hypothesis of no significant association between the presence of porotic hyperostosis in general and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between the presence of porotic hyperostosis and social status.

Presence of Dental Pathology

There were no significant relationships between the presence of dental pathology and grave location, grave type, or grave goods. The association between dental pathology and associated structure resulted in a Pearson Chi-Square value of 2.252 and a significance of p = .133. The association between dental pathology and grave type resulted in a Pearson Chi-Square value of 5.781 and a significance of p = .216. The association between dental pathology and grave goods resulted in a Pearson Chi-Square value of .055 and a significance of p = .815.

Accept the null hypothesis of no significant association between the presence of dental pathology in general and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between the presence of dental pathology and social status.

Presence of Enamel Hypoplasia

There were no significant associations between the presence of enamel hypoplasia and grave location, grave type, or grave goods. The associations between enamel hypoplasia and grave location resulted in a Pearson Chi-square value of .081 with a significance of p = .776. The association between enamel hypoplasia and grave type resulted in a Pearson Chi-square value of 5.957 with a significance of p = .202. The association between enamel hypoplasia and grave goods resulted in a Pearson Chi-Square value of 1.594 with a significance of p = .451.

Accept the null hypothesis of no significant association between the presence of enamel hypoplasia and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between the presence of enamel hypoplasia and social status.

Presence of Infection

There were no significant relationships between the presence of infection and grave location, grave type, or grave goods. The association between infection and associated structure resulted in a Pearson Chi-Square value of .053 and a significance of p = .819. The association between infection and grave type resulted in a Pearson Chi-Square value of .907 and a significance of p = .341. The association between infection and grave goods resulted in a Pearson Chi-Square value of .503 and a significance of p = .637. Accept the null hypothesis of no significant association between the presence of Infection in general and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between the incidences of non-specific infection and social status.

There were also no significant relationships between presence of infection and the presence of any other pathology. The association between infection and porotic hyperostosis resulted in a Pearson Chi-Square value of .053 with a significance of p=.819. The association between infection and dental pathology resulted in a Pearson Chi-Square value of 2.431 with a significance of p=.119. The association between infection and the presence of enamel hypoplasia results in a Pearson Chi-square value of .911 with a significance of p = .340. Accept the null hypothesis of no significant associations between the presence of infection and the presence of any other pathology.

Infection - State of Healing

There were no significant relationships between the state of infection (active or healed) and associated structure, grave type, or grave goods. The association between state of infection (active or healed) and associated structure resulted in a Pearson Chi-Square value of .771 and a significance of p = .680. The association between state of infection (active or healed) and grave type resulted in a Pearson Chi-Square value of 2.121 and a significance of p = .346. The association between state of infection (active or healed) and grave goods resulted in a Pearson Chi-Square value of 2.904 and a significance of p = .234.

Accept the null hypothesis of no significant association between the state of infection (active or healed) and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between state of infection and social status.

There were also no significant relationships between the state of infection (active or healed) and the presence of any other pathology. The association between state of infection (active or healed) and porotic hyperostosis resulted in a Pearson Chi-Square value of 2.893 with a significance of p=.235. The association between state of infection (active or healed) and dental pathology resulted in a Pearson Chi-Square value of .411 with a significance of p=.814. The association between state of infection (active or healed) and enamel hypoplasia resulted in a Pearson Chi-Square value of 1.918 with a significance of p = .590.

Accept the null hypothesis of no significant association between the state of infection (active or healed) and the presence of other pathology.

Infection Type – Local or Systemic

There were no significant relationships between infection type (local or systemic) and associated structure, grave type, or grave goods. The association between infection type (local or systemic) and associated structure resulted in a Pearson Chi-Square value of 1.25 and a significance of p = .535. The association between infection type (local or systemic) and grave type resulted in a Pearson Chi-Square value of 2.0 and a significance of p = .368. The association between infection type (local or systemic) and grave goods resulted in a Pearson Chi-Square value of .900 and a significance of p = .638.

Accept the null hypothesis of no significant association between infection type (local or systemic) and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between infection type and social status.

There were also no significant relationships between infection type (local or systemic) and the presence of any other pathology. The association between infection type (local or systemic) and porotic hyperostosis resulted in a Pearson Chi-Square value of 2.563 with a significance of p=.278. The association between infection type (local or systemic) and dental pathology resulted in a Pearson Chi-Square value of 2.562 with a significance of p=.278. The association between infection type (local or systemic) and enamel hypoplasia resulted in a Pearson Chi-square value of 2.388 with a significance of p = .496.

Accept the null hypothesis of no significant association between infection type (local or systemic) and the presence of other pathology.

Infection Severity

There were no significant relationships between infection severity (scored severity) and associated structure, grave type, or grave goods. The association between infection severity (scored severity)) and associated structure resulted in a Pearson Chi-Square value of 2.917 and a significance of p = .233. The association between infection severity (scored severity) and grave type resulted in a Pearson Chi-Square value of 4.375 and a significance of p = .358. The association between infection severity (scored severity) and grave goods resulted in a Pearson Chi-Square value of .875 and a significance of p = 646.

Accept the null hypothesis of no significant association between infection severity (scored severity) and the mortuary variables of grave type, grave location and grave goods, and thus no relationship between infection severity and social status.

There were also no significant relationships between infection severity (scored severity) and the presence of any other pathology. The association between infection severity (scored severity) and porotic hyperostosis resulted in a Pearson Chi-Square value of 2.917 with a significance of p=.233. The association between infection severity (scored severity) and dental pathology resulted in a Pearson Chi-Square value of 2.917 with a significance of p=.233. The association between infection severity (scored severity) and enamel hypoplasia resulted in a Pearson Chi-square value of 6.426 with a significance of p = .170. Accept the null hypothesis of no significant association between infection severity (scored severity) and the presence of other pathology.

Summary

This chapter reviewed the data analysis conducted to determine what associations exist between the presence and severity of non-specific infection and both social status and other pathology within the 8N-11 compound. The tests of association resulted in very few significant relationships between non-specific infection and both the social and pathology variables. However a number of patterns did emerge from the results; including a high frequency of infection, a large representation of juvenile burials, and a relationship between grave location and grave good type. These patterns will be further examined in the following chapter.

Chapter Five

Discussion

This research had two goals: to understand the state of health for the 8N-11 population based on infection distribution and to examine if infection severity could be indicative of intra-group social ranking, based on the assumption that higher ranking individuals within the extended family may have had some level of privileged access to resources. This chapter will further discuss the results of the data analysis and discuss how these results provide insight into the questions posed regarding health at 8N-11 and the greater Copan urban core.

Hypothesis One: Non-specific infection at 8N-11 will occur at a high rate, greater than 50%, due to the effects of high population density within the urban core

Previous research at Copan has shown a highly stressed population with a high rate of infection regardless of social status and residence. The null hypothesis stated there will be no significant difference between group 8N-11 and other Copan samples in regards to the presence of infection; results from the data analysis show that group 8N-11 faced a rate of infection greater than 50%. The null hypothesis was accepted, as 8N-11 faced a similar rate of infection to other Copan elite samples. These results suggest that the population of 8N-11 was not buffered from their environment. This further suggests that the effects of high population density are a primary factor to consider regarding the state of health in the Copan urban core.

Hypothesis Two: Infant mortality at 8N-11 will occur at a high frequency, greater than 40%, as infants and young children of weaning age were affected by the transmission of disease due to high population density

Previous research at Copan has shown a highly stressed population with a high frequency of infant and childhood mortality. The null hypothesis stated there will be no significant difference between group 8N-11 and group 9N-8 in regards to mortality in children under the age of five. Children under the age of five represented 52% of the 8N-11 sample. The null hypothesis was accepted, suggesting that infants and young children across the Copan urban core were facing similar stresses and were not buffered from their environment despite their privileged living conditions. Together with high rates of infection, this result also suggests that high population density is a primary factor to consider regarding the state of health in the Copan urban core.

Hypothesis Three: Severity of infection will manifest differentially within the 8N-11 sample; burials associated with the unelaborate, lower status residential buildings within the compound will present with increased severity of infection.

The second aim of this research was to assess how infection severity may answer questions regarding intra-group social ranking. Previous research has found that elite residential groups at Copan were internally ranked, suggesting a differential access to resources (Hendon 1991; Gerry 1993; Webster 1997; Kintz 2004). Considering the relationship between malnutrition and infection (Whittington 1989; Wright and White 1996; Larsen 1997; Danforth 1999; Betsinger 2007) this research aimed to determine if social status could influence the severity of infection within a group. The null hypothesis stated that no difference in infection severity will be detected within the group as related to markers of social status, including grave location, grave type, and grave goods. Data analysis showed no significant associations between severity of non-specific infection and all three variables used to represent social status. The null hypothesis was accepted, suggesting that intra-group social ranking did not affect severity of infection. This suggests that either resource access did not significantly affect health within the elite compounds, or that resource distribution was not significantly affected by social ranking. However, with no differential distribution of infection, it also remains unclear as to what extent individuals within the group were internally ranked, despite the significant architectural differences between the residential structures.

This chapter will examine the results of analysis in more detail, addressing a number of patterns that were observed in the results, including: the relationship between grave type and grave location, the high rate of infection throughout the sample, the distribution of age at death, and will conclude with a discussion regarding how the interaction between environmental degradation and the water supply may have exacerbated disease transmission within the urban community.

Mortuary Characteristics

In this study, three mortuary variables were used as indicators of social status: grave type, grave location, and grave goods. These variables have been shown to represent social status as the energy and resources devoted to particular individuals is believed to represent social significance. This section will review the results of analysis regarding how these variables were distributed within the 8N-11 sample.

As discussed previously, burial location was used to represent intra-group social status due to the architectural differences observed between the buildings of the compound. The burial locations of the individuals recovered from 8N-11 were split between these two residential groupings: the 66 Complex, a group of three buildings of high quality architecture, and the 50/51 buildings, two buildings of more modest architecture. The 50/51 buildings were located behind the 66 complex and were not included within the primary patio group. Given the differences between the two groups and the physical separation of 50/51 from the rest of the compound, it was postulated that burial location could be indicative of intra-group social ranking within the compound.

Grave type and grave good type were also used to determine social status, as both variables can be suggestive of social status. Both variables followed the categories previously used at Copan. The grave type variables included the six categories of grave type as taken from Diamanti (1991): simple pit, cobblestone, capstone, cist, rough stone tomb, and dressed stone tomb. Grave goods included three categories as taken from Hendon (1991): ceramics, obsidian, and ornaments. However, ceramic vessels and ornaments were merged into a single category given the association of both ceramic vessels and ornaments with social status.

Results of data analysis found two significant associations occurring within the three mortuary variables of grave location, grave type, and grave good type. Chi-square analysis found a significant association between grave location and grave type, as well as between grave location and grave good type. However the results were not complimentary.

Regarding grave location and grave type, it was assumed that if an association existed between the two variables, they would correspond in their indications of social status; burial types associated with a higher social ranking would be located with a building also associated with a higher social ranking. However, in this result, an inverse association occurred. In group 8N-11, the grave types more typically associated with a lower social ranking were more likely to be found at the 66 complex, which included the most elite buildings of the compound. Pit and cobblestone burials were heavily represented in association with the 66 Complex, 75% and 100% respectively, while capstone burials were strongly associated with the 50/51 complex at 80%. Cists and stone tombs were split between the residences with one at each site for each category, so there was no association between these higher ranking burials and location. However, two individuals were removed from analysis due to incomplete data, had these individuals been included in analysis 75% of cist burials would have occurred at 50/51 as well. Had those burials been included in analysis the association between location and grave type would have increased in significance to p=.019.

A similar result, an inverse social relationship between grave type and grave location has been preciously observed at Copan. Group 9N-8, another elite residential compound in Las Sepulturas, exhibited a similar relationship, with capstone burials more frequently associated with the lower status patios (Diamanti 1991). Burials were considered to be indicative of intra-group, or intra-patio, ranking at 9N-8 based on age and burial location, with infants mostly representing simple pit burials. Although a similar pattern emerges at 8N-11, with no infants placed in cists or stone Tomb and represented mostly in cobblestone and simple pits, the association between age and burial type was not significant. However, it is interesting to note that the cist burials removed from analysis due to insufficient data were adults; the association between burial type and age at 8N-11 would have been strengthened if included analysis had they been included, but would still not have been statistically significant.

Given the similarities of burial type associations between group 8N-11 and 9N-8, it is assumed that burial types are an appropriate indicator of social status; however the lack of association with the elite residential buildings is interesting. The difference in grave types and location types could have implications for the interpretation of 50/51 complex. The main differences observed between the buildings are architectural characteristics and placement of 50/51 off of the main patio group, in addition to similarities of the artifact assemblage of 50/51 with rural type 1 sites. This relationship is interesting, especially since it contradicts the analysis of the other mortuary variable, grave goods.

Despite the association of burials requiring greater investment, or higher social status, with the lower status buildings, there was a significant association between grave good type and grave location. The presence of grave goods was not significantly associated with any other variable. However when analyzed by type, with the two categories of ceramic vessels/ornaments and obsidian, an association did occur. Grave good type was significantly associated with grave location at a significance of $p = .050$. The results indicated that the grave good type of ceramic vessels/ornaments were associated with the 66 complex. Those burials with only obsidian included were associated with the 50/51 buildings. In this result, the categories associated with higher social status did correspond, with the more valuable grave goods of ceramic vessels/ornaments associated with the elite buildings of the compound.

These results are interesting as they provide contradictory conclusions. The architectural differences between the buildings do strongly suggest social variation, especially given the segregation of the 50/51 buildings from the main patio group. The use of space has been found to reinforce the existing social hierarchy at Copan and the exclusion of the 50/51 buildings from the main patio group could suggest a different status (Richards-Rissetto 2010). Although grave good type does support the assumption of a higher social status for residents of the 66 Complex, the grave type distribution contradicts this at a statistically significant level. Thus it remains difficult to come to firm conclusions regarding social status within the 8N-11 compound based on these results.

High Rate of Infection

To understand the state of health for group 8N-11 in general, the distribution of non-specific infection, porotic hyperostosis, dental enamel hypoplasia, and other dental pathologies were examined. Of particular interests were the high rates of infection shown across the sample.

Infection frequency within the 8N-11 sample showed a high rate of infection across the population, regardless of age. Out of the total sample of 25 individuals, 72% (18) suffered from infection at some point in their lives. Seven individuals showed no evidence of infection, five of whom were infants (including newborns). The distribution of infection was relatively even throughout the site. The burials associated with the 50/51 residences resulted in a 75% occurrence of infection; while the burials associated with the 66 Complex resulted in a 70.6% occurrence of infection. Although the frequencies were slightly different, they were not statistically significant; there was no clear association between incidences of infection and burial location. There was also no clear association between the distribution of infection severity and any of the mortuary variables. Although one of the aims of this study was to determine if infection severity could be indicative of intra-group social status, the results did not support that assumption.

In comparison to the non-specific infection, other pathologies occurred at a lesser frequency. Porotic hyperostosis was present in 32% of the sample; however in all cases it occurred along with infection, enamel hypoplasia or both. Porotic hyperostosis was especially low amongst the subadults, with only 25% of those displaying porotic hyperostosis being under the age of 5, despite making up more than 50% of the sample overall. Although there was not a significant association between porotic hyperostosis and age, the analysis did come close to significance with a p value of .064. This could be representative of the lower rate of porotic hyperostosis among the subadult sample. Enamel hypoplasia was present in 52% of the sample, and similar to porotic hyperostosis, often occurred with either infection, porotic hyperostosis or both. The statistical association between age and enamel hypoplasia was not significant, however the high rate of enamel hypoplasia amongst adults, 75%, suggest that significant stresses were occurring during childhood for this population.

A high frequency of infection has been found previously throughout the Copan population. Whittington (1989) found infection in 40% of his low-status sample, with adults particularly affected with a high rate of infection, suggesting that those individuals that survived childhood had at least one infection severe enough to appear on the skeleton. Padgett (1996) also found a high rate of infection in her sample of the urban/elite population at group 9N-8, with a 69.7% rate of infection. The rate of infection within Padgett's urban sample is very similar to the rate of infection in 8N-11, suggesting that the urban population as a whole was facing considerable stress during the Late Classic period. The lack of difference in malnutrition or nutritionally related stress between the urban core and rural population (Whittington 1989), together with the non-discriminatory frequency and heightened severity of infection within the urban core (Padgett 1996), suggested that the high population density was a prime contributor to the transmission and progression of infection in the population. Highly dense populations often contribute to an environment of poor sanitation and hygiene, as well as higher rates of transmission and repeated exposure to disease. Repeated exposure can lower resistance and the ability to heal from an active infection (Padgett 1996; Whittington 1989). Poor sanitation can also increase disease concentrations and exacerbate transmission. Water and sanitation management is a significant component in addressing the manifestation of infection in a population (Padgett 1996; Webster et al 2000), so it must be considered that water contamination as affected by population density and environmental degradation may have contributed to the high frequencies of infection within the urban core. This possibility will be further discussed below.

Infant Mortality

Another interesting result provided by this analysis was the high frequency of infant mortality present in the 8N-11 sample. In this sample of 25 individuals, 52% were represented by subadults under the age of five. This result also corresponds with the results obtained from group 9N-8, in which 46% of the sample was represented by subadults under the age of five (Storey 2005). This is not a common result in most archaeological samples. Due to the fragile nature of infant skeletal remains, infants and young children are often underrepresented (Halcrow et al 2008). The presence of high infant mortality, even if expected, may have implications regarding the health and exposure to disease of any population.

A high infant mortality rate can be a sign of significant nutritional stresses affecting both children and adults, as infant mortality can be representative of inadequate maternal nutrition affecting the quality and quantity of breast milk (Danforth, 1999; Whittington, 1989; Katzenberg et al, 1996). However, given that the rate of births at Copan is unknown, it is difficult to make assumptions regarding the actually infant mortality rate, but it is possible that the rate may have been high. Infants and young children are at particular risks of disease and malnutrition. Between the complex nutritional requirements needed for proper growth and development and their underdeveloped immune system, young children are particularly vulnerable to disease.

Infants must rely on the immunities provided through breast milk to protect them from disease; however weaning practices may have a considerable impact on nutritional quality and infant survival. Nutritional requirements may not be met with the weaning diet and exposure to pathogens increase with the addition of food and water to their diet (Goodman and Armelagos, 1989; Santley and Rose 1979). Assuming that process of weaning was similar at Copan as other Maya sites, it could have begun during the latter half of the first year of life. The process would start with the introduction of maize to the infant's diet between six and twelve months of age, with a gradual decline in breastfeeding until an age between three and four years. Excluding newborns, 40% of the sample from 8N-11 is represented by infants and toddlers who could have likely been going through the process of weaning at the time of death (assuming food supplementation begins at some point during six to twelve months of age and breastfeeding does not fully cease until three or four years of age). The stresses associated with weaning may have been compounded by the other environmental factors affecting health at Copan. The combination of environmental degradation, high population density and malnutrition may have all been contributing to an already stressful period for young children.

Environmental Degradation, Water Quality and Infection

The high rates of infection throughout the sample, as well as the large representation of children under the age of five, suggest that the population of the urban core was under particular stress during the Late Classic period. It has been discussed previously how at this time, late Classic Copan was facing considerable environmental degradation due to the intensive agriculture that was required to support the large population. Although infection can be the result of multiple factors, given the dense population of the urban core it is necessary to examine how sanitation and water quality contribute to the transmission and severity of infection. Water quality within Copan may have been impacted by the expansion of agriculture into the hillsides of the valley and the effects of increasing environmental degradation. Soil erosion resulting from deforestation and intensive agriculture can contribute to the spread of infection and disease in downstream communities. In Las Sepulturas, two streams enter the community from the north-west and pass through the large reservoir of the ward during the rainy season (Davis-Salazar 2006). An image detailing the location of the Las Sepulturas reservoir and the type 4 sites nearby, including Group 8N-11, can be seen below in Figure 8. The quebradas (streams) that enter the community are seen to the upper left of the image with the Copan River on the lower right.

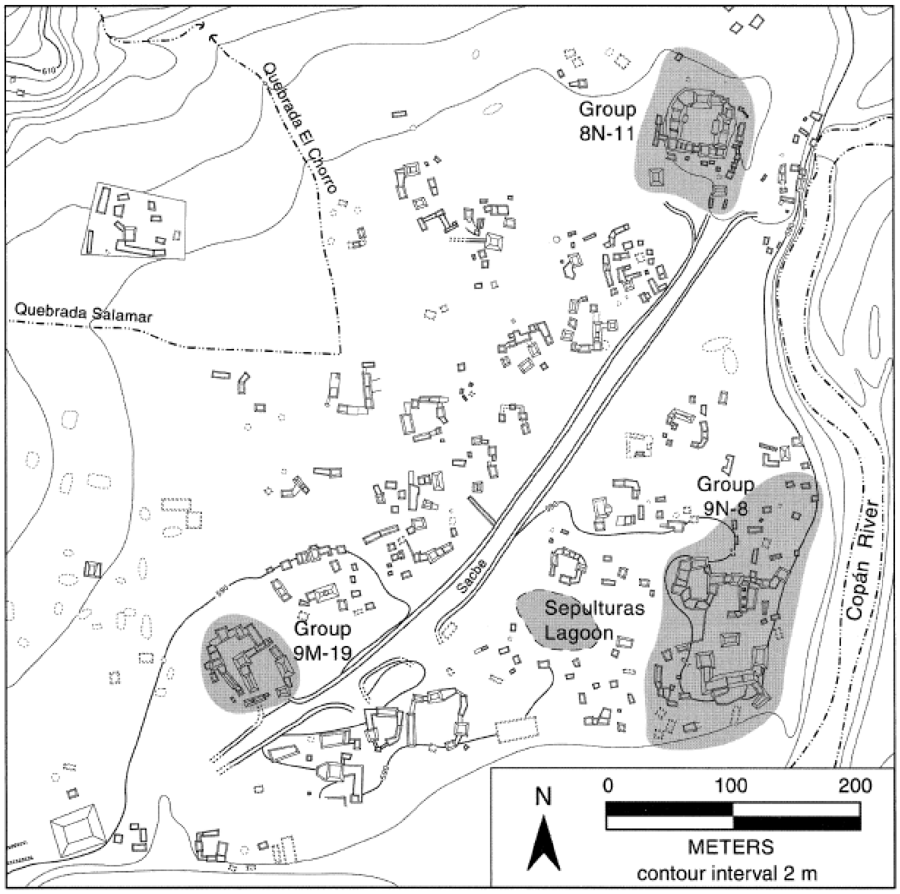

Figure 8 Las Sepulturas Reservoir (Adapted from Davis-Salazar 2006)

Had soil erosion caused an increase in the amount of sediment and other contaminants to enter the water supply through runoff, it is possible that the main water sources of the urban core could have become contaminated. The expansion of agriculture into the hillsides of the valley could have contributed to the high rates of infection within the urban core as increasing soil erosion affected the water quality of Copan reservoirs.

Many have suggested that extensive deforestation and intensive agriculture were having a profound effect on the local environment during the late classic period (Wingard 1992). The deforestation of the surrounding forest and expansion of maize agriculture into the hillsides would have caused significant soil erosion, with a worst cases scenario of 5.5 million metric tons of soil being redeposited annually (Wingard 1992). The topsoil located at the surface is the most susceptible to erosion and also contains the majority of contaminants exposed to the soil, serving as a reservoir for fecal material. As the run-off due to erosion increases, the sediment increases the amount of contaminants, including fecal material, flowing into water sources (Crabill et al. 1999; Van der Perk 2006). This would have increased the sediment burden of the river, which could lead to severe flooding, affecting any agriculture occurring on the lower alluvial terraces and further exacerbating the problems around agricultural production and supply. Additionally, the increasing sediment loads would also have an effect on water supply as soil run-off would enter the water reservoirs, increasing the amount of fecal material, and the pathogens they carry, accumulating within the Copan reservoirs.

Most known water-borne diseases are caused by microorganisms found in the intestinal tracts of human and other animals, and fecal contamination is thus a primary source of disease transmission (Hoyle 2008). Water –borne pathogens, including campylobacter, salmonella, shigella, and Escherichia coli (E.coli), occur globally and are especially prevalent in warm and moist tropical climates, and all of these can result in severe diarrhea and dehydration (Barzilay et al. 1999). As sediment builds up in still water sources, the possibility of increased transmission of these pathogens is likely, especially through those sub-populations most susceptible to disease and infection, such as infants and young children.

The quality of the water contained in the Copan reservoirs may also have been affected by the decentralization of the polity. Still water reservoirs require a significant amount of maintenance. Typically maintenance emphasizes participation at a community level as it requires significant levels of cooperation; unlike physical property a water source cannot be easily and distinctly divided, bulk collection and storage is necessary (Davis-Salazar 2001). Sediment is not easily removed from reservoirs; maintenance is an important factor in ensuring the quality of the water contained. The community leaders of Copan were responsible for organizing the needed maintenance of the water reservoirs (Lucero 2002). Declining community maintenance could have led to an increase in water pollution and declining water quality, particularly with an increase in fecal material. This would have increased community exposure to a variety of pathogens (Scarborough 2003; Cohen and Crane-Kramer 2003; Fash 2005).

Had decentralization of the polity affected the level of community involvement in water maintenance, it may have been difficult to control and mitigate the possible increase in pollution and sediment build up due to soil runoff in the Copan reservoirs, increasing the possible exposure to fecal material and infection throughout the community. The combination of increasing soil erosion due to environmental degradation, political decentralization, and depopulation occurring during the terminal Classic period may have all affected the quality of the water supply in the urban core. Despite depopulation and political decline, many did remain in the core in the years following dynastic collapse. Had erosion and sediment buildup affected the water quality, this could be a probable, though not lone, cause of high rates of infection in the urban population, especially amongst infants and children of weaning age. That age is particularly susceptible to gastrointestinal infections, which are often caused by exposure to pathogens carried in fecal matter. Declining water quality often includes an increase in exposure to these very pathogens that so easily affect young children.

Suggestions for Future Research

Given the results of this study, it is suggested that future research into the weaning practices of the Classic Maya could contribute to an understanding of the effects of population density and malnutrition on the subadult population of Classic Maya centers.

Further information regarding the weaning and breast feeding practices within the Copan urban population would provide further context in understanding health of the subadult population. Declining breast feeding during infancy could contribute to a decline in passive immunity, as breast milk provides protection against gastrointestinal pathogens, while simultaneous exposure to contaminated food and water increases with the introduction of a weaning diet. Additionally, nutritionally inadequacy of a weaning diet could further compound the effects infection and disease, as malnutrition can weaken an underdeveloped immune system. Suggestions for future research include further investigation of the breastfeeding and weaning practices of Maya and possibly Copan populations. Isotopic analysis has been used to research the weaning process and to determine how those processes affected infant mortality and malnutrition in European populations (Burt 2013). Similar investigations into the weaning practices of Classic Maya populations would contribute to these interpretations regarding infection and mortality amongst the subadult population of Copan.

General Conclusions

This research aimed to answer questions regarding the state of health for a particular late Classic Copan population, those individual recovered from the elite Group 8N-11 of the Las Sepulturas ward of the urban core. Although results were able to provide insight into the general state of health of the group, results did not provide evidence that intra-group social ranking could affect the transmission and progression of disease within the urban population.

A primary goal of this research was to try to identify if intra-group social ranking may have affected the occurrence and severity of infection within an elite residential group. Based on the available literature it was assumed that elite residential groups were internally ranked, due to an assumed differential access to nutritional resources (Hendon 1991; Gerry 1993; Webster 1997; Kintz 2004). Given the strong synergistic relationship between malnutrition and infection, this research aimed to determine if infection severity would show differential distribution of ill health within the group. The results did not support this interpretation; infection was not differentially distribution in any manner, including severity. Infection of varying severity was present throughout the sample, including amongst subadults under the age of five, and showed no strong patterns of association with any social and cultural markers, including grave location, grave type and grave goods. Although the goal of this research, to identify intra-group ranking through infection severity, was not met, the results do conform to results from other Copan samples. This implies that the presence and severity of infection was tied to the effects of high population density and environmental degradation, given the nondiscriminatory manifestation of infection amongst the population.

These results suggest that social status had no bearing on environmental exposure to pathogens or immune response, despite the evidence for intra-group social ranking with the 8N-11 group Social ranking did not buffer elite residents of the urban core from their environment; the population of the urban core was equally exposed to the stressors affecting Copan during the Terminal Classic period. The results of analysis have shown that 8N-11 faced many of the similar health stresses that were facing other Copan populations of the time, with a high rate of infection regardless of social status and a high frequency of infant mortality, due to the greater effects of population density and environmental degradation. Although the results of this study do conform to previous results regarding the effects of population density on health within the Copan population, both rural and urban, it is also inferred that environmental degradation could have contributed to the presence of infection in multiple ways.

Environmental degradation could have compounded the effects of a high population density on the urban core, as both malnutrition and disease transmission can be affected by soil erosion. Combined, these factors could have contributed to the state of health for the urban core population, especially for the younger population. The environment and agricultural production could have further exacerbated the distribution of infection as soil erosion may have increased sediment load and pathogenic transmission through the water supply of the Copan reservoirs. The high frequency of infant mortality within the sample provides support for this interpretation. Infants and young children are particularly susceptible to gastrointestinal diseases. Soil erosion can be a significant cause of water contamination as the pathogens that cause gastrointestinal disease are transmitted through the fecal material that adheres to sediment particles.

Given the support for models of environmental degradation occurring in the Copan valley during the Terminal Classic, this research concludes that the transmission and progression of disease within Copan was severely affected by the environmental stressors of soil erosion and malnutrition. The high frequency of infection suggests that the population was equally exposed to the transmission and progression of disease as social ranking was unable to buffer the elite population from the effects of environmental degradation.

References

Abrams, Elliot M.
1989 Architecture and Energy: An Evolutionary Perspective. Archaeological Method and Theory 1: 47-87

Abrams, Elliot M. and David J. Rue
1988 The Causes and Consequences of Deforestation among the Prehistoric Maya. Human Ecology 16(4): 377-395

Andrews, E. Wyllys and William L. Fash
2005 Copan: The History of an Ancient Maya Kingdom. Santa Fe, NM: School of American Research Press.

Aoyama, Kazuo.
2001 Classic Maya State, Urbanism, and Exchange: Chipped Stone Evidence of the Copan Valley and Its Hinterland. American Anthropologist 103(2): 346-360.

Arrieta, M.A., M.A. Bordach, and O.J. Mendonca
2011 Pre-Columbian Tuberculosis in Northwest Argentina: Skeletal Evidence from Rincon Chico 21 Cemetery. International Journal of Osteoarchaeology (published online)

Barzilay, Joshua I., Winkler G. Weinberg, and J. William Eley
1999 The Water We Drink: Water Quality and Its Effects on Health. New Jersey: Rutgers University Press.

Bauer, Arnold J.
1990 Millers and Grinders: Technology and Household Economy in Meso-America. Agricultural History 64(1): 1-17

Betsinger, Tracy C.
2007 The Biological Consequences of Urbanization in Medieval Poland. PhD Dissertation, Department of Anthropology, Ohio State University

Buikstra, Jane E. and Douglas H. Ubelaker
1994 Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at The Field Museum of Natural History. Arkansas Archaeological Survey Research Series 44

Burt, Nicole M.
2013 Stable Isotope Ratio Analysis of Breastfeeding and Weaning Practices of Children from Medieval Fishergate House York, UK. American Journal of Physical Anthropology 152: 407-416

Christensen, Tina, Manuel Martinez-Lavin, and Carlos Pineda
2011 Periostitis and Osteolysis in a Medieval Skeleton from South-West Hungary: (Leprosy, Treponematoses, Tuberculosis or Hypertrophic Osteoarthropathy) A Diagnostic Challenge! International Journal of Osteoarchaeology (published online)

Cohen, M.N and G. Grace-Kramer
2003 The State and Future of Paleoepidemiology In Emerging Pathogens: the Archaeology, Ecology, and evolution of Infectious Disease. Charles L Greenblatt and Mark Spigelman, eds. Pp. 79-92. Oxford University Press.

Crabill, Christine, Ravin Donald, Julie Snelling, Richard Foust, and Gordon Southam
1999 The Impact of Sediment Fecal Coliform Reservoirs on Seasonal Water Quality in Oak Creek, Arizona. Water Research 33(9): 2163-2171

Danforth, Marie Elaine
1999 Nutrition and Politics in Prehistory. Annual Review of Anthropology 28: 1-25

Davis, Salazar, Karla L.
2001 Late Classic Maya Water Management at Copan, Honduras. PhD Dissertation, Department of Anthropology, Harvard University

2003 Late Classic Maya Water Management and Community Organization at Copan, Honduras. Latin American Antiquity 14 (3): 275-299

2006 Late Classic Maya Drainage and Flood Control at Copan, Honduras. Ancient Mesoamerica 17(1): 125-138.

DeWitte, Sharon N. and Jelena Bekvalac.
2011 The Association between Periodontal Disease and Periosteal Lesions in the St Mary Graces Cemetery, London, England A.D. 1350-1538. American Journal of Physical Anthropology 146: 609-618

Diamanti, Melissa
1991 Domestic organization at Copan: Reconstruction of Elite Maya households through ethnographic models. PhD Dissertation, Department of Anthropology, The Pennsylvania University.

Dutour, O, Y. Ardagna, M. Maczel, and M. Signoli
2003 Epidemiology of Infectious Diseases in the Past; Yersin, Koch, and the Skeletons *In* Emerging Pathogens: the Archaeology, Ecology, and evolution of Infectious Disease. Charles L Greenblatt and Mark Spigelman, eds. Pp. 151-166. Oxford Universities Press.

Fash, Barbara W.
2005 Iconographic Evidence for Water Management and Social Organization at Copan *In* Copan: the History of an Ancient Maya Kingdom. E. Wyllys Andrews and William L. Fash, Eds. Pp. 103-138. Santa Fe, NM: School of American Research Press.

2011 The Copan Sculpture Museum: Ancient Maya Artistry in Stucco and Stone. Cambridge: Peabody Museum Press

Fash, William L.
1983 Deducing Social Organization from Classic Maya Settlement Patterns: a Case Study from the Copan Valley *In* Civilization in the Ancient Americas: Essays in Honor of Gordon R. Willey. Richard M. Leventhal, and Alan L. Kolat, Eds. Olympic Marketing Corporation

Fash, William L., E. Wyllys Andrews and T. Kam Manahan
2004 Political Decentralization, Dynastic Collapse, and the Early Postclassic in the Urban Center of Copan, Honduras *In* The Terminal Classic in the Maya Lowlands: Collapse, Transition, and Transformation. Arthur A Demarest, Prudence M. Rice, and Don S. Rice Eds. Pp. 260-287. University Press of Colorado.

Fash, William L. and Ricardo Agurcia Fasquelle
2005 Contributions and Controversies in the Archaeology of Copan *In* Copan: the History of an Ancient Maya Kingdom. E. Wyllys Andrews and William L. Fash, Eds. Pp. 3-32. Sante Fe: School of American Research Press.

Fash, William L. and Robert J. Sharer
1991 Sociopolitical Developments and Methodological Issues at Copan, Honduras: A Conjunctive Perspective. Latin American Antiquity 2(2):166-187

Ferguson, William M. and John Q. Royce
1984 Maya Ruins in Central America in Color: Tikal, Copan, and Quirigua. Albuquerque: The University of New Mexico Press

Freter, AnnCorinne
2004 Multiscalar Model of Rural Households and Communities in Late Classic Copan Maya Society. Ancient Mesoamerica 15:93-106.

Gerry, John Phillip
1993 Diet and Status among the Classic Maya: An Isotopic Perspective. PhD Dissertation, Department of Anthropology, Harvard University

Goodman, Alan H. and George J. Armelagos
1989 Infant and Childhood Morbidity and Mortality Risks in Archaeological Populations. World Archaeology 21(2):225-243

Goodman, Alan H. and Debra L Martin
2002 Reconstructing Health Profiles from Skeletal Remains *In* The Backbone of History: Health and Nutrition in the Western Hemisphere. Richard H. Steckel and Jerome C. Rose, Eds. Pp. 11-60.Cambridge University Press

Gummerman, George
1997 Food and Complex Societies. Journal of Archaeological Method and Theory 4(2): 105-139

Halcrow, Sian E., Nancy Tayles, and Vicki Livingstone
2008 Infant Death in Late Prehistoric Southeast Asia. Asian Perspectives 47(2): 371-404

Hendon, Julia Ann.
1987 The Uses of Maya Structures: a Study of Architecture and Artifact Distribution at Sepulturas, Copan, Honduras. PhD Dissertation, Department of Anthropology, Harvard University

1991 Status and Power in Classic Maya Society: An Archaeological Study. American Anthropologist 93(4): 894-918

Herring, D. Ann, S.R. Saunders, and M.A. Katzenberg
1998 Investigating the Weaning Process in Past Populations. American Journal of Physical Anthropology 105: 425-439

Hoyle, Brian
2008 Water-borne Diseases *In* Infectious Diseases: In Context, Brenda Wilmoth Lerner and K. Lee Lerner, Eds. Detroit: Gale

Huss-Ashmore, Rebecca, Alan H. Goodman, and George J. Armelagos
1982 Nutritional Inference from Paleopathology. Advances in Archaeological Method and Theory 5: 395-474

Inhorn, Marcia C. and Peter J. Brown
1990 The Anthropology of Infectious Disease. Annual Review of Anthropology 19: 89-117

Kardatzke, Tim
1991 The Study of Kitchen Behaviors with Implications for the Social Organization of the Classic Maya site of Copan, Honduras. Master's Thesis, Department of Anthropology, The University of Houston

Kintz, Ellen R.
2004 Considering the Ties that Bind: Kinship, marriage, household, and territory among the Maya. Ancient Mesoamerica 15(1): 149-158

Kratzenberg, M. Anne, D. Ann Herring, and Shelley R. Saunders.
1996 Weaning and Infant Mortality: Evaluating the Skeletal Evidence. Yearbook of Physical Anthropology 39:177-199

Kreger, Meggan M. Bullock
2010 Urban Population Dynamics in a Preindustrial New World City: Morbidity, Mortality, and Immigration in Postclassic Cholula. PhD Dissertation, Department of Anthropology, The Pennsylvania State University.

Lallo, John W.
1973 The Skeletal Biology of Three Prehistoric American Indian Societies from Dickson Mounds. PhD Dissertation, Department of Anthropology, University of Massachusetts

Larsen, Clark Spencer
1997 Bioarchaeology: Interpreting Behavior from the Human Skeleton. Cambridge University Press

Lucero, Lisa
2002 The Collapse of the Classic Maya: A Case for the Role of Water Control. American Anthropologist 104(3): 814-826

Lucero, Lisa, Joel Gunn, and Vernon Scarborough
2011 Climate Change and Classic Maya Water Management. Water 3: 479-494

Manahan, T. Kam
2004 The Way Things Fall Apart: Social Organization and the Classic Maya Collapse of Copan. Ancient Mesoamerica 15 (1): 107-125

2003 The Collapse of Complex Society and Its Aftermath: A Case Study from the Classic Maya Site of Copan, Honduras. PhD Dissertation, Department of Anthropology, Vanderbilt University

Mata, Leonardo J, Richard A. Kronmal, Bertha Garcia, William Butler, Juan J. Urrutia, and Sandra Murillo
1976 Breast-feeding, weaning, and the diarrhoeal syndrome in a Guatemalan Indian village *In* Acute Diarrhoea in Childhood: Ciba Foundation Symposium 42 Pp. 311-336. Amsterdam: Elsevier-Excerpta Medica-North Holland

Mays, Simon
2010 The Archaeology of Human Bones. New York: Routledge

McNeil, Cameron L., David A. Burney, Lido Pigott Burney and Joyce Marcus.
2010 Evidence Disputing Deforestation as the Cause for the Collapse of the Ancient Maya Polity of Copan Honduras. Proceedings of the National Academy of Sciences of the United States of America 107 (3): 1017-1022

Medina-Elizalde, Martin, Stephen J. Burns, David W. Lea, Yemane Asmerom, Lucien von Gunten, Victor Polyak, Mathias Vuille, and Ambarish Karmalkar
2010 High Resolution Stalagmite Climate Record from the Yucatan Peninsula Spanning the Maya terminal classic period. Earth and Planetary Science Letters 298: 255-262

Morfin, Lourdes Marquez, Robert McCaa, Rebecca Storey, and Andres Del Angel
2002 Health and Nutrition in Pre-Hispanic Mesoamerica *In* The Backbone of History: Health and Nutrition in the Western Hemisphere. Richard H. Steckel and Jerome C. Rose, Eds. Pp. 307-342. Cambridge University Press

Morris, Gregory L. and Jiahua Fan
1998 Reservoir Sedimentation Handbook. New York: McGraw-Hill

Newburg, David S.
2005 Innate Immunity and Human Milk. The Journal of Nutrition 135(5): 1308-1312

Ortner, Donald J.
2003 Identification of Pathological Conditions in Human Skeletal Remains. San Diego, CA: Academic Press.

2011 Human Skeletal Pathology. International Journal of Paleopathology 1: 4-11

Padgett, Paige M.
1996 The Effects of Social Status and Residency Patterns on Infection among the Late Classic Maya at Copan, Honduras. M.A. Thesis, Department of Anthropology, University of Houston

Powell, Mary Lucas Powell
1988 Status and Health in Prehistory: A Case Study of the Moundville Chiefdom. Washington D.C: Smithsonian Institution Press Washington

Rautanen, Sanna-leena
2010 Sanitation, Water and Health. Environment and History 16: 173-194

Reed, David Millard
1998 Ancient Maya Diet at Copan, Honduras. PhD Dissertation, Department of Anthropology, The Pennsylvania State University

Reidpath, D.D. and P. Allotey
2003 Infant Mortality Rate as an Indicator of Population Health. Journal of Epidemiology and Community Health 57(5): 344-346

Rice, Prudence M., Arthur A. Demarest, and Don S. Rice
2004 The Terminal Classic and The Classic Maya Collapse in Perspective *in* The Terminal Classic in the Maya Lowlands: Collapse, Transition, and Transformation. Arthur A Demarest, Prudence M. Rice, and Don S. Rice Eds. Pp. 1-11. University Press of Colorado.

Richards-Rissetto, Heather M
2010 Exploring Social Interaction at the Ancient Maya City of Copan, Honduras: a Multi-Scalar Geographic Information Systems (GIS) Analysis of Access and Visibility. PhD Dissertation, Department of Anthropology, The University of New Mexico

Roberts, Charlotte and Keith Manchester
1995 The Archaeology of Disease. Ithaca, NY: Cornell University Press.

Robin, Cynthia
2001 Peopling the Past: New Perspectives on the Ancient Maya. Proceedings of the National Academy of Sciences of the United States of America 98(1): 18-21

Sanders, William T.
1989 Household, Lineage, and State at Eigth-Centiry Copan, Honduras *In* The House of the Bacabs, Copan, Honduras. David L. Webster, Ed. Pp. 89-105. Dumbarton Oaks.

Sanders, William T. and David Webster
1988 The Mesoamerican Urban Tradition. American Anthropologist 90(3): 521-546.

Santley, Robert S. and Eric K. Rose
1979 Diet, Nutrition and Population Dynamics in the Basic of Mexico. World Archaeology 11(2): 185-207

Scarborough, Vernon L.
2003 The Flow of Power: Ancient Water Systems and Landscapes. Sante Fe: School of American Research.

Sharer, Robert J. and Loa P. Traxler
2006 The Ancient Maya. Stanford University Press

Shuler, K.A.
2011 Life and Death on a Barbadian Sugar Plantation: Historic and Bioarchaeological Views of Infection and Mortality at Newton Plantation. International Journal of Osteoarchaeology 21: 66-81

Spence, Michael W. and Christine D. White
2009 Mesoamerican Bioarchaeology: Past and Future. Ancient Mesoamerica 20(2): 233-240

Storey, Rebecca
1985 An Estimate of Mortality in a Pre-Columbian Urban Population. American Anthropologist 87: 519-535.

2005 Individual Frailty, Children of Privilege, and Stress in Late Classic Copan. *In* Bones of the Maya: Studies of Ancient Skeletons. Stephen L. Whittington and Lori Wright, eds. Pp. 116-126. Tuscaloosa, AL: University of Alabama Press.

2005b Health and Lifestyle Among the Copan Elite *In* Copan: the History of an Ancient Maya Kingdom. E. Wyllys Andrews and William L. Fash, Eds. Pp. 315-344. Sante Fe: School of American Research Press.

2006 Mortality through Time in an Impoverished Residence of the Pre-Columbian City of Teotihuacan. *In* Urbanism in the Preindustrial World. Glenn Storey, Ed. Pp. 277-295. Tuscaloosa, AL: University of Alabama Press.

Storey, Rebecca and Patricia A. McAnany
2006 Children of K'axob: Premature Death in a Formative Maya Village *In* The Social Experience of Childhood in Ancient MesoAmerica, Traci Anderson and Scott R. Huston, eds. Pp. 53-72. University Press of Colorado.

Storey, Rebecca, Lordes Marquez Morfin, and Vernon Smith
2002 Social Disruption and the Maya Civilization of Mesoamerica: A Study of Health and Economy of the Last Thousand Years *In* The Backbone of History: Health and Nutrition in the Western Hemisphere. Richard H. Steckel and Jerome C. Rose, Eds. Pp. 283-306. Cambridge University Press

Ubelaker, D.H.
2003 Anthropological Perspectives on the Study of Ancient Disease In Emerging Pathogens: the Archaeology, Ecology, and evolution of Infectious Disease. Charles L Greenblatt and Mark Spigelman, eds. Pp. 93-102. Oxford Universities Press.

Van der Perk, Marcel
2006 Soil and Water Contamination from molecular to catchment scale. London: Taylor and Francis Group

Webster, David
1985 Surplus, Labor and Stress in Late Classic Maya Society. Journal of Anthropological Research 41(4): 375-399.

1989 The House of the Bacabs: Its Social Context *In* The House of the Bacabs, Copan, Honduras. David L Webster, Ed. Pp. 5-40. Dumbarton Oaks

1999 The Archaeology of Copan, Honduras. Journal of Archaeological Research 7(1): 1-52

2005 Political Ecology, Political Economy, and the Culture History of Resource Management at Copan *In* Copan: the History of an Ancient Maya Kingdom. E. Wyllys Andrews and William L. Fash, Eds. Pp. 33-72. Sante Fe: School of American Research Press.

Webster, David, Barbara Fash, Randolph Widmer, and Scott Zeleznkik
1998 The Skyband Group: Investigation of a Classic Maya Elite Residential Compound at Copan, Honduras. Journal of Field Archaeology 25: 319-343.

Webster, David, AnnCorinne Freter, and Nancy Gonlin
2000 Copan: The Rise and Fall of an Ancient Maya Kingdom. Wadsworth Group: Belmont, CA.

Webster, David, AnneCorinne Freter, and Rebecca Storey
2004 Dating Copan Culture History: Implications for the Terminal Classic and the Collapse *In* The Terminal Classic in the Maya Lowlands: Collapse, Transition, and Transformation. Arthur A Demarest, Prudence M. Rice, and Don S. Rice Eds. Pp. 231-259. University Press of Colorado.

Weeks, John M.
1993 Maya Civilization. New York: Garland Publishing.

Weston, Darlene A.
2008 Investigating the Specificity of Periosteal Reactions in Pathology Museum Specimens. American Journal of Physical Anthropology 137: 48-59.

2009 Brief Communication: Paleopathological Analysis of Pathology Museum Specimens: Can Periosteal Reaction Microstructure Explain Lesion Etiology? American Journal of Physical Anthropology 140: 186-193.

2011 Nonspecific Infection in Paleopathology: Interpreting Periosteal Reactions. *In* A Companion to Paleopathology, Anne L. Grauer, ed. Pp.492-512. Hoboken, NJ: John Willey and Sons.

White, Christine D., Paul F. Healy and Henry P. Schwarchz
1993 Intensive Agriculture, Social Status, and Maya Diet at Pacbitun, Belize. Journal of Anthropological Research 49(4): 347-375

White, Christine D., David M. Pendergast, Fred J. Longstaffe and Kimberley R. Law
2001 Social Complexity and Food Systems at Altun Ha, Belize: the Isotopic Evidence. Latin American Antiquity 12(4):371-393

Whittington, Stephen L.
1989 Characteristics of Demography and Disease in Low Status Maya from Classic Period Copan, Honduras. PhD Dissertation, Department of Anthropology, Pennsylvania State University

Willey, Gordon J., Richard M. Leventhal and William L. Fash, Jr.
1978 Maya Settlement in the Copan Valley. Archaeology 31(4): 32-43.

Williams, Jocelyn S., Christine D. White, and Fred J. Longstaffe
2005 Trophic level and Macronutrient Shift Effects Associated with the Weaning Process in the Postclassic Maya. American Journal of Physical Anthropology 128: 781-790.

Wingard, John Davis
1992 The Role of Soils in the Development and Collapse of Classic Maya Civilization at Copan, Honduras. PhD dissertation, Department of Anthropology, The Pennsylvania State University

Wood, James W.
1998 A Theory of Preindustrial Population Dynamics: Demography, Economy, and Well-Being in Malthusian Systems. Current Anthropology 39(1): 99-135

Wood, James, George R. Milner, Henry C. Harpending and Kenneth M. Weiss
1992 The Osteological Paradox. Current Anthropology 33(4): 343-370

Wright, L.E.
2013 Examining Childhood Diets at Kaminaljuyu, Guatemala, through Stable Isotopic Analysis of Sequential Enamel Microsamples. Archaeometry 5(1): 113-133

1997 Intertooth Patterns of Hypoplasia Expression: Implications for Childhood Health in the Classic Maya Collapse. American Journal of Physical Anthropology 102: 233-247

Wright, Lori E. and Francisco Chew
1998 Porotic Hyperostosis and Paleoepidemiology: A Forensic Perspective on Anemia among the Ancient Maya. American Anthropologist 100(4): 924-939

Wright, Lori E. and Christine D. White
1996 Human Biology in the Classic Maya Collapse: Evidence form Paleopathology and Paleodiet. Journal of World Prehistory 10(2): 147-198

Zorola, Jessica Therese
2009 The Effects of Diet and Environment: The Impact of Natural and Cultural Resources on Prehistoric Health in Mesoamerica. Master’s Thesis, Department of Anthropology, The University of Houston