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I am submitting herewith a dissertation written by Elizabeth Ann DiGangi entitled "Application of the Western Hemisphere Health Index to Prehistoric Populations from Tennessee and the Semi-arid North of Chile: A Comparative Bioarchaeological Study of the Implications of Subsistence Choice." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

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APPLICATION OF THE WESTERN HEMISPHERE HEALTH INDEX TO
PREHISTORIC POPULATIONS FROM TENNESSEE AND THE SEMI-ARID
NORTH OF CHILE: A COMPARATIVE BIOARCHAEOLOGICAL STUDY OF
THE IMPLICATIONS OF SUBSISTENCE CHOICE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Elizabeth Ann DiGangi
May 2008

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Dedication

This work is dedicated to the memory of Elizabeth Brown and Eulace Peacock
and to all the individuals whose remains I handled for this research.

May their stories not be forgotten.

“For in the seemingly little and insignificant things that accumulate to create a
lifetime, the essence of our existence is captured.” – James Deetz (1977)

Acknowledgments

Twelve years ago when I began my higher education journey I could never have imagined that it would end with a Ph.D. and a dissertation being the last paper I had to write to earn a degree. Within the past couple of years especially there were times when the task of writing this dissertation seemed insurmountable. It was only through the support, encouragement, and inspiration from numerous individuals throughout my college and graduate school career that this achievement has been made possible. I would like to acknowledge each person who was instrumental in my decision to embark upon this journey and thank them for the role they played in the completion of this endeavor.

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Each of my doctoral committee members have been instrumental in my intellectual development and I thank each of them for their insightful comments

and suggestions regarding this and other research I've worked on. My committee chair, Dr. Murray Marks, is an inspiration. The knowledgeable and "cool" forensic anthropologist he personifies is what I want to be when I grow up. He played a key role in securing a graduate assistantship for my first year at UT, without which I would have been unable to attend the program. The encouragement and constructive criticism of my work he has given me over the years have helped with my scholarly development, for which I am appreciative.

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Finally, I remain in awe that I have the privilege of studying human skeletal remains. I have nothing but respect for this honor, and it is my hope that my interpretations regarding the health of these once-living individuals have done them justice.

Abstract

The Western Hemisphere Health Index was applied to prehistoric contemporaneous skeletal populations from Tennessee and the semi-arid North of Chile to ascertain four things: 1. overall health status for each culture; 2. comparison of health status between contemporaneous cultures; 3. if subsistence change (i.e., transition from gathering-hunting to agriculture) is consistently accompanied by a decline in overall health; and 4. the utility of the health index methodology. The skeletal populations analyzed from the semi-arid North of Chile were Archaic (7730 B.C. – A.D. 245) and Diaguita (A.D. 1000 – 1536). Prehistoric individuals examined from Tennessee were Archaic (8000 – 1000 B.C.); Woodland (1000 B.C. – A.D. 1000); and Mississippian (A.D. 1000 – 1600). (Total n = 433 individuals). Both Archaic populations had primarily a gathering and hunting subsistence strategy, Woodland peoples were emerging horticulturalists, and Mississippian and Diaguita populations practiced full-scale agriculture.

As per health index methodology, seven indicators of health were scored (stature, linear enamel hypoplasia, dental disease, anemia, infection, degenerative joint disease, and trauma). Health index statistical methodology and Pearson chi-square were used to test the proposed hypotheses. Results indicated that the Archaic Tennessee population had the lowest health index value, and both Chilean populations had the highest. The results of the chi-

square analyses run on each of the health indicators by population were in tandem with the health index results. In Tennessee, health appeared to improve through time; while in Chile, health essentially stayed the same during the subsistence transition.

Such results suggest that the hypothesis of a health decline during and after subsistence change to agriculture is not always demonstrated. These findings further indicate that general rules regarding the association between health and subsistence change do not exist. Rather than applying generalizations to populations, research should focus on the specific situation of each population (environment, subsistence, socio-political organization, etcetera) followed by a comparison between populations to reveal similarities and differences. Such analyses will assist with identifying the relative importance of particular factors for each site.

The utility of the health index methodology was also discussed. The index is a useful tool for population comparison, though further refinement of the methodological protocol is warranted.

Table of Contents

Chapter 1	
<u>Introduction</u>	1
Chapter 2	
<u>Prehistoric Health Assessment</u>	12
Theory in Paleopathology	12
Health in Foragers and Agriculturalists	22
Chapter 3	
<u>Northern Chilean Prehistory</u>	48
Environmental Setting of the Semi-arid North of Chile	48
Culture Process of the Prehistoric Chilean Semi-arid North	52
Previous Work: Bioarchaeology of Prehistoric Northern Chileans	65
Chapter 4	
<u>Tennessee Prehistory</u>	71
Environmental Setting of Tennessee	71
Culture Process of Prehistoric Tennessee	73
Previous Work: Bioarchaeology of Prehistoric Tennesseans	90
Chapter 5	
<u>Materials</u>	101
Northern Chile Sample	101
Tennessee Sample	106
Chapter 6	
<u>Methods</u>	113
The Western Hemisphere Health Index: Statistical Methodology	113
Data Collection Protocol	119
Chapter 7	
<u>Results</u>	123
Chapter 8	
<u>Discussion and Conclusion</u>	129
Bibliography	153
Appendix	196
Vita	227

List of Tables

Table 1. North and South American Culture Chronology	197
Table 2. Chilean Archaic Chronology	198
Table 3. Chilean Diaguita Chronology	198
Table 4. Tennessee Culture Chronology	198
Table 5. Archaic Sites Analyzed	199
Table 6. Diaguita Sites Analyzed	199
Table 7. Tennessee Sites Analyzed	199
Table 8. Data Collection Protocol for Categorical Variables	200
Table 9. Calculated Health Index Results	201
Table 10. Calculated Health Index Attribute Values	201
Table 11. Cribra Orbitalia Frequency	201
Table 12. Porotic Hyperostosis Frequency	201
Table 13. Auditory Exostosis Frequency	202
Table 14. Tibial Infection Frequency	202
Table 15. Skeletal Infection Frequency	202
Table 16. Shoulder and Elbow Degenerative Joint Disease Frequency	203
Table 17. Hip and Knee Degenerative Joint Disease Frequency	203
Table 18. Cervical Vertebrae Degenerative Joint Disease Frequency	203
Table 19. Thoracic Vertebrae Degenerative Joint Disease Frequency	204
Table 20. Lumbar Vertebrae Degenerative Joint Disease Frequency	204
Table 21. Temporomandibular Joint Degenerative Disease Frequency	204
Table 22. Wrist Degenerative Joint Disease Frequency	205
Table 23. Hand Degenerative Joint Disease Frequency	205
Table 24. Arm Trauma Frequency	205
Table 25. Leg Trauma Frequency	206
Table 26. Nasal Bones Trauma Frequency	206
Table 27. Facial Bones Trauma Frequency	206
Table 28. Skull Vault Trauma Frequency	207
Table 29. Hands Trauma Frequency	207
Table 30. Weapon Wounds Frequency	207
Table 31. Dental Caries Frequency	208
Table 32. Premortem Tooth Loss Frequency	208
Table 33. Abscesses Frequency	208
Table 34. Calculated Significant Pearson Chi-Square Values	208
Table 35. Significant Crosstabulation for Porotic Hyperostosis	209
Table 36. Significant Crosstabulation for Tibial Infection	209
Table 37. Significant Crosstabulation for Skeletal Infection	210
Table 38. Significant Crosstabulation for Shoulder/Elbow and Hip/Knee Degenerative Joint Disease	210

Table 39. Significant Crosstabulation for Wrist Degenerative Joint Disease.....	210
Table 40. Mean Age by Score for Porotic Hyperostosis	211
Table 41. Mean Age by Score for Tibial Infection.....	211
Table 42. Mean Age by Score for Skeletal Infection.....	212
Table 43. Mean Age by Score for Shoulder/Elbow Degenerative Joint Disease	212
Table 44. Mean Age by Score for Hip/Knee Degenerative Joint Disease.....	213
Table 45. Mean Age by Score for Wrist Degenerative Joint Disease	213

List of Figures

Figure 1. Archaeological Sites of the Chilean Semi-arid North	214
Figure 2. Analyzed Archaeological Site Locations in Tennessee	215
Figure 3. Cherry Age Distribution.....	216
Figure 4. Cherry Age Distribution, Adult Males and Females	216
Figure 5. Woodland Age Distribution	217
Figure 6. Woodland Age Distribution, Adult Males and Females	217
Figure 7. Ledford Island Age Distribution.....	218
Figure 8. Ledford Island Age Distribution, Adult Males and Females.....	218
Figure 9. Diaguaita Age Distribution.....	219
Figure 10. Diaguaita Age Distribution, Adult Males and Females.....	219
Figure 11. Chilean Archaic Age Distribution.....	220
Figure 12. Chilean Archaic Age Distribution, Adult Males and Females	220
Figure 13. Cribra Orbitalia and Porotic Hyperostosis Frequency.....	221
Figure 14. Infection Frequency	221
Figure 15. Auditory Exostosis Frequency.....	222
Figure 16. Arm and Leg Degenerative Joint Disease Frequency	222
Figure 17. Vertebral Column Degenerative Joint Disease Frequency	223
Figure 18. TMJ, Wrist, and Hand Degenerative Joint Disease Frequency	223
Figure 19. Trauma Frequency	224
Figure 20. Dental Disease Frequency	224
Figure 21. Pearson Chi-square Results, Enamel Hypoplasia Occurrence	225
Figure 22. Pearson Chi-square Crosstabulation, Enamel Hypoplasia Occurrence .	225
Figure 23. Kruskal-Wallis Ranks, Dental Caries by Culture.....	226
Figure 24. ANOVA Test Results on Dental Caries Kruskal-Wallis Ranks	226

Chapter 1

Introduction

It can be argued that good health has been most important to humankind throughout history. After all, poor health increases mortality, decreases productivity and fertility, and taxes the resources of the group because people who are sick or injured must be cared for. Physical anthropology has long been interested in the health of past populations, as understanding it brings us closer to answering questions about quality of life in the human experience. Steckel and Rose (2002) assert that inequalities in nutrition and health have been an impetus for social, political, and economic culture change. The role of health in human history is therefore an important one to comprehend, and one key to unlocking its impact is through the study of skeletal remains.

The use of human skeletal remains to answer questions about human health and disease has become a common method of inquiry in anthropology over the past two hundred years or so (Ortner 1991). There is a significant amount of data that can be gleaned from a skeleton, such as age-at-death, sex, and stature; and in some cases, pathology and trauma. Constructing this so-called “biological profile” on an individual level is the first step in bioarchaeology and forensic anthropology alike, however, taking it a step further to make deductions about life and death on a population level has proven to be a more complicated endeavor.

Health status assessment from skeletal biology requires that exact comparisons be made between different populations. However, until recently, reliable comparisons were not always possible due to differences in data collection and demography specific to each population. Steckel and colleagues (2002) have developed a standardized method to encourage comparability and enhance collaboration. Their method gives standards for data collection, defines seven health measurements, and adjusts for differences in population demographics, resulting in comparisons of health that are compatible.

This method has broad implications. The ability to compare populations at the same level of technological and cultural development allows for much more accurate interpretations regarding the evolution of human health. This dissertation presents a comparative study of North and South American native peoples, specifically the cultures dating to the Archaic, Late Woodland, and Mississippian periods of the Tennessee River Valley in the United States and the Archaic and Diaguita cultures of the semi-arid North, in Chile. Technological and cultural developments in these two regions followed a remarkably similar course and were roughly contemporaneous, especially during the Archaic periods (Cohen 1977).

While regional studies that focus on specific questions of health for a particular circumscribed area are common, studies that take a broader approach, that of comparing health across regions, are not. This is probably due to the fact

that there are numerous variables that affect health in one region alone, and teasing out these variables for multiple regions would be problematic. In the case of the populations studied here, they were chosen due to their proximity in terms of similar technology and subsistence strategy, and therefore, several variables that affect health should be similar between the two regions. While some stark differences exist (i.e., coastal vs. riverine environments) the standardization that the health index method provides should allow the elucidation of variables that might be involved with health for populations on a relatively similar playing field.

The cultures on each continent were categorized based on archaeological evidence documenting a shift in subsistence from gathering-hunting and horticulture to agriculture. Archaic period populations on both continents are contemporaneous (for Tennessee: 8000 – 1000 B.C. and for Northern Chile: 7730 B.C. – A.D. 245) (Table 1)¹ and in general, both cultures practiced a gathering-hunting subsistence strategy (Anderson 2001; Kuzmanic and Castillo 1986). The succeeding periods of the Woodland culture in the Southeast (1000 B.C. – A.D. 1000) and the El Molle culture (300 B.C. – A.D. 700) in Northern Chile were transitional: essentially they were emerging horticulturalists who maintained gathering and hunting (Chapman and Shea 1981; Crites 1978; Niemeyer et al. 1989). The Mississippian and Diaguita cultures both practiced full scale

¹ All tables and figures are located in the appendix.

agriculture, and are contemporaneous – the Mississippian peoples dating to about A.D. 1000 – 1600; and the Diaguita to A.D. 1000 to 1536² (Table 1).

In order to reveal if changes in health accompanied the transition in subsistence strategy, skeletal samples from the periods of the Archaic, Woodland (1000 B.C. – A.D. 1000), and Mississippian in the Southeast and the Archaic and Diaguita in Northern Chile were analyzed. Unfortunately, preservation and sample sizes of the periods intermediate to the Archaic and Diaguita in Northern Chile were poor, and therefore were not analyzed here. Skeletal remains analyzed from the Archaic, Late Woodland, and Mississippian peoples comprise part of the Tennessee Valley Authority (TVA) archaeological collections, curated at the Frank H. McClung Museum at the University of Tennessee in Knoxville. Remains of the Chilean inhabitants are curated at the *Museo Arqueológico* in La Serena, Chile.

One goal was to determine whether the South American natives or the North American ones had a better measured health status, and what the implications of these findings were for future studies of peoples with similar lifestyles in terms of teasing out what some of the key variables may be. The hypothesis was that a difference would be seen in the health patterns between the foragers and the agriculturalists, based on previous studies that suggest such a difference is seen between groups of differing subsistence strategies,

² Prior to the Diaguita culture in Northern Chile, the Las Animas culture was the first to incorporate full scale agriculture along with the retention of a fishing subsistence strategy (Castillo 1989).

population size, and sociopolitical organization; i.e., differing caries rates (Larsen 1987; Larsen et al. 1991; Milner 1984), and more infectious disease in agricultural groups attributable in part to larger population size (Black 1975; Cohen and Armelagos 1984; Brothwell 1967; Larsen 1987).

For the sites in North America, it was hypothesized that overall health decreased during and after the transition from gathering and hunting to emerging agricultural activity based on three observations: 1) a multitude of previous work suggesting a decrease in health for native North Americans during this time period (e.g., papers in Cohen and Armelagos 1984; Powell et al. 1991; Lambert 2000a, 2000b; and Larsen 1990; among others); 2) archaeological evidence indicating that maize became the primary component in the diet to the exclusion of other food sources in this region (Smith 1989, 1992); and 3) the fact that maize lacks certain key nutrients and contains compounds that prevent others from being digested properly (Cohen 1989; Larsen 1995; Stuart-Macadam 1989).

The hypothesis concerning a comparison between the continents was that the Diaguita would exhibit a better health pattern than the Mississippians. This hypothesis was based on archaeological and bone chemistry evidence suggesting a more varied (and therefore nutritious) diet for the Diaguita (Ampuero 1994; Rosado 1994), and on previous skeletal analyses suggesting that there was no decline in health between Archaic and Diaguita populations (Rosado 1994). The

methodology developed by Steckel et al. (2002a) was used to test the hypotheses proposed.

In addition, the results were compared with the Steckel et al. (2002a) database containing 12,520 individuals from 65 sites from North, Central, and South America going back 7,000 years. This kind of comparison allows determinations to be made regarding not only how unique each culture was based on its own specific health history, but how each culture fit into the emerging picture of human health history overall.

In an evolutionary context, we can begin to understand how health has changed in response to different environments (Steckel and Rose 2002). Identification of the prehistoric and historic patterns involved has implications for understanding the evolution of modern medical problems. More data are needed before generalizations can be made regarding long term changes in the past in health status. However, a variety of factors are clearly involved, including subsistence change, population growth, and climate fluctuations (Steckel and Rose 2002).

For the populations examined here specifically, Smith (1982, 1987) found that caries rates increased from the Archaic to the Mississippian time periods, which she attributed to subsistence changes. In addition, Jablonski (1983) found that population growth and subsistence shifts contributed to an increase in dental stress indicators between the Archaic, Woodland, and Mississippian

periods in Eastern Tennessee. However, Rosado (1994) discovered no general decline in health from the Archaic to the Diaguita peoples of Northern Chile. This difference suggests that the hypothesis that shifting to agricultural subsistence results in a decrease in health may not always be demonstrated. Rosado's (1994) findings further indicate that the question concerning subsistence change and health is multi-factorial, and it is important to discover which other variables may be involved. Clearly, if the adoption of full-scale agriculture has had a negative impact on health in some cases and not in others, there are additional factors at play here.

The hypothesis that the shift from hunting and gathering to agriculture results in a general decrease in overall health has drawn attention from skeletal biologists in the past 30 years or so (e.g., Cohen and Armelagos 1984) as a response to Childe (1951) who asserted that the shift to agriculture led to an improvement in health because there was a decreased demand for labor to produce food. The primary advantage of agriculture was thought to be that growing food could feed more people who were non-food providers than food collecting could, thus giving the majority of the population time and energy to focus on other pursuits (Childe 1951; Cohen 1977). Studies that challenged this assertion found problems with Childe's interpretation. For example, Lee and DeVore (1976) found that modern day gatherer-hunter groups such as the !Kung

San of the Kalahari Desert had more provisions, better nutrition and health, and more leisure time than did their farmer counterparts.

Therefore, a new interpretation developed: that the adoption of agriculture as the primary method of subsistence had negative effects on health (Cohen 1977; Cohen and Armelagos 1984). The main danger that accompanies an emphasis on mono-crop agriculture is the possibility of famine due to drought and blight (Cohen and Armelagos 1984; Swedlund and Armelagos 1990).

Gatherer-hunter groups are not tied to one specific area like sedentary agricultural groups, and in case of food shortages, they can move to areas where food is present.

Another disadvantage that results from agricultural dependence on a single staple crop as the main subsistence strategy is that the crop may be deficient in necessary nutrients, resulting in nutritional stress. Typically, an increase in agricultural intensification leads to dependence on cereal grains alone and many of these staples are deficient in essential minerals and amino acids (Cohen and Armelagos 1984; Cohen 1989; Larsen 1995; Stuart-Macadam 1989). For example, while maize is high in carbohydrates, it is deficient in three necessary amino acids; and maize also has phytates which inhibit the absorption of important minerals like iron (Cohen 1989; Larsen 1995; Stuart-Macadam 1989).

Therefore, the cultivation of one plant is dangerous because not only can it fail due to uncontrollable factors with the natural environment (lack of rain,

insect activity) – and this possibility of failure would obviously lead to periods of starvation – but even when the crop is in abundance, if it makes up the majority of the diet, its habitual consumption subjects people to nutritional stress because the diet is not providing all the necessary nutrients. Starvation and nutritional stress lead to weakened immune systems which practically invite disease to take hold (Martorell 1980; Scrimshaw et al. 1968). The spread of infectious disease is facilitated by increased population size and density as well (Black 1975; Brothwell 1967; Larsen 1987). In addition, sedentism and increasing population size allows for diseases to become endemic (Armelagos 1990). As outlined above, foragers would not be subject to the same types of stressors and therefore their health patterns should differ.

While there are several studies that have focused on the issue of health for prehistoric populations in the Southeastern United States (Larsen 1984, 1990a, 1990b; Powell 1990, 1991; Hutchinson and Larsen 1990; Schoeninger et al. 1990; Larsen and Sering 2000; Driscoll and Weaver 2000; Lambert 2000a, 2000b; Rose et al. 1984, 1991; Milner 1991; Bridges 1991b; Miller-Shaivitz and İşcan 1991; among others) only a handful has systematically examined the association between health and the transition between time periods for Tennessee specifically (e.g., Smith 1982, 1987, 2006; Jablonski 1983; Richardson 1988). This association is relevant because the areas studied here have a unique climate and available environmental resources in contrast to some other more intensively studied sites

in the Southeast which are located in different ecological zones (e.g., the coastal Georgia Bight). Therefore, this is a region of the Southeast that deserves further bioarchaeological inquiry.

In contrast to work done in the Southeastern United States, there is a paucity of studies focusing on odontoskeletal pathology for the Chilean skeletal collection. The studies that have been done focus mainly on biological profile assessment (Ericksen 1960a, 1960b; Quevedo 1987); and biological distance studies (Cocilovo et al. 1987-1988; Quevedo et al. 1982; Soto et al. 1975). The few studies that examine paleopathology for prehistoric populations from the semi-arid North are mainly limited to unpublished manuscripts (Costa-Junqueira et al. 1998; Quevedo 1976; Rosado 1994) which are not available to a wide audience. Therefore, a secondary goal of this research is to contribute to the record regarding the health of these South American populations.

The comparative nature of this research aids in placing each population in the context of human health history through time. This broad anthropological perspective allows for more precise interpretations to be made regarding the overall quality of life for these cultures. Generating reports on the TVA excavated sites adds to our overall knowledge of the people who lived out their lives in the Tennessee River Valley hundreds and thousands of years ago. Similarly, the gap in the knowledge of the Chilean skeletal sample has meant that there could not be a full reconstruction of the daily lives of the prehistoric native

peoples of the semi-arid North of Chile. This project is the first to analyze multiple indicators of skeletal health for these cultures, which results in a much more accurate and complete picture of the health status of the populations examined through time. A third goal of this research was therefore to expand what is known of both the prehistoric native peoples of Northern Chile and of Tennessee.

In keeping with these goals, Chapter 2 herein reviews paleopathological theory and presents a discussion of prehistoric health assessment from skeletal remains for foraging and agricultural populations. The prehistory of Northern Chile and of Tennessee, including a review of culture process and results from previous bioarchaeological studies in these regions is presented in Chapters 3 and 4. Chapter 5 describes the utilized skeletal samples and their provenience, and Chapter 6 presents the statistical and data collection methodology of the Western Hemisphere Health Index used in this study. The results are presented in Chapter 7, and finally, Chapter 8 is a discussion of the implications of these findings.

Chapter 2

Prehistoric Health Assessment

Theory in Paleopathology

Any sound scientific discipline is firmly rooted in theory and paleopathology is no exception. While the discipline had beginnings as primarily reporting on “gee whiz” phenomena, scholars such as Hooton and Angel were among the first to begin to utilize the epidemiological and biocultural approaches to the study of disease in past human populations (Ubelaker 1982). As early as the 1930’s, Hooton was exploring the effects of diet and culture on disease expression for Pecos Pueblo, and in the 1970’s Angel looked at disease as one component in a broad biocultural study (Ubelaker 1982). Ortner (1991, 1992, 2003) has been one of the main scholars who has expounded upon paleopathological theory and the effect it has on methodology.

While the term “paleopathology” was coined by R.W. Shufeldt in 1892 and later widely disseminated by Sir Marc Armand Ruffer in his 1921 publication on ancient Egyptian pathology, the practice of being interested in and reporting on prehistoric disease and abnormalities dates back at least to the Renaissance (Cook and Powell 2006). During the early stages of scientific inquiry, the main question asked with regard to bone abnormalities was, “what is it?” (Ubelaker 1982; Ortner 1991). However, once a sufficient number of pathologies

had been described, the subsequent question asked was, “what does it mean?” (Ortner 1991). At the present stage in the development of the discipline, questions of importance include clarifying the role that disease has played in the process of adaptation to the environment and questioning the evolutionary and biological significance of a particular disease (Ortner 1991). The direction of research in paleopathology for the future should include the examination of evolutionary dynamics between humans and disease agents (Ortner 2003).

The fact that paleopathology is integral to bioarchaeology, the anthropological sub-discipline concerned with human remains in archaeological contexts, is important due to the advances in that discipline in recent years. Bioarchaeology has improved its methods of inquiry, branching out to embrace techniques developed for other sciences (Larsen 2006). In addition, the recent emphasis placed on the importance of skeletal data collection standardization (Buikstra and Ubelaker 1994; Larsen 2006) has created a situation where questions of a comparative and evolutionary nature can now be addressed.

The biocultural view, as discussed by Armelagos and Van Gerven (2003) is that culture is an environmental force effecting and interacting with biological adaptation. The key here is that society plays a major role in creating or inhibiting opportunities for disease to be expressed (Armelagos and Van Gerven 2003). A related perspective is to take the functional approach, which considers and interprets adaptive complexes (Armelagos et al. 1982), i.e., while neither

European colonists nor Native Americans had natural remedies for viral diseases like smallpox, the curative properties of bedrest and drinking fluids were known to the Europeans (Thornton et al. 1992). The lack of similar knowledge among the post-contact Native Americans may have partially contributed to the massive population decline (Thornton et al. 1992).

An ecological approach to examining nutritional status in anthropology was proposed by Jerome et al. (1980) and this model suggests that variables such as social organization, environment, technology, and varying biological needs of people of different ages and sexes all have a bearing on diet and nutrition. This model holds special relevance for biological anthropology as for much of the discipline's history it has been stuck in the realm of typology (Larsen 1987). In order to gain a broader perspective on human behavior and adaptation in the past, bioarchaeology and paleopathology need to move beyond simplistic studies focused on basic description into the more complex realm of interpretation (Larsen 1987; Ortner 2003). Larsen (1987: 409) states that there is a need for "...a broader understanding of the biological significance of the variables that form the basis for interpretation" [of human variability].

The key to obtaining this broader understanding is to shift our focus to the interpretation of behavior and adaptation. As Larsen asserts,

"The recent shift in paradigm from emphasis on typology and description of anatomical and pathological variation to that of processual and behavioral interpretation is a breakthrough that is providing the basis for a more meaningful understanding of past adaptation" (1987: 410).

Every bioarchaeologist would agree that the study of human skeletal remains is a method of inquiry that holds the potential to reveal unique information regarding life and death in the past. By broadening our lens and examining skeletons in the context of culture along with biology, we can begin to answer questions about human adaptation.

A methodological protocol is necessary in order to put these perspectives into action. Description is still the first step when encountering lesions in dry bone (Ortner 1991; Lovell 2000). It is critical that this description be accurate and encompassing. Differentiation between the basic conditions of bone deposition by osteoblasts and bone resorption by osteoclasts, as well as describing the lesion distribution throughout any one skeleton is necessary (Ortner 1991; Lovell 2000). Once description has been accomplished, the paleopathologist can begin to ask questions regarding the significance of the bone lesion for both the individual and the population – i.e., did it result in an increase in morbidity or mortality (Ortner 1991)? Paying close attention to demography is also important, as the age-at-death distribution will reveal at what age those with lesions/without lesions were dying (Ortner 1991). Ubelaker (1982) suggests that the description step is the most important one, as it will enable other scholars to critically examine the presented evidence and interpretations – and perhaps come to their own conclusions. Such reinterpretation is crucial to continued growth in the discipline.

After description and analysis, the next steps include relating what was found to other conditions and relating findings to existing theory. While paleopathology is reconstructive rather than experimental in nature (Ortner 2003), nonetheless, the discipline can contribute to theory building and hypothesis testing (Ortner 1992). An example is Ortner et al.'s (1999) study on scurvy in prehistoric Peruvians. The hypothesis being tested was that scurvy would result in bilateral lesions on the greater wings of the sphenoid (from the abrasive action of temporalis during mastication), and that these would be correlated with lesions on the orbital roof, therefore ruling out iron-deficiency anemia as the causal agent of cribra orbitalia for those individuals (Ortner et al. 1999). Ortner et al. (1999: 325) found that the sphenoid lesions were bilateral 97% of the time, and that they were also associated with cribra orbitalia 97% of the time, thus confirming the hypothesis.

It is important to mention that part of paleopathological theory is grounded in the fact that very few conditions affect bone and of those that do, there is a convergent nature of the pathological changes seen in bone (Ortner et al. 1992; Wood and Milner 1994). For example, many conditions can cause similar changes to bone, such as scurvy and iron-deficiency anemia, and determining the correct differential diagnosis requires careful recording of lesion description and distribution (Ortner 2003). Moreover, the conditions that do affect bone typically only do so when the diseases are in chronic form – i.e., the individual has been

infected for months and even years. This being the case, there are at least three reasons why there may be an absence of bone disease in any given skeleton: 1) the individual may have died of a disease that does not involve the skeleton; 2) the individual may have died of a disease that does affect the skeleton, but before it reached that stage; and 3) the individual may have had a disease at some point in their life that affects the skeleton, but their immune system killed the pathogen before the disease could affect them at all (Ortner 2003). While these are limitations that prevent paleopathologists from attempting an all-encompassing reconstruction of prehistoric health, there remain nevertheless numerous questions we can address.

The above statements are relevant to the osteological paradox (Wood et al. 1992): perhaps one of the most important hypotheses set forth in bioarchaeology in recent years. One of the major points raised by Wood and colleagues was the possibility that those skeletons with lesions were healthier in life than at least some skeletons without lesions (1992). Wood and colleagues set forward three hypothetical populations:

Population A:	low stress	low lesions	low mortality
Population B:	moderate stress	high lesions	low mortality
Population C:	high stress	low lesions	high mortality

Population A in the example has low lesions because they are under low amounts of stress, and for Population B, the hypothesis is that having lesions

indicates a good immune response because skeletal disease is chronic and therefore the immune system was able to adjust to the disease well enough that the individual survived the initial acute stage (Ortner 2003; Wood et al. 1992). Population C has low lesions because they are under high amounts of stress and therefore dying of acute disease before the disease leaves skeletal evidence (Wood et al. 1992).

Several scholars have countered Wood and colleagues' argument, among them Cohen (1994), who states that current ethnographic evidence from food collectors and agricultural groups supports the accepted interpretation of skeletal lesions in the context of subsistence change: that health in general decreases with the advent of agriculture, observed in prehistoric populations as an increase in skeletal lesions in agricultural groups. In addition, Goodman (1993) states that Wood and colleagues neglected to include the examination of population demography associated with frequency of lesions: Population A will have low morbidity and low mortality; Population B will have high morbidity and low mortality; and Population C will have low morbidity and high mortality. The examination of demography in tandem with skeletal disease frequency allows a more accurate interpretation of population health, as the age-at-death distribution will reveal information regarding both quality and length of life.

In a later paper, Wood and Milner (1994) conceded that while the model presented in the 1992 publication has pitfalls, the important point remains that

models for making interpretations about the living population based on the dead (skeletal) population are lacking. Essentially, the skeletal series is ultimately not representative of the living population because death is not necessarily random – individuals have differential characteristics that predispose them towards or away from death at given times, known as the concept of differential frailty (Wood and Milner 1994).

Explaining the above further, Wood and Milner (1994: 635) state, “If a skeletal lesion has any relationship whatsoever to the risk of death, ... the skeletal population *must* be a biased sample for the living population” (emphasis in original). Essentially, people die for a reason – even accidental deaths can differentially affect certain individuals over others – and therefore the skeletal sample of those who have died (assuming the sample accumulated over time) tells us little about those who did not die (Wood and Milner 1994). While this is true, paleopathologists are obviously limited in terms of the sample at their disposal. While a given skeletal series may be a snapshot in time of the deceased population, one of the inherent facts is that everyone dies, sooner or later. While unfortunate for each individual, this fact gives a great advantage to the study of health in the past – that we can look at dead populations through time and space. We therefore can identify trends and patterns seen between and even within populations. This is where the examination of multiple indicators of stress (i.e., linear enamel hypoplasia, evidence of nutritional deficiency, Harris lines) in

conjunction with investigating lesion frequency and the age-at-death distribution becomes especially important, if we want to make accurate interpretations about the living population (Goodman 1993).

Steckel et al. (2002a, 2002b) acknowledge the possibility of a paradox in certain situations where health conditions are so poor that individuals die from acute insults before bone lesions can accumulate, such as in the 19th century poorhouse population from Rochester, New York (Higgins et al. 2002). However, this paradox emphasizes the importance of understanding life expectancy for examined populations and mortality rates, when possible (Steckel et al. 2002a). This example also calls attention to the significance of including multiple health indicators in any particular analysis of human skeletal remains.

To this end, Steckel and colleagues needed to choose which variables should be included in a health index that would evaluate health and quality of life. It was necessary to find a way to demarcate several different categories which had a bearing on health (i.e., age, sex, trauma, linear enamel hypoplasia, etcetera) that dozens of studies had in common in order to set up a meaningful way to compare studies across populations (Steckel et al. 2002a). The variables chosen have all been shown in multiple studies to have a bearing on health, insofar as they are markers of stress suffered by an individual during life (Goodman and Martin 2002). The stress model set forth by Goodman et al. (1984) as cited in Goodman and Martin (2002) includes environmental factors, such as

parasites and climate, the effect of culture as a buffer against various stressors, and host resistance factors. While stress cannot be measured *per se*, skeletal markers that record instances of stress, such as linear enamel hypoplasia, can be useful in assessing the severity and amount of stress to which an individual was subjected over their lifetime (Goodman and Martin 2002).

The extent to which the nature of the sample under study affects method and theory depends on the structure of the skeletal series. For example, preservation of a series can range from excellent (all bones present) to very poor (just fragments) (Waldron 1987). A problem that exists here is differential survival – bones that have undergone lytic disease processes (e.g., Pott's disease) are less likely to survive than those that are healthy or have undergone blastic disease processes (e.g., treponematoses) (Powell 1991). However, while these are limitations, most paleopathologists will work with what is present in the series, always keeping in mind that if the preservation is poor, some diseases may not be represented not because the population was disease-free, but because the evidence has since deteriorated (Waldron 1987).

While scholars acknowledge the limitations inherent with making interpretations about past populations solely based on their skeletal remains, bioarchaeology and paleopathology nevertheless offer tools for obtaining unique information not available from other avenues of inquiry. A single skeleton offers a snapshot in time of not only what may have been happening at the time of

death, but of what conditions were like months and years (if applicable) prior to death, including infancy and childhood. The study of individual skeletons and pathologies remains of importance; however, the true value lies in studying skeletal remains on a large-scale, population level. Such analyses give bioarchaeologists the ability to infer not only biological trends in health, but cultural patterns in adaptation as well. It is these sorts of interpretations that will comprise the future of the discipline and give weight to its holistic perspective.

Health in Foragers and Agriculturalists

Approximately ten thousand years ago, human groups in different parts of the world began shifting from the mode of subsistence practiced for the majority of human existence, namely, foraging and hunting, and commenced the purposeful cultivation of crops as a full time endeavor. While this shift was not a universal one, agriculture as the mode of subsistence has become the primary one in the world today. There are a variety of hypotheses that attempt to account for the reasons human populations chose to adopt agriculture, including climate change and increasing population (Smith 1998). Whatever the causes, the adoption of agriculture results in a number of potentially beneficial changes socially, politically, and economically including food surpluses, food storage, and increased political complexity (Smith 1998; Cohen 1989; Fagan 2000). However, since the transition from food collecting to full-scale agriculture occurs on a scale of thousands of years rather than mere decades, it is important to keep

in mind that these changes occurred gradually through time (Anderson and Mainfort 2002; Cohen 1989; Fagan 2000).

Agriculture's popularity in part is surprising, due to the findings by numerous researchers that health (as measured by skeletal markers of stress) in fact declines during the transition between subsistence strategies (Cohen and Armelagos 1984; Larsen 1982a, 1990a; Hutchinson and Larsen 1990; Schoeninger et al. 1990; Eisenberg 1991; Bridges 1991b; among others). In fact, the research that suggests the shift to agriculture was not accompanied by better patterns of health and nutritional status is all relatively recent, spurred on by the hypothesis (Childe 1951) stating that agriculture led to an improvement in health over the lot of the nomadic forager, with a concomitant decrease in demand on the population for food (because surpluses could be stored) and labor (due to the resultant increase in population). Several scholars disputed this hypothesis, as evidence for it was not borne out by contemporary studies of living gatherer and hunter groups (Lee and DeVore 1976; Rosenberg 1990). In fact, surpluses often do not serve as a buffer against famine in agricultural groups (Cohen 1989; Swedlund and Armelagos 1990) and foragers have considerably more leisure time than do agriculturalists (Lee and DeVore 1976; Gould 1969).

The thought process that regarded agriculture as a completely positive development began to change in the late 1960's, mainly with the publication of ethnographic studies on the !Kung Bushmen, foragers from the Kalahari Desert

(Larsen 1995). While this served as contemporary evidence for the status of health in foraging populations, data on prehistoric populations was necessary as well in order to make broader conclusions regarding the state of health during and after the transition to agriculture. Now a seminal work in the field, Mark Cohen and George Armelagos' Paleopathology at the Origins of Agriculture (1984) was the first to synthesize multiple studies that examined health status for prehistoric populations before, during, and after the transition to agriculture. This compilation was integral to the new interpretation: that the adoption of full scale agriculture had negative effects on populations, including the danger of nutritional deficiencies, famine (due to drought, blight, etcetera), and increased risk of disease (due to increased population and sedentism) (Cohen and Armelagos 1984).

A new direction that such research has taken is to make interpretations regarding different indicators of health by examining the frequency and pattern of disease within and between populations (Martin and Goodman 2002). Cohen (1989) was among those who suggested that comparing paleopathological data between populations would be a beneficial undertaking to the understanding of the evolution of human health and adaptation. Steckel et al.'s (2002a) health index is one example of this new methodology put to work.

In addition, scholars are aware that health and subsistence strategies for populations are not tied to each other in a vacuum void of any other variables

(Jerome et al. 1980). In particular, the environmental setting is important when one considers that different biomes have a distinct resource biomass and availability. Much discussion has specifically focused on the unique characteristics that a coastal environment has to offer (Erlandson 1988, 2001; Hutchinson 2004; Moseley 1975; Quilter and Stocker 1983; Yesner 1980a). This “maritime hypothesis” was initially developed to explain the origin of state level societies in Peru and states that subsistence strategies focused on the exploitation of coastal resources are capable of supporting large populations to the same extent that full-scale agriculture might be (Moseley 1975; Quilter and Stocker 1983).

The distinct coastal environment along the western border of the South American continent consists of the cold Humboldt Current, which when combined with the high solar radiation in the area, creates conditions that are conducive towards the proliferation of marine life (Grosjean et al. 2007). Yesner (1980a) states that the greater species diversity available in coastal zones can contribute to the potential for increased human population size and increased life expectancy. While these hypotheses deserve further exploration, numerous studies have shown that a diet which consists of shellfish is protein-rich (Erlandson 1988; Yesner 1980a) and therefore at the very least a potential exists for interpretations regarding the effect such a diet had on overall health.

The nutrient, caloric, and protein content for several species of shellfish (fresh and seawater) have been determined and these studies agree that shellfish represent a very poor resource in terms of caloric content, but are high in protein and vitamins (Klippel and Morey 1986; Parmalee and Klippel 1974; Yesner 1980a). While some studies suggest that it follows that shellfish were only used as a supplement and not as a staple (Parmalee and Klippel 1974), other researchers have emphasized the importance of evaluating the role of shellfish specifically for different subsistence economies (Erlandson 1988). Essentially, coupled with the fact that shellfish remains are common in archaeological middens from coastal and riverine environments (Claassen 1986; Klippel and Morey 1986; Waselkov 1987) and that shellfish are rich in protein, the hypothesis that the consumption of shellfish served as a health benefit seems likely.

However, determining whether or not shellfish were actually consumed and to what extent can be problematic, even when it appears obvious, such as when shell middens are present at a site. Shells are used for purposes other than human food (e.g., bait and tools) (Claassen 1998; Bonomo 2007) and middens can also in part be the result of taphonomic processes, such as animal activity (Klippel and Morey 1986; Claassen 1998). In short, dietary reconstruction based on ecofacts in shell middens alone should be done with caution.

In addition to environment, the consideration of variables such as social organization, aspects of culture such as technology, and the biological needs of

people of varying ages and sexes as well as diet and nutritional status is crucial if a truly holistic view of health is to be appreciated (Jerome et al. 1980). Essentially, populations in transition experience a change in the relationship they have with their environment and this change has an impact on the development of new sociocultural behaviors that are tied to not only nutritional status, but health status as well (Armelagos 1990; Aufderheide 1992).

Culture and biology are both equally relevant when it comes to a discussion of human nutritional needs. Cultural factors such as status differences, food preparation and storage practices, and rules regarding food taboos are all pertinent to a discussion of nutritional status (Jerome et al. 1980; Danforth 1999). For example, even in egalitarian societies, people of different ages and sexes are not truly equal – rules dictate which foods are eaten by whom, when, and how often (Danforth 1999). These differences can obviously become significant if and when there is a bias towards certain individuals in a society consuming foods with higher nutritional value. In addition, something seemingly innocuous as the way in which foods are prepared can decrease the available nutrients to the individual (Danforth 1999; Katz et al. 1974; Yesner 1980b). Even the storage of foods long term may decrease or increase the vitamin content, depending on the technique used (Cohen 1989). Other practices, such as food taboos that prohibit certain subgroups (i.e., pregnant women, men preparing for battle, children) from consuming particular types of foods can be

deleterious especially when you consider that nutrient needs differ by age and sex (Jerome et al. 1980). There is obviously no way to determine exactly which of these cultural practices were adhered to from the study of skeletal remains, indeed, there is little way to determine them from the archaeological record in general. However, by applying the principle of uniformitarianism we can assume that many of these customs were practiced in the past.

Human ancestors and modern humans up to ten thousand years ago were exclusively gatherers, hunters, and scavengers, and throughout the seven million year or so history of the *Hominidae* family, we evolved with that diverse diet to have certain nutritional requirements. The need for protein, eight essential amino acids, and certain vitamins and minerals all evolved in tandem with our omnivorous eating behavior (Kandel et al. 1980; Yesner 1980b). It stands to reason that after millions of years of subsisting on a varied diet allowed by a foraging lifestyle that the switch to staple crops which make up the majority of calories consumed would have some sort of effect on nutrition and health.

Taking the above statement a step further, it is nevertheless important not to focus on a simple cause-and-effect explanation for some of the patterns seen in the health of populations with the transition to agriculture. Nutritional status involves the balance between the nutrients consumed and digested and the subsequent energy expenditure by the individual (Goodman 1994). This balance indicates that an individual's nutritional status is much more complex than

simply which foods are being consumed (Goodman 1994; Yesner 1980b).

Goodman (1994: 165) states, “Numerous factors affect access to and utilization of nutrients”. It is likely that these factors include and are not limited to the types of foods being eaten, their nutritional content, the age and sex of the individual, pregnancy/lactation status for females, disease load, and amount of physical labor undertaken, among others. In addition, it is critical to determine from the archaeological record to what extent each food contributed to the diet (Cassidy 1980), as this will aid with the full reconstruction of nutritional status.

In the Eastern Woodlands of the United States beginning about 250 B.C., indigenous people began cultivating local wild flora, including goosefoot (*Chenopodium berlandieri*), sunflower (*Helianthus annuus*), marshelder (*Iva annua*), maygrass (*Phalaris caroliniana*), knotweed (*Polygonum erectum*), and little barley (*Hordeum pusillum*) (Asch and Asch 1978; Larsen 1995; Smith 1992). Known as the Eastern Agricultural Complex, the cultivation of these plants in horticultural gardens was in tandem with socioeconomic change (Anderson 2001; Larsen 1995). While a few researchers have noted changes in health markers during this time period (e.g., Rose et al. 1991), the subsequent adoption of maize agriculture and its corresponding social, political, and economic changes had a remarkable impact on demography and health condition (Larsen 1995).

Maize (*Zea mays*) was one of the crops domesticated in the New World and began to be relied upon heavily between A.D. 800 and 1100 (Smith 1989).

While other crops were farmed as well, (i.e., beans and squash), maize made up the majority of calories consumed by people after the transition to agriculture in Eastern North America and parts of Central and South America (Smith 1989, 1992; Bruhns 1994). While maize provides an ample amount of calories which are converted into energy for the individual, like other domesticated cereals, it is lacking in certain essential nutrients (Cohen 1989; Larsen 1995; Stuart-Macadam 1989). Unlike animal meat which has the right balance of protein and amino acids required by the human body, maize is deficient in the necessary amino acids lysine, isoleucine, and tryptophan (Cohen 1989; Larsen 1995). In addition, maize is a very poor source of protein (Buikstra 1992; Cohen 1989). Even when maize is processed using lime, which increases available dietary calcium and the amount of the amino acid lysine, this alkali treatment simultaneously reduces the amounts of the vitamins thiamine, riboflavin, and niacin (Yesner 1980b).

Furthermore, maize contains phytates, which inhibit the absorption of minerals such as calcium, iron, and zinc in the intestine (Cohen 1989; Larsen 1995). Therefore, even if these minerals are consumed in sufficient quantities from other food sources, subsisting on a maize-dominant diet will prevent the body from utilizing them (Cohen 1989). Vitamin B₃ (niacin) is also chemically bound when a predominantly maize diet is eaten (Larsen 1995). A clear outcome of these deficiencies with a maize diet is the potential for the development of nutritional deficiency diseases, such as iron-deficiency anemia, and the

likelihood of increased susceptibility to infectious disease (Cohen 1989; Martorell 1980; Scrimshaw et al. 1968; Stuart-Macadam 1989). In fact, agriculturalists in general (regardless of crop) are probably more susceptible to infectious disease due to nutritional changes and sedentism (Yesner 1980b).

The adoption of agriculture has certain consequences, such as an increase in zoonotic infections and diseases from close contact with domesticated animals (e.g., tuberculosis), and an increase in vector-borne illnesses such as malaria due to forest clearing, which puts people in close contact with newly created habitats for insects like mosquitoes (Yesner 1980b). The proximity to human waste and refuse dumps coupled with the increase in population that sedentism inherently causes additionally contributes to an increase in infectious disease for agricultural populations (Yesner 1980b).

In a landmark treatise, Scrimshaw and colleagues (1968) demonstrated that malnutrition and infectious disease are tied to each other in a “vicious” cycle. Essentially, being malnourished increases the likelihood of catching an infectious disease, because among other vital tasks, vitamins and minerals help to maintain a healthy immune system (Kwak and Blumberg 2004; Scrimshaw et al. 1968). Rarely is there a deficit of only one essential nutrient when an individual is malnourished, because foods typically either are abundant in or lack several nutrients together (Danforth 1999). There is extensive evidence that vitamins A, B₆, C, and E, as well as carotenoids, folic acid, iron, selenium, and

zinc are crucial for proper immune system function, as in addition to being integral to immune cell growth and enzyme function, they also have significant antioxidant properties (Anderson 2004; Beckett et al. 2004; Han and Meydani 2004; Hughes 2004; Ibs and Rink 2004; Kwak and Blumberg 2004; Semba 2004; Weiss 2004). Clearly, if the immune system has been deprived of these nutrients, it will not be at its peak performance, setting the stage for the onset of infectious disease.

In addition, being afflicted with an infectious disease can directly lead to malnutrition itself, hence the cycle (Martorell 1980; Scrimshaw et al. 1968). Bouts of acute illness can lead to a state of malnourishment in mere days, and in addition being ill affects appetite, so that sick individuals may not want to eat (Martorell 1980). Chronic illness poses further problems other than malnutrition, such as the depletion of fat stores (Martorell 1980). Moreover, particularly with diarrheal diseases, food doesn't remain in the intestines long enough for proper nutrient absorption (Martorell 1980). Furthermore, bacteria and viruses have been shown to effect if and how any consumed nutrients are metabolized by the body and can result in ingested protein catabolism (Martorell 1980). Parasites pose a similar problem, as they will absorb ingested nutrients before their human hosts can (Martorell 1980).

In essence, malnutrition is affected by two major factors: a diet of low nutritional quality and infectious disease (Martorell 1980). It is important to

consider the additional effects that a state of malnourishment has on the individual. Not only does it negatively affect the immune response, but it also affects work performance and higher mental functioning (Martorell 1980). Armelagos (1994) states that there is a direct relationship between disease and nutrition, and in fact, a discussion of the cycle of malnutrition, infectious disease, and poverty is relevant to contemporary applied anthropology today³.

Malnutrition is more common in children (Martorell 1980) for a variety of reasons, biological and social, and this pattern clearly has implications for populations as a whole. Goodman (1994: 170) cites a contemporary medical anthropological study by Chavez and Martinez (1982) which found that children who were just moderately malnourished were sick up to 50% of their childhoods. The obvious question this sobering statistic begs is the sort of impact that this has on their families and on society (Goodman 1994). We must assume that the stress chronic illness places on familial and societal resources would have been similar in prehistory as well (Goodman 1994).

There are additional factors that need to be considered during a discussion of infectious disease, such as how infectious pathogens are transmitted. Certain features of the physical and cultural environment play a role here. There are essentially six methods of disease transmission (vector-borne, zoonotic, fecal-oral, water-borne, respiratory, and sexual), and each of these is

³ Social inequality, in the form of class-based social structure (usually associated with chiefdom and state systems of political organization) has also been shown to negatively affect the health of those in the lower classes through the denial of access to resources (Cohen 1998; Danforth 1999).

dependent upon social or biological factors (Sattenspiel 2000). For example, cultural factors such as agricultural activities and sanitation contribute to the first four methods listed and environmental factors such as high humidity, abundant rainfall, and a large number of co-circulating pathogens contribute to all six (Sattenspiel 2000). This correlation serves as a re-emphasis of the fact that biological and cultural factors, i.e., a biocultural approach, need to be considered together when investigating health.

Black (1975) states that there are essentially two types of infectious diseases: those that chronically infect individuals, and those that are infectious only in an acute phase. The latter type of disease did not place selective pressure on populations until relatively recently, due to population size and sedentism (Armelagos 1990; Black 1975; Brothwell 1967; Larsen 1987). These two factors have a significant contribution to whether or not infectious diseases will become endemic (Armelagos 1990; Black 1975; Brothwell 1967; Larsen 1987). When an infectious organism is introduced, if the population is below a certain size threshold, everyone becomes sick essentially simultaneously and therefore, when the epidemic passes, so does the infectious organism from the population (Bartlett 1960; Black 1975; Cliff et al. 2000). This pattern obviously only holds true for those organisms which are eliminated completely from the individual and not those which can have a dormant phase, such as the bacterium that causes tuberculosis (*Mycobacterium tuberculosis*) (Ortner 2003).

Epidemiological theory states that diseases can become endemic when the population is above a certain size, known as the critical community size (Cliff et al. 2000). This size threshold appears to vary depending upon the particular pathogen and on other, as yet unknown factors (Cliff et al. 2000). It does seem that thousands, if not tens of thousands of people are necessary for endemicity of a particular disease to occur. In populations above this critical community size, people get sick at staggered times, allowing the organism to be present in its acute infectious state in some and not in others at the same time, which in turn allows it to be repeatedly passed on (Cliff et al. 2000).

In fact, Martin and Goodman (2002: 66) assert that “infectious diseases are among the most significant selective forces in human evolution” and that along with malnutrition are the largest causes of morbidity and mortality throughout the world today. The same probably held true for prehistory as well. As far as disease agents present in the New World prior to European contact, the treponemal diseases (i.e., yaws, pinta, syphilis, and bejel), tuberculosis, fungal diseases, and intestinal parasites among others all exerted pressure on indigenous populations (Merbs 1992). It is likely that common bacteria such as staphylococcus and streptococcus were also very common (Martin and Goodman 2002).

While this seems a considerable disease load for New World populations, the pattern observed in the Old World was very different in terms of the

presence of “crowd diseases” such as smallpox, measles, and yellow fever (Merbs 1992: 3). This disparity obviously became of great importance during European contact, when indigenous New World populations with no immunity to these crowd diseases and others, e.g., malaria, diphtheria, and typhus, were exposed to them for the first time and died in epidemic proportions (Merbs 1992; Thornton et al. 1992). In fact, Larsen and Harn (1994) found that infection rates observed on the skeleton were the highest during the contact period with Europeans as compared to pre-contact periods for the Georgia Bight region. This dichotomy is not surprising considering the above discussion. That infectious disease exerted a considerable amount of selective pressure during contact is undeniable, especially when considering that “most of the present population of the western hemisphere draws its recent ancestry from the Old World rather than the Americas” (Merbs 1992: 4).

There are a number of contemporary medical anthropological studies that suggest health in foraging groups at the very least displays a different pattern from agricultural groups and for the most part, appears to be better (Lee and DeVore 1976; Kent and Dunn 1996; Rosenberg 1990). While modern-day foraging groups are not in isolation from the rest of the world (hence the possibility of cultural diffusion) and the environments they inhabit are probably very different from the environments in prehistory at least in terms of game animal availability, the use of these modern corollaries is the closest example we have to the way

humans lived for 99% of our history (Cohen 1989). Kent and Dunn (1996) found that for the !Kung San of the Kalahari Desert, there were notable dietary changes associated with high morbidity for those in transition from the nomadic lifestyle to a sedentary one. The high rates of morbidity observed probably were not only related to the dietary differences, but to socioeconomic change and changes in political organization as well (Kent and Dunn 1996). For the same population 20 years earlier, Lee and DeVore (1976) found that those still maintaining a traditional lifestyle had better nutrition and overall health than their farmer counterparts.

A number of studies have examined these issues for prehistoric populations as well (e.g., papers in Cohen and Armelagos 1984; Cassidy 1980; Larsen and Harn 1994; Larsen et al. 1991; among others). In their summary chapter, Cohen and Armelagos (1984) discuss that the major trend observed is an increase in infection incidence for agricultural groups over foraging ones. Specifically, there is a general increase in skeletal stress markers that indicate nutritional deficiency and an increase in infectious lesions like periostitis and dental caries (Cohen and Armelagos 1984).

In an early study, Cassidy (1980) found that cribra orbitalia, a marker of iron-deficiency anemia and other nutritional deficiencies, was absent in the Archaic period forager group from Indian Knoll, Kentucky. In contrast, this marker was common in individuals from Hardin Village, Kentucky, a

Mississippian period site (Cassidy 1980). In addition, while those from Indian Knoll had evidence of Harris lines (typically associated with bouts of growth cessation), these occurred at regular intervals in the bones, probably associated with seasonality, while the Harris lines in individuals from Hardin Village were distributed randomly (Cassidy 1980). This patterning suggests that periods of stress occurred in regular intervals for the foragers, perhaps during the winter and were therefore predictable, while stress episodes severe enough to halt growth for the agriculturalists were random in their occurrence (Cassidy 1980). Further evidence that supports this observation is the severity of linear enamel hypoplasias observed for those from Hardin Village (Cassidy 1980). The overall picture corroborates with other studies, namely, that stress episodes are more severe in agriculturalists which may be related to the quality of nutrition and stability of the food supply (Cassidy 1980), even access to food itself.

Specific skeletal markers that are analyzed for signs of stress include dental caries, linear enamel hypoplasia, cribra orbitalia, porotic hyperostosis, evidence of non-specific infection (e.g., periostitis), stature, and robusticity (cf. Goodman and Martin 2002). Caries are frequently cited as being less frequent in foraging groups, probably due to the specific components of the foods eaten, e.g., abrasive vegetal foods vs. carbohydrates (Danforth 1999; Kelley et al. 1991; Larsen 1987; Larsen et al. 1991; Larsen 1995; Milner 1984). However, there are situations where caries rates in particular foraging groups is high, but these are

typically secondary to dental wear that exposes the pulp cavity (Costa-Junqueira et al. 1998; Jurmain 1990; Rosado 1998; Smith 1982). With a maize diet, the high carbohydrate content is implicated in the drastic increase in attendant caries rates (Caselitz 1998; Hillson 1979, 1986; Larsen 1983) as the sugars in carbohydrates are fermented by oral bacteria and byproducts of the fermentation process degrade enamel (DePaola 1982; Hillson 1986). Maize contains between 2-6% sucrose, and as a simple sugar it is easily metabolized by oral bacteria (Larsen et al 1991). Dental hygiene or the lack thereof, is clearly a factor as well.

The vast majority of studies that have examined the shift from hunting and gathering to agriculture in terms of differences in dental disease have found that there is a marked increase in dental caries rates among the agriculturalists (Larsen 1983; Larsen et al. 1991; Kelley et al. 1991; Caselitz 1998; Cucina and Tiesler 2003). This observation holds true for regions all over the world, not just in the Southeastern United States. For example, in a comparative study of 518 populations from 10,000 B.C. to the present, Caselitz (1998) found an increase in caries rates linked with the shift to sedentism, which indicates an agricultural subsistence strategy. An additional finding was that the lowest caries rates were in hunting-gathering groups (1998).

For the Southeast specifically, Larsen (1983) found that in Georgia, Mississippian people had an increase in caries rates for each tooth type compared to their Woodland predecessors. In addition, females had higher caries

rates than did the males (Larsen 1983), which indicates a difference in the relative amounts of foods the sexes consumed – women probably ate more maize, because they were the ones preparing it. Men still did some hunting, and therefore gave themselves preferential access to the protein-rich meat. In a later study, Larsen et al. (1991) found for the Southeastern coast, there had been a 50% increase in caries rates from foragers to agriculturalists.

Developmental enamel defects, including enamel hypoplasia, result from stress-induced cessation in ameloblast activity (Duray 1996; Goodman and Rose 1991). Indications in teeth of encountered stress are nonspecific – meaning they have recorded that a stress occurred, but there is no way to know specifically what type of stress it was (Goodman and Rose 1991). Enamel hypoplasias consist of deficiencies in enamel thickness, and this can range from a single pit to missing enamel entirely (Goodman and Rose 1991). Linear enamel hypoplasias can clearly be detected in teeth – represented by one or more transverse lines or grooves in the enamel of the crown.

The most common type of enamel hypoplasia seen in skeletal series fit a chronologic pattern and appears to be the result of systemic metabolic stress and therefore is known as linear enamel hypoplasia (Goodman and Rose 1991). Linear enamel hypoplasia is found on a variety of teeth developing at the time of stress and the specific location of defects on the crown reflects how complete the crown was at the time of the insult (Lukacs 1989). Clearly, this pattern has

implications for being able to assess at what age stress insults occurred, as the sequence and timing of dental growth and development is known (Gustafson 1950; Hillson 1996; Massler et al. 1941; Schour and Massler 1940).

Linear enamel hypoplasias represent a serious, prolonged stress insult and results from periods of metabolic stress ranging from several weeks to two months (Rose et al. 1985). Goodman and Rose (1991) state that early research on animals showed that factors like nutritional and hormonal imbalance, and disease – i.e., anything that disrupted normal physiology and growth could lead to enamel defects. In addition, studies of contemporary and prehistoric populations have shown that there is a general trend towards an increase in defects at the time of weaning (Cassidy 1980; Schultz et al. 1998), but it is unclear how important nutrition is and which nutrients are most important (Goodman and Rose 1991). Schultz et al. (1998) list a number of possible causes of enamel defects, further reinforcing the idea that defects are nonspecific representations of some metabolic stress. These causes include: insufficient calcium and/or vitamin D, malnutrition in general, infectious disease, and fluorosis (fluorine poisoning) (Schultz et al. 1998).

Multiple studies have found that the frequency of linear enamel hypoplasias increase in severity and number with the advent of agriculture, which suggests that stress episodes such as acute or chronic illness, periods of starvation or inadequate nutrition occurred frequently and were severe (Cohen

and Armelagos 1984; Duray 1996; Rose et al. 1985). Furthermore, deciduous teeth with hypoplastic defects are more common in agriculturalists than in foragers, which suggests that pregnant women underwent considerable stress as well (Cohen and Armelagos 1984).

For individuals from Woodland and Mississippian cultures in prehistoric Illinois there was a decrease in disease resistance among subadults with the increased consumption of maize, and this decrease resulted in a higher infection rate and a higher probability that Wilson bands (microscopic defects in enamel, sometimes associated with hypoplasia) would be produced (Rose et al. 1985). For a Late Woodland skeletal series from North America, Duray (1996) found that those with enamel defects had an average age-at-death of 5 years less than those without defects. Possible reasons include that an individual with defects was biologically damaged by whatever the metabolic insult had been, and therefore had a decreased ability to cope with later stressors; that an individual with defects had them because they were socially disadvantaged (did not have access to foods high in nutritional value) and therefore suffered increased stress exposure; or that an individual with defects had some genetic susceptibility to certain stressors, which resulted in a lifelong pattern of illness (Duray 1996).

Anemia in general is some abnormality of the red blood cells that affect the ability of the circulatory system to exchange oxygen (Ortner 2003). Typically, this abnormality revolves around the concentration of hemoglobin, the molecule

that binds oxygen to red blood cells (Stuart-Macadam 1989). Since iron is a major component of hemoglobin, a deficiency in iron results in iron-deficiency anemia. Among other things, iron is important for the regulation of oxygen transfer to cells (Stuart-Macadam 1989). Dietary sources of iron consist of heme and non-heme iron, the former being obtained from meat, fish, and poultry; and the latter from plants (Larsen and Sering 2000). In addition, the heme iron is much more efficiently absorbed by the stomach and intestines than is the iron obtained from plant sources (Larsen and Sering 2000). Iron-deficiency anemia is not necessarily linked to dietary deficiency alone, as blood loss, parasites, diarrhea, even genetics and strenuous exercise are all causal factors (Buikstra 1991; Larsen 1995; Larsen and Sering 2000; Stuart-Macadam 1989, 1992).

When the body is in an iron-deficient situation, it compensates by producing more red blood cells – trying to make up for quality by producing quantity. As the red blood cells are manufactured in the red marrow spaces of the skull vault, this process puts pressure on the marrow space to expand (Ortner 2003). The diploë in bones such as the parietals will enlarge, putting pressure on the outer table, and this pressure eventually destroys the outer table of bone (Ortner 2003). The outer table becomes porous during the destruction process, which presents itself as porotic hyperostosis (Ortner 2003). There will be no changes seen on the inner table of bone until the outer table has been completely destroyed (Ortner and Ragsdale 2004). The parietal is the most common area in

the skull for lesions, followed by the orbital roof (Ortner 2003; Stuart-Macadam 1989), with those lesions known as cribra orbitalia (Lallo et al. 1977).

Iron-deficiency anemia is commonly seen in populations such as the Mississippians in Eastern North America who were habitually consuming maize as the primary staple food. Maize is low in useable iron and additionally contains phytates, which bind iron, thus further decreasing the amount of iron that is useable (Lallo et al. 1977; Stuart-Macadam 1989). Lallo et al. (1977) found a significant association between porotic hyperostosis and infectious disease for Mississippian populations. The reliance on maize led to the dietary stress of lack of iron. In addition, this dietary stress probably also partially contributed to the higher amounts of infectious disease seen with the Mississippians when compared to the Woodland peoples (1977). However, Larsen and Sering (2000) describe a low incidence of porotic hyperostosis for prehistoric agriculturalists from the coastal Georgia Bight region. They cite Layrisse and colleagues (1968) who found that the absorption of the non-heme iron present in maize increases by as much as 300% when maize is consumed in tandem with fish. Therefore, this indicates that the relationship between maize subsistence and iron-deficiency anemia is not necessarily straightforward.

The vast majority of infectious diseases that affect bone are called nonspecific reactions or diseases (Armstrong 1990; Ortner et al. 1992). One of the most common is periostitis, or infection of the periosteum, the fibrous layer that

covers bone and is nutritive to bone. The invasion of bacteria, typically *Staphylococcus aureus*, from trauma (such as a fracture) or via a bloodborne route, will cause the elevation of the periosteum from the compression and stretching of blood vessels (Ortner 2003). This is the typical inflammatory reaction of the vessels to the infection (Ortner 2003). The elevation of the periosteum leads to a subperiosteal hemorrhage, which results in the death of portions of the cortical bone due to the decreased blood supply (Ortner 2003).

The other commonly encountered nonspecific diseases include osteitis and osteomyelitis. Their etiologies are similar to that described for periostitis, except osteitis is seen in compact bone, and osteomyelitis occurs in the marrow space and primarily affects the endosteal surface of the bone (Ortner 2003). The interpretation of such lesions goes further than the mere observation that they were present. In an example from the literature, Eisenberg (1991) found that for Averbuch, a Mississippian population from Middle Tennessee, the distribution and severity of tibial periostitis indicated that infants and young children had the highest rate of infection, followed by children older than two and a half years, which indicates that the infection in older juveniles had progressed to a chronic state and that infection was endemic in this population.

Stature comprises part of the basic “biological profile” conducted when analyzing skeletal remains and its interpretation has important implications for revealing the overall health or stress level of a population. A number of

contemporary studies show that children who are growth-suppressed are short as adults, and this is direct evidence of disease and/or malnutrition during childhood (Cohen 1994; Larsen 1987). Furthermore, it is clear that nutrition is an integral aspect for proper growth, as other contemporary studies have shown that stature increases as economic conditions and nutritional status improve (Larsen 1987). Short-statured children suffer disease episodes that are of longer duration and are more frequent than those suffered by taller children (Cohen 1994). This disparity spills over into adulthood as well, as women who were growth-stunted as children are more likely to carry growth-retarded infants (Cohen 1994).

Evidence from the archaeological record reveals that several populations experienced reductions in adult stature, mostly correlated with a dependence on mono-crop agriculture (Larsen 1987). For example, Larsen found stature reductions in agricultural populations from the prehistoric Georgia coast compared to the earlier foraging peoples (1982a; cited in Larsen 1987). In addition, Lambert (1993, 1994) found a 10 centimeter stature decrease over a period of about 8000 years for native peoples from southern California, which she attributed to subsistence change. However, this decrease is not universally observed among analyzed agricultural populations, suggesting that other factors are involved (Cohen and Armelagos 1984; Larsen 1987).

To summarize, when attempting to reconstruct patterns of prehistoric health, it is important to consider several factors simultaneously, including aspects of climate, demography, economy, and subsistence (Goodman 1994; Lambert 1993; Martin and Goodman 2002). Larsen (1995) states that the interpretation of poor health patterns can be supported by understanding the relationship between infection and biocultural stressors. As such, a simplistic explanation of maize or mono-crop agriculture as being the primary causal factor in declining health is additionally no longer acceptable. A truly holistic view will take into account the cultural and environmental changes that accompany such a radical subsistence shift (cf. Lambert 2000a; Schoeninger et al. 1990).

Data from the archaeological record will assist with understanding the environmental context, which is crucial towards interpreting the possibilities and limitations involved with food procurement, clothing, and shelter (Martin and Goodman 2002). Additionally, it is no longer sufficient to simply report frequencies of skeletal markers of stress such as linear enamel hypoplasia and cribra orbitalia; rather these markers must be interpreted in terms of the larger sociopolitical climate that may have contributed to their development (Goodman 1994). This context becomes especially critical when attempting a comparison between groups of differing subsistence or sociopolitical economies.

Chapter 3

Northern Chilean Prehistory

Environmental Setting of the Semi-arid North of Chile

Geographically, the semi-arid North of Chile is located between latitudes 26 and 33 degrees south and includes parts of the Atacama, Coquimbo, and Valparaíso regions (Niemeyer and Cereceda 1983; Rosado 1994). See Figure 1. The Andes Mountains lie to the east and the Pacific Ocean to the west. The northern reaches of the semi-arid region end at the basin of the Salado River, and the southern boundary is the Aconcagua River (Niemeyer and Cereceda 1983). Chile's semi-arid north has multiple ecological zones: the coastal, valley, and mountainous regions each have their own ecological regimes and resources (Niemeyer and Cereceda 1983).

Aridity is the main feature of this area of South America which is located adjacent to the Atacama Desert, the driest in the world. Yearly rainfall averages between 10 mm in Chañaral, which is located in the northernmost part of the region and 444 mm in Valparaíso, located to the south (Niemeyer and Cereceda 1983: 88). Winter (June, July, August) is the season of the heaviest precipitation for the coast, with approximately 100 mm falling in the northernmost part and over 300 mm in the southernmost part (Grosjean et al. 2007: 56). Despite the paucity of rainfall, fresh water is abundant, as the semi-arid North is supplied by

eight rivers arising from glacial runoff from the Andes Mountains which drain into the Pacific Ocean (Niemeyer and Cereceda 1983). In the coastal zone, the climate is temperate, with the average difference between mean summer (December, January, February) and mean winter (June, July, August) temperatures about 7.6 degrees Celsius (Niemeyer and Cereceda 1983: 87).

For the coastal portion of the Elqui River Valley specifically, where most of the sites analyzed in this work are located, the weather is humid and foggy all year long, with annual relative humidity of 70% (Niemeyer and Cereceda 1983: 87). The median annual temperature in the city of La Serena, located on the coast and central to the Elqui River Valley, is 14.9 degrees Celsius (Niemeyer and Cereceda 1983: 87). Paleoenvironmental data from paleosols, regional groundwater tables, and other sources reveals that the climate was very humid during the Early Holocene (c. 14,000 – 9,500 years ago) and that there was a shift to very dry conditions between 9,000 and 4,000 years ago (Grosjean et al. 2003; Grosjean et al. 2007). The effect of this shift in climate was reduced precipitation for the semi-arid North (Veit 1996) which consequently affected patterns in human occupation (Grosjean et al. 2007).

However, terrestrial plant pollen from lake sediments has revealed that there were no major changes during the Early Holocene (Grosjean et al. 2003). Pollen analysis in general reveals changes in climate on a decade-to-century sensitivity level. The pollen record in this region indicates that while there were

some major changes that occurred in terms of climate, most of these were not rapid and therefore had an effect on long-term human adaptation rather than short-term adaptation. At the level of human populations, this slow change indicates that the human residents of the semi-arid North within one generation or another have experienced no dramatic climatic changes at least since the end of the Pleistocene era. In addition, several current sources and locations of fresh water (rivers, underground springs, etcetera) have not changed since prehistory, as archaeological sites are all found in close proximity to currently utilized fresh water sources (Ampuero pers. comm. 2007).

While for the most part during the Holocene the climate has remained stable, there were two major departures from this rule: one occurring about 9,000 years ago and the second about 5,000 years ago (Grosjean et al. 2007). During these time periods, there was a marked increase in aridity, which led to the increased mobility of human populations and an inclination for populations to remain near areas with stable resources, such as along the coast or near freshwater springs (Grosjean et al. 2007). At first glance, the Pacific coast may appear unattractive for human settlement, but in fact this ecosystem is one of the most productive in the world, due to the effects of the Humboldt Current, which allows for a high nutrient content in the water (Grosjean et al. 2007). When these nutrients are coupled with the high solar radiation in this area, it creates conditions that are very favorable for the proliferation of a variety of marine flora

and fauna, such as mollusks, fish, sea mammals, and seaweed (Grosjean et al. 2007). As a result, despite the fact that this coastal environment is lacking in many terrestrial floral and faunal resources, the abundance of marine resources more than makes up for this deficit. In addition, with the exception of periodic El Niño events, these marine resources are not affected by climate change on the same order as terrestrial resources. Consequently, the marine environment represents a stable and predictable source of subsistence (Grosjean et al. 2007).

Camelids, birds, and rodents were the most important terrestrial animals hunted (Grosjean et al. 2007). The terrestrial vegetation is characteristic of an arid environment and the valleys contain numerous plant species. Cacti and trees are abundant, and in fact, one of the Spanish chronicles describes the area as having many of the same types of plants that are found in Spain (De Bibar 1966 [1555]). The depiction of the environment by a variety of chroniclers at the time of contact (A.D. 1537) is essentially identical to the ecology in the region today (Ampuero 1994).

It is clear that climate change was important at certain times during the Archaic era and in addition, paleoenvironmental evidence suggests that the climate in general for the semi-arid North has become more variable during the Holocene era, with fluctuations in aridity and humidity (Veit 1996). However, as discussed for the southeastern United States, whether or not this variability in climate had an effect on human culture change remains to be elucidated.

Culture Process of the Prehistoric Chilean Semi-arid North

Human beings have occupied the semi-arid North of Chile for at least 12,000 years (Ampuero 1994). As in North America, the people of the earliest period of Chilean prehistory are referred to as Paleoindians, and their subsistence strategy consisted of hunting large, now extinct mammals such as the mastodon, the giant sloth, extinct llama species and wild plant gathering (Ampuero 1986). Perhaps owing to the antiquity of this culture or the fact that people lived in small bands of people and were highly mobile, scant archaeological evidence and few human remains thus far discovered provide any further evidence that elucidates their culture. For example, the site of La Fundición excavated by *Museo Arqueológico* archaeologists uncovered only one poorly preserved skeleton, dated to 7000 BP (Rosado pers. comm. 2007).

The extinction of large mammals such as the mastodon approximately 10,000 years ago marked the end of the Paleoindian period and the commencement of the Archaic period for Northern Chile. This period is divided into four phases and the earliest evidence for human occupation is in the interior valleys of the semi-arid North (Rosado 1994; Kuzmanic and Castillo 1986; Niemeyer et al. 1989). The entire Archaic period dates from 7730 B.C. to A.D. 245. See Tables 1 and 2.

The climate change that accompanied the end of the Pleistocene era required people to adapt to a new environment with fewer large mammals to

hunt (Ampuero 1986). The new possibilities posed by the postglacial environment led to a restructuring of society in the categories of subsistence, technology, and social organization (Bogucki 1999). While several large mammal species had disappeared, there were nevertheless numerous species to exploit, including different species of foxes, rodents, marine birds, fish, mollusks, cetaceans; and mammals such as the sea lion (*Otaria flavescens*), marine otter (*Lutra felina*), guanaco (*Lama guanicoë*) and vicuña (*Vicugna vicugna*) (Costa-Junqueira et al. 1998). While there is no evidence for ceramic technology or agriculture, grinding stones are common indicating the processing of plants (Rosado 1994). Archaic coastal populations had technology such as nets for fishing, and also specialized in the collection of clams (Grosjean et al. 2007).

Essentially, Archaic peoples were food collectors, migrating seasonally through the valleys from the Pacific coast to the foot of the Andes following their primary game animal, the guanaco, a camelid in the same family as the llama (*Lama glama*), alpaca (*L. pacos*) and vicuña (Ampuero 1994). In essence, this practice allowed for the evolution of transhumance later on, as people incorporated the domestication of the llama and alpaca into their subsistence strategy (Ampuero 1986). It is important to note that the main bulk of the Archaic diet consisted of gathered plants such as quinoa and cactus fruits (Ampuero 1994). The gathering of plants enabled people to expand their knowledge of wild flora, which would become important with the advent of agriculture in later

periods (Ampuero 1986). In fact, Archaic populations in general have in common the focusing on seasonally abundant resources and storable foods which was a subsistence strategy that preceded subsequent socioeconomic change, including agriculture (Bogucki 1999).

Evidence for the first Archaic phase has been found at the interior valley sites of El Teniente and Las Conchas in Antofagasta represented by the Huentelaquen culture, so named by Iribarren (1961). The site of Las Conchas is the earliest known Early Holocene site south of 22°S, and the people here specialized in extracting marine resources (Grosjean et al. 2007). Harpoons, projectile points, fish nets, plant remains, and grinding stones typify the material remains found at the Huentelaquen sites (Grosjean et al. 2007; Rosado 1994). Radiocarbon dating places this phase at 7730 – 7450 B.C. (Table 2). It is postulated that these people migrated from arid Northern Chile, and little is known about them other than their adaptation to a maritime subsistence strategy (Rosado 1994).

The second Archaic phase as defined by Kuzmanic and Castillo (1986) dates from 5500 to 1800 B.C. (Table 2). The reason for the gap in dates between the Archaic I and II phases is due to the dearth of archaeological sites showing a consistent habitation sequence temporally, which may be in turn linked to rising sea levels in later times that obliterated evidence of occupation (Grosjean et al. 2007). In addition, only one radiocarbon date exists for this phase from the site of

Guanaqueros, a coastal site located south of Coquimbo Bay (Rosado 1994). A problem with this date is that it overlaps with the date proposed for the succeeding Archaic phase, phase III. The current consensus is that this overlap is due to the evolution of phase III directly from phase II (Rosado 1994), and for dynamic reasons, different sites show defining characteristics at varying times. Additionally, phase II sites are located along the entire desert coastline and the fertile southern area of the semi-arid North, while phase III sites are limited to the southern border of the semi-arid region (Kuzmanic and Castillo 1986).

Bird (1943) referred to the Archaic II phase as the “*Cultura Anzuelo de Concha*” (shell fishhook culture) due to the relative abundance of this artifact found in middens dating to this period (Kuzmanic and Castillo 1986; Rosado 1994). Projectile points and shell necklaces round out the common artifacts found in grave contexts for this period (Kuzmanic and Castillo 1986). Based on the abundance of these artifacts, it is clear that people during this phase were well adapted to a gathering-hunting and maritime subsistence strategy (Kuzmanic and Castillo 1986).

Artifacts like compound fishhooks and bone harpoons indicate that about 2500 B.C., people migrating from Argentina and from northern Chile contacted the Archaic peoples already settled in the valleys and coasts of the semi-arid North (Ampuero 1994; Rosado 1994). These migrants brought with them knowledge of cultivated and domesticated plants, such as maize and squash

(Ampuero 1994). While maize, beans, and gourds have been found archaeologically beginning about 2750 B.C., evidence of people in the semi-arid North utilizing an agricultural subsistence strategy *senso stricto* does not appear in the archaeological record until the Ceramic period (300 B.C. – A.D. 1536) (Ampuero 1986).

Characteristic burial goods seen in the succeeding Archaic II period consisted of lithic projectile points, bone harpoons, shell fishhooks, and other artifacts made of shell and bone (Rosado 1994). The abundance of fishing tools made of shell, such as fishhooks and harpoons, emphasizes the importance of the marine environment as a major subsistence resource to this culture. These artifacts additionally reflect the link between populations in more northern regions of Chile and people in the semi-arid North, as bone harpoons and compound fishhooks are also seen in Antofagasta (Ampuero 1986). In addition, further evidence for culture contact is seen in contemporaneous sites located in the interior high valleys of Chile, where marine gastropod shells are found among the material artifacts (Grosjean et al. 2007). Rock art is found at some of these sites as well (Grosjean et al. 2007) and it can be assumed that this cultural artistic expression occurred in populations located closer to the coast as well (Ampuero pers. comm. 2007).

Several sites characterize the Archaic III phase, including El Cerrito, La Herradura, and upper levels of Guanaqueros (Rosado 1994). All of these sites are

coastal and are located in the Coquimbo Bay area, just adjacent to the Pacific Ocean. Radiocarbon dates from various sites place this phase at 2955 – 500 B.C. (Table 2). The temporal overlap observed between dates for the Archaic period relates to the fact that regional continuity exists between the phases for several of the sites. For example, different levels of Guanaqueros date to phases II and III (Kuzmanic and Castillo 1986; Rosado 1994).

Burials covered with stone slabs are seen during phase III, as well as the presence of numerous types of grave goods. A defining characteristic of this phase is a large decrease in hunting implements found with a resultant increase in different types of grinding implements, such as grinding stones and pestles (Rosado 1994; Kuzmanic and Castillo 1986). This evidence indicates that a substantial change in subsistence began to take place with the addition of plant gathering and processing; however, marine resources continued to be important based on the continuing presence of grave goods like fish and sea mammal bones (Kuzmanic and Castillo 1986; Rosado 1994).

The Archaic IV phase dates to A.D. 30 – 245 and the presence of new artifacts indicating culture contact defines the phase transition (Rosado 1994). See Table 2. Grave goods such as copper sheets, beads of bone and malachite, stone pipes, and shell and bone necklaces are seen in this period for the first time and their similarity to artifacts from northwestern Argentina suggests the migration of peoples into the semi-arid North from Argentina (Rosado 1994; Kuzmanic and

Castillo 1986; Ampuero 1986). However, archaeological evidence is still unclear as to whether these new artifacts are a result of actual migration or just due to cultural diffusion (Rosado 1994). Even if the mechanism was solely cultural diffusion, it is clear that substantial diffusion took place as there were changes on multiple fronts: new technologies, such as metal working, indicated by the presence of copper, and new perceptions of aesthetics, as indicated not only by the shell and bone necklaces but by the presence of intentional cranial modification and the use of the *tembeta*, or lip plug (Rosado 1994; Ampuero 1986; Munizaga 1971, 1980). The presence of intentional cranial modification is seen for the first time during this period and it is a practice that continues throughout the Ceramic period. However, during the Archaic the modification appears to be solely of aesthetic significance as it does not appear to differentiate between people based on sex or social status (Ampuero pers. comm. 2007).

The Ceramic period consists of the El Molle, Las Animas, and Diaguita cultures and it dates to 300 B.C. – A.D. 1536 (Ampuero 1986). See Table 1. The disparity between the ending date for the Archaic (A.D. 245) and the beginning date for the Ceramic period (300 B.C.) is based on the consensus among Chilean archaeologists that the Ceramic period begins when the first populations underwent a change in their subsistence strategy to agriculture and the recognition that other populations maintained their primarily maritime adaptation for several hundred years longer (Ampuero pers. comm. 2007).

Similar to the preceding Archaic IV period, the El Molle period (300 B.C. – A.D. 700) has links with northwest Argentina, in terms of the similarity of artifacts recovered from sites in the semi-arid North to artifacts from Argentinean sites (Ampuero 1994). Ampuero (1986) hypothesizes that northwest Argentina was the catalyst for all Andean cultures as the people there were the first to develop efficient agricultural techniques and the most sophisticated pottery techniques. New groups of people migrating from northwest Argentina into the semi-arid North therefore brought this knowledge with them, and the admixture of these new migrants with present Archaic peoples resulted in the creation of the El Molle culture (Ampuero 1986). The defining difference between the Archaic IV and El Molle is the presence of horticulture and evidence of llama domestication (Ampuero 1994). The use of the lip plug continued as did intentional cranial modification, and the use of tobacco was introduced (Ampuero 1986, 1994).

The Las Animas culture succeeds the El Molle complex in the semi-arid North, and dates to A.D. 800 – 1000. See Table 1. At the end of the 7th century A.D., new migrants of people from northwest Argentina emigrated to the semi-arid North, settling from the Copiapó to the Limarí River Valleys (Ampuero 1986). This culture continued the tradition of incipient horticulture/agriculture and exploitation of marine resources, but was most heavily oriented towards pastoralism (Rosado 1994; Ampuero 1986). In fact, the characteristic trait of Las

Animas is llama sacrifice – with llama bodies placed so that their forelegs embraced the human decedent in the grave (Ampuero 1986). This practice illustrates the importance of the llama not only in practical everyday life, but probably also to beliefs held about the supernatural. The inclusion of llamas in human graves, be it entire bodies or isolated bones, is a practice that continues through the Diaguita period, and constitutes part of the contributory evidence that the Las Animas culture gave rise to the Diaguita culture. This continuity between the two cultures is further evidenced by genetic distance studies and the archaeological record (Rosado 1994; Quevedo et al. 1982; Strange 1988).

The Diaguita culture succeeds Las Animas, and it was the last indigenous culture to populate the semi-arid North before the arrival of the Spanish in the 16th century. Lothrop (1946) among other early archaeologists hypothesized a direct connection between the Argentinean Diaguita and the people who populated the semi-arid North of Chile just prior to European arrival based on stylistic similarities in ceramics and tools. Since the Spanish chronicles had not recorded the native peoples' name for themselves, archaeologists therefore assigned the name of Diaguita to this culture (Rosado 1994). However, today it is recognized that the Chilean and Argentinean Diaguita are distinct culturally and ethnically (Rosado 1994; Ampuero 1986, 1989).

Archaeologists recognize three distinct phases for the Diaguita, which dates in its entirety to A.D. 1000 – 1536 (Ampuero 1971, 1972, 1986, 1989;

Biskupovic 1985; Rosado 1994). See Tables 1 and 3. According to Ampuero (1986), Cornely initially defined three phases for the semi-arid North: 1: Archaic (which included the Archaic culture); 2: Transitional (El Molle and Las Animas); and 3: Classic (Diaguita). These categories have since been redefined based on new archaeological evidence and interpretation (Ampuero 1986, 1989, 1994). The Diaguita in general continued the agricultural-maritime-pastoralist tradition begun by El Molle and their political organization was a tribal one (Rosado 1994; Ampuero 1994).

Diaguita I, or Transitional Diaguita, dates to A.D. 1000 – 1200 (Table 3). As previously mentioned, subsistence was on three fronts and therefore varied. Mortuary behavior during this phase continued with the use of stone slabs, and graves were typically shallow (Ampuero 1986; Rosado 1994). Heads were covered with pottery sherds in the grave and common burial goods included copper fishhooks, bone artifacts such as needles, tweezers, and earrings, and tools of copper and stone (Ampuero 1986, 1994; Rosado 1994). In contrast to the Archaic period, very few burials are collective ones and the position of the bodies was flexed, with the head towards the east (Rosado 1994). In addition, a few of the burials included sacrificed llamas and/or alpacas (Rosado 1994). Such a mortuary practice along with the presence of artifacts such as grinding stones, bones of marine fauna, and maize is further evidence of their subsistence strategy (Rosado 1994).

The second Diaguita phase is known as Classical Diaguita, and dates to A.D. 1200 - 1450 (Table 3). Two characteristics set this phase apart from phase I: both the burials and the pottery are more complex than what is seen for the previous period (Ampuero 1986, 1994). The graves are rectangular cysts with covering slabs consisting of granite, limestone, or sandstone (Rosado 1994; Ampuero 1986). Ampuero (1994) describes the stone box graves as true “sarcophagi” as they are fully lined in stone with a stone or limestone cover. In these burials, the remains were arranged in a dorsal position, with the head to the east (Rosado 1994). Non-stone box graves are also common during this phase, and these burials are much less complex. They consist of simple earthen graves with the remains flexed and positioned laterally, with fewer grave goods than the stone cyst burials (Rosado 1994; Ampuero 1986, 1994). This difference is probably related to social status.

Similar to the Transitional Diaguita phase, collective burials remain common (especially in the stone cysts), and frequently encountered grave goods include sacrificed camelids for inclusion with the human remains (Rosado 1994). Additional grave goods characteristic of Phase II include elaborately carved bone artifacts, projectile points, grinding stones, and ceramics (Rosado 1994; Ampuero 1994). Metal artifacts continue to be relatively uncommon and mainly consist of items like tweezers and silver or copper earrings (Ampuero 1986, 1994). As

previously mentioned, the complexity of the ceramics distinguishes this phase and anthropomorphic jars as well as large urns are common (Ampuero 1986).

The final indigenous culture to occupy the semi-arid North before the arrival of the Spanish conquistadors was the Diaguita-Inca, A.D. 1450 - 1536 (Table 3). According to Spanish accounts, about A.D. 1470, the Inca king Topa Inca Yupanqui began his conquest of the semi-arid North of what is now Chile (Ampuero 1994). At the time, the Inca Empire had expanded from Peru to include Ecuador and parts of Bolivia and Argentina (Ampuero 1986). The Spanish chronicles state that the Inca army consisted of 10,000 men and violent clashes between the Inca and Diaguita occurred in the semi-arid North, between the Copiapó and Aconcagua valleys, for six years (Ampuero 1994). However, these figures are probably an exaggeration as the archaeological record does not support these numbers in terms of large scale cemeteries or other remains/sites expected from a war-torn region (Ampuero pers. comm. 2007).

Several changes took place under Inca rule, especially in terms of political organization. Under the Diaguita, the society was arranged as a chiefdom, with one chief in charge of the coastal part of the valley and another who controlled the interior part of the valley (Rosado 1994; Ampuero 1986). As the main rivers and tributaries run through the valleys, these waterways enabled the chiefs to control irrigation and therefore, agriculture. In addition, the chiefdom was divided up into smaller areas ruled over by *caciques* (Rosado 1994). When the

Inca conquered the Diaguita, they set up their own chiefs (*kurakas*) to replace the *caciques* and occasionally they allowed loyal Diaguita chiefs to remain in their positions (Rosado 1994; Ampuero 1986, pers. comm. 2007).

As far as cultural changes are concerned, mortuary practice essentially remained the same during the Diaguita III phase, with the continuation of the stone cyst burials. However, more pottery was included in burials during this phase compared to the others (Rosado 1994; Ampuero 1986, 1994). The most obvious cultural influence of the Inca is seen in the ceramic styles, which show clear Inca cultural diffusion during this period (Rosado 1994; Ampuero 1986, 1994). Burial goods also include a large number of bronze and copper artifacts compared to earlier periods, such as chisels and knives (Ampuero 1994). Intentional cranial modification appears to be a practice that continued through the Diaguita-Inca phase. However, in contrast to earlier phases, it seems to be associated strictly with social status here as individuals with modified crania were interred with large assemblages of non-utilitarian ceramics as grave goods (Rosado 1994).

The first Spaniards came to the semi-arid North in A.D. 1536 on exploratory missions, and the conquistadors Pedro de Valdivia and Diego de Almagro officially claimed this region for Spain in A.D. 1537 (Ampuero 1994). The combination of the diseases they brought with them, the capturing of indigenous people as slaves, and generalized decimation of the native

populations effectively ended the population by indigenous peoples in this region. Spanish accounts estimated the population of native peoples to be approximately 30,000 for Northern Chile at their arrival and by the end of the 16th century, there were fewer than 2,000 indigenous people remaining (Ampuero 1986). While the Spanish ethnohistorical accounts are invaluable in terms of their informative content, in the vast majority of cases, they are nevertheless disappointingly brief when it comes to the description of the Diaguita – their language, their customs, even their name for themselves is lost (Ampuero 1994). In this regard, the information contained in the archaeological record is all that remains to reconstruct their culture.

Previous Work: Bioarchaeology of Prehistoric Northern Chileans

There are few studies that concern skeletal biology and/or paleopathology for the semi-arid North of Chile, especially when compared to the literature on bioarchaeology of prehistoric people from the Atacama Desert, known as the arid North (for example, refer to Arriaza 1995; Arriaza et al. 1984a; Arriaza et al. 1984b; Arriaza et al. 1995; Aufderheide et al. 1993; Cocilovo et al. 2004; Fontana et al. 1983; Gühl et al. 1999; Munizaga 1980; Neves et al. 1999; Rothhammer et al. 1982, 1984; Standen 1982; Standen et al. 1984; Standen and Arriaza 2000; Torres-Rouff 2003). This difference is probably related to the nature of the collections themselves, as museums in the extreme north of Chile curate several hundred well-preserved mummies, and there are few mummies curated

in La Serena, where the majority of archaeological remains from the semi-arid North are housed.

The research that has been conducted on Archaic and Diaguita peoples for the semi-arid North mainly focuses on biological profile assessment (Ericksen 1960a, 1960b; Quevedo 1987); and biological distance studies (Cocilovo et al. 1987-1988; Quevedo et al. 1982; Soto et al. 1975). However, there are a handful of studies that focus specifically on odontoskeletal pathology for the Diaguita and Archaic populations of the semi-arid North. Quevedo (1976) examined populations of people from the Archaic and El Molle cultures, from the site of Punta Teatinos, located on the coast north of the Elqui River. She found a significant amount of tooth wear, suggesting an abrasive diet; and that there were low caries rates (1976). In addition, there was no evidence of nutritional deficiency diseases but osteoporosis and osteoarthritis were common (Quevedo 1976). She also found that mortality was highest among women of childbearing age (1976).

Costa-Junqueira et al. (1998) conducted a large scale bioarchaeological examination of five prehistoric Archaic coastal populations in the semi-arid North. All the populations surveyed exhibited high rates of periostitis and osteomyelitis, ranging from 42% at the site of Morro de Uhle to 68% at Punta Teatinos (Costa-Junqueira et al. 1998). It is unclear as to the reason for this, but one possibility is from repeated episodes of bacteria being introduced via minor

trauma, such as cuts and scrapes on the limbs from wading in rocky and slippery tidal pools gathering shellfish (Rosado and Vernacchio-Wilson 2006). In addition, while there were low caries rates (3% and less), there were high rates of dental abrasion, probably from the abundance of shellfish in the diet (1998).

Rosado (1994, 1998) was the first to examine the effects of full-scale agriculture and sedentism on health between the Diaguita and the preceding Archaic peoples. Archaeological and ethnohistorical evidence indicates a marine subsistence strategy for the Archaic peoples and agricultural-pastoralist-maritime subsistence strategy for the Diaguita. For example, grave inclusions consist of fish, sea lion, and camelid bones in addition to artifacts like pots and grinding stones (Rosado 1994). Maria Rosado (1994) performed trace element analysis on the barium and strontium content of the human remains and confirmed the archaeological evidence suggesting a primarily marine diet for Archaic populations and an agricultural-pastoralist-maritime subsistence strategy for Diaguita populations. Essentially, her results indicated that the Archaic population had a significantly higher amount of marine resources in their diet than did the Diaguita. In addition, while the Diaguita maintained a partial marine subsistence strategy, they had a more varied diet than did the Archaic, subsisting upon a combination of terrestrial (camelids, domesticated and wild plants) and marine resources.

While there was an increase in caries rates and periodontal disease for the agricultural Diaguita, the Archaic populations had higher frequencies of calculus deposition and abscesses (Rosado 1994, 1998). This finding was unexpected and indicates that factors other than diet (such as use-wear) contribute to dental pathology (Rosado 1994, 1998). In addition, even though the Diaguita exhibited higher caries rates, these rates were lower than what would be expected for an agricultural population (Rosado 1994, 1998). In this case, the high levels of fluorides in the sea water probably aided in reducing the rate of caries for both populations (Rosado 1994, 1998).

The fact that a general decrease in health (as defined by dental disease and skeletal pathology) was not observed between the gatherer-hunter Archaic people and the agricultural Diaguita was unexpected and contrary to what several other studies had shown, especially for North America (for example, see Cohen and Armelagos 1984). Focusing on a single crop for the majority of the diet is often cited as a major reason agriculturalists display poorer health (Cohen and Armelagos 1984; Larsen 1982, 1990; Hutchinson and Larsen 1990; Schoeninger et al. 1990; Eisenberg 1991; Bridges 1991b; among others), and while doing so may be efficient in terms of calories consumed per day, typically staple crops are deficient in several important nutrients (Buikstra 1992; Cohen 1989; Larsen 1995; Stuart-Macadam 1989).

While the Diaguita had adopted maize-beans-squash agriculture, they did not abandon the marine and pastoralist aspects of subsistence that their ancestors had utilized. Essentially, their subsistence was not agriculture-dependent, as was the strategy of many other prehistoric populations. Maintaining this subsistence triad gave them a diverse diet, rich in protein and all the necessary nutrients (Quevedo et al. 1982). Even though most fish and shellfish are low in calories when compared to terrestrial animals, these marine animals provide a rich source of protein, calcium, and minerals (Yesner 1980a). In fact, when the caloric investment of energy per gram of protein yield is analyzed, a fish diet provides more protein than a diet based on intensive agriculture (Yesner 1980a).

Most of the previous work conducted on the skeletal populations from Northern Chile is limited to the area bounded by the Atacama Desert, and therefore scant information is available for the semi-arid North, which contains a unique ecology and distinct cultural occupation. Furthermore, most of the paleopathological and bioarchaeological research completed on prehistoric semi-arid North populations is not available to a wide North American audience in part due to non-published reports and dissertations, most of which are in Spanish. The research presented here attempts to fill in some of these gaps of knowledge by making this information available to a broader audience. The comparative nature of this project is valuable because it assesses change not only

through time for specific cultures, but for geographically distant populations, through which broad patterns of human adaptation can emerge.

Chapter 4

Tennessee Prehistory

Environmental Setting of Tennessee

The state of Tennessee is located at longitude 81°37' W to 90°28' W and latitude 35° N to 36°41' N. Its main geography consists of mountains along its eastern border (Blue Ridge; part of the Appalachian Chain), ridges, valleys, and plateaus in the eastern part of the state, the western highland rim and the Nashville Basin in the state's center, and coastal plain bounded by the Mississippi River in the western region. See Figure 2. Although landlocked, a large portion of the state is covered by water, and the Tennessee River is one of the largest rivers that along with its tributaries, supplies the region. The contemporary climate is temperate with four distinct seasons (Chapman 1994). For the eastern part of the state, the average winter temperature is 39.3 degrees Fahrenheit, with the average summer temperature 78.9 degrees Fahrenheit (Chapman 1994). There is additionally an average of 58.9 inches of precipitation per year in the eastern part of the state (Chapman 1994).

In the geological past, what is now Tennessee went through phases of swamplands, exposed lowlands, and even was inundated by shallow seas at times (Chapman 1994). The sediments that were gradually deposited during this period became the limestone, shale, and sandstone evident in the geology of East Tennessee today (Chapman 1994), which was important for prehistoric material

culture, such as in raw material utilization for tool manufacture. The floodplains of the various rivers which would be critical for human exploitation formed during the warming periods of the Pleistocene era (c. 1.8 million – 10 thousand years ago) (Chapman 1994). It was during the latter Pleistocene that humans first settled the Eastern Woodlands, of which Tennessee is a part (Anderson 2001; Chapman 1994).

The widespread extinctions that denoted the end of the Pleistocene era took place in both North and South America, with the disappearance of 30 genera of megafauna which included the mammoth, saber-tooth tiger, camel, and giant sloth by approximately 12,900 years ago in North America (Anderson 2001: 153). By the end of the Pleistocene, animals that are found in the region today were present, such as raccoon, rabbit, white-tail deer, turkey, and bear (Anderson 2001; Chapman 1994). These animals populated the deciduous forests containing mixed hardwood trees during the Early Holocene and later, during the Middle to Late Holocene, added to with oak, chestnut, and southern pine trees⁴ (Chapman 1994; B. Smith 1986). In fact, early explorers' accounts of the region effuse with the abundance of animals like fish, otters, beavers, reptiles, birds, buffalo, wolves, and foxes; along with vegetation like birch and pine trees; and several varieties of berries and edible roots (Williams 1927 cited in Chapman 1994).

⁴A blight at the beginning of the 20th century decimated most of the chestnut tree population in this region (Chapman 1994).

Analysis of paleoclimatic data for North America and the Southeast specifically reveals that there has been a variety of temperature and climatic fluctuations over the past 10,000 years or so, several of these dramatic and occurring on a scale noticeable by human individuals, with changes on the order of years or decades (Anderson 2001). Several attempts have been made to correlate these climatic changes with human culture change, and it appears to some extent there is at least a loose relationship (see Anderson 2001 for a review). However, if a connection exists between demonstrable climate and culture change, this does not necessarily indicate that one led to the other (Anderson 2001). In spite of this, it is clear that climate and environment is one of many variables that human agents must contend with in order to be successful. Specific climate fluctuations as they relate to the different prehistoric culture periods in the Southeast and Tennessee will be discussed in the succeeding section.

Culture Process of Prehistoric Tennessee

The exact timing of when humans populated the Eastern Woodlands remains uncertain; however, currently available evidence suggests that people could have migrated to this area several thousand years before 13,450 years ago – the first date for which irrefutable evidence exists (Anderson 2001: 154). While there is no evidence of such early occupation at any sites in Tennessee, there are early sites that are proximal in Virginia, Florida, and South Carolina (Anderson 2001). These early sites are referred to as “pre-Clovis”, as the recovered artifacts

don't appear to share recognizable attributes, unlike the ensuing Clovis culture (Anderson 2001).

The first clear evidence for “widespread human occupation” in North and South America consists of a characteristic material culture, namely, Clovis points, and dates to 13,450 BP (Anderson 2001: 154). Clovis technology radiated over a large region of Eastern North America, and people tended to settle in areas proximal to major rivers, probably due to the abundant resources located in these environmental niches (Anderson 2001). Human groups were mobile, and as a result, a variety of animals and plants were likely targeted as food sources (Anderson 2001).

Marked changes in cultural organization took place with the onset of dramatically colder conditions, during the period known as the Younger Dryas (Anderson 2001). These changes are one of the first examples of human social organization restructuring possibly as a result of climatic changes and pressures in North America. During this period that lasted approximately 1300 years, megafauna went extinct and subregional cultural traditions emerged (Anderson 2001: 156).

Remarkably, this prolonged period of colder conditions ended rather abruptly, within one to four decades, and its end signifies the beginning of the Archaic era: 11,450 – 3200 BP (Anderson 2001: 156). (See Table 4 for the Tennessee culture chronology). Archaic era people are typically characterized as

food collectors, with populations organized as band-level societies, with the seasonal exploitation of available resources (Anderson 2001; Griffin 1967). During the Early Archaic, people were undergoing cultural change in response to the changed post-glacial environment, including adapting their subsistence strategy to include smaller game animals (Anderson 2001; Griffin 1967). In general, Archaic cultures can be defined as having “broad spectrum foraging adaptations” (Bogucki 1999: 138). While regional variation is seen, there is the appearance of semi-permanent settlements located along river/marsh edges or hilltops, which were occupied at least during the summer season (Bogucki 1999; B. Smith 1986). The sites of Eva in West Tennessee and Koster in Illinois serve as examples (Bogucki 1999).

At the Icehouse Bottom site in Monroe County, East Tennessee, several households were located on the bank of the Tennessee River, each with a clay hearth (Chapman 1988). Substantial shelters (e.g., shelters with post holes) were not evident, but it is clear from the archaeological evidence that life was centered around the hearth (Chapman 1988). It is likely that temporary shelters (such as lean-tos) were constructed, using animal hides and bark for roofing (Chapman 1988). Food processing tools such as flat river stones are found in association with some hearths, and remains of animals such as white-tailed deer, black bear, turtles, and others were present (Chapman 1988). The collection of plants was

important, and nuts such as hickory and acorns were of primary importance to all Archaic groups (Chapman 1988).

During the Middle Archaic, there was considerable culture change, evidenced by the institution of shell and earthen mounds along streams, long distance trade networks, new tools, such as those of ground and polished stone, and increased evidence for interpersonal violence (Anderson 2001; Griffin 1967). Population growth continued from the Middle Archaic into the Late Archaic, as well as other trends, such as intensive shellfish collection, mound construction and interregional trade (Anderson 2001; Griffin 1967). It was during the Late Archaic (5700 – 3200 BP) that modern vegetation and climate were established (Anderson 2001; Schroedl et al. 1990). In addition, the subsistence complex consisting of the intensive cultivation of plants known as the Eastern Agricultural Complex (EAC) was initiated during this time (Anderson 2001; Schroedl et al. 1990; Smith 1992).

The Eastern Agricultural Complex consisted of sunflower, sumpweed, goosefoot, maygrass, knotweed, little barley, and various species of gourds (Smith 1992). This initial cultivation began at sites in the Midsouth and Midwest, and these weedy annuals were attractive partially due to their ease of cultivation and storage potential (Smith 1992). It appears that the starchy seed plants (maygrass, knotweed, little barley, goosefoot) were of more importance economically than were the cultivated oily seed plants (marshelder, sunflower);

however, cultivation in general set the stage for cultural innovations that would be necessary with the adoption of maize in later times (B. Smith 1986). These plants were a valuable addition to the diet, with their high carbohydrate and fat content (Anderson 2001). Seasonally-available nuts, such as acorns and hickory, likely comprised part of the diet as well (Anderson 2001), however, these became less important with the advent of maize in later periods (Chapman and Shea 1981).

Griffin (1967: 178) recounts early explorers' accounts of the variety of foods native peoples utilized upon contact – as many as 130 different species of plants for food were eaten. It is likely that this variety was characteristic of earlier cultures as well, including the Archaic. Dye (1977) discusses the primary importance of wild plant foods to the Archaic diet, with resources such as maritime and terrestrial animals being secondary. Wild plants such as different species of berries, roots, tubers, nuts and seeds are all represented in the archaeobotanical record at a variety of Archaic sites (Dye 1977).

As the Archaic drew to a close, interregional interaction in the form of warfare, collective ceremonial behavior, and trade increased and reached its peak (Anderson 2001; Smith 1993b, 1995, 1996, 1997). The cutoff point for the end of the Archaic era and the initiation of the Woodland era (3200 – 1000 BP) is the collapse of this interregional interaction, with the cessation of trade networks and the abandonment of burial mound construction (Anderson 2001: 163). The

culture chronology for the Woodland era as originally defined for eastern Tennessee by Lewis and Kneberg in the 1940's (Lewis et al. 1995) was primarily based on ceramic assemblage typology. However, questions since then have arisen regarding continuity of aspects of the Woodland era into the Mississippian era, and as a result, numerous researchers have determined that a Woodland culture sequence should be based on more than ceramic typology (for a review, see Schroedl et al. 1990).

The primary marker of the initiation of the Woodland era is the extensive use of pottery, beginning about 1000 B.C. (Anderson and Mainfort 2002). In addition, the Woodland period is characterized by increased sedentism, increased population, organizational complexity, and cultivated plants (Anderson and Mainfort 2002; Wetmore 2002). These above traits typified the Early Woodland period (1000 B.C. – 200 B.C.) in the Southeast, until increased burial mound construction in some areas around 200 B.C. indicated the commencement of the Middle Woodland period (Anderson and Mainfort 2002).

With the advent of the Middle Woodland period (200 B.C. – A.D. 400) interregional interaction as evidenced by a regionally shared religious iconography and cosmology had emerged (Anderson 2001; Anderson and Mainfort 2002). In addition, the construction of elaborate earthworks, including burial mounds, had commenced in many parts of the Southeast by 200 B.C. (Anderson and Mainfort 2002). This regionally shared cultural complex is known

as Hopewell, after the type site in Ohio (Anderson 2001; Griffin 1967). The Pinson Mounds site, spread out over 600 acres, is located in Madison and Chester counties in Tennessee and is an example of a Middle Woodland ceremonial center (Mainfort 1988).

Gathering and hunting as a subsistence strategy continued during the Middle Woodland period, and maize and squash cultivation was initiated (Griffin 1967). In fact, the earliest evidence for maize cultivation in the Southeast comes from south-central Tennessee, where it dates to A.D. 465 – 500, which falls just on the cusp of the end of the Middle Woodland period (Crites 1978), although maize was not an important crop until about A.D. 800 (B. Smith 1986). Evidence for the increasing importance of cultigens (such as the EAC species) comes from pollen and wood charcoal analysis, which suggests that people were extensively clearing the forests to make room for fields (Anderson 2001; Chapman and Shea 1981; Chapman 1994).

The Late Woodland era, A.D. 400 – 1000 (Anderson and Mainfort 2002), in East Tennessee is a time period that has received much attention from archaeologists primarily due to the Hamilton burial mounds and their hypothesized relationship to the succeeding Mississippian period (Cole 1975; Crane and Griffin 1961; Faulkner 1975; Lewis et al. 1995; Schroedl 1973; Schroedl et al. 1990). The characteristic traits of the Hamilton mound focus as defined by Lewis and Kneberg consists of cordmarked and limestone tempered plain

ceramics, and was defined based on numerous mounds located in the Chickamauga and Watts Bar Basins (Lewis and Kneberg 1946; Lewis et al. 1995; Schroedl et al. 1990). The presence of large shell middens is diagnostic as well, and Lewis and Kneberg hypothesized that these sites represented possible year-round occupation based on these middens and additionally on the presence of reptile bones and nuts (Schroedl et al. 1990). However, this hypothesis has yet to be accepted (Schroedl et al. 1990). Regardless of site occupation, it is clear that the people responsible for these sites maintained a varied diet, as in addition to the various species of mussels, fish, reptiles, and EAC plants they exploited (Schroedl et al. 1990), improved strains of maize had appeared in the region by about A.D. 1000 as well (Faulkner 1975).

Radiocarbon dates obtained for Hamilton mounds at the sites of Alford (Crane and Griffin 1961) and McDonald (Schroedl 1973) indicate that contrary to Lewis and Kneberg's original interpretation in the 1940's, these mounds were in use well into the Mississippian period (Cole 1975; Schroedl et al. 1990; Faulkner 1975; Wetmore 2002). The dates for the mounds range from A.D. 697 – 1335 (Schroedl et al. 1990), which encompasses the end of the Woodland period (1000 B.C. – A.D. 1000), the Martin Farm phase (early Mississippian: A.D. 900 – 1100), and Hiwassee Island phase (Mississippian: A.D. 1100 – 1300). However, in part due to preservation, it is not possible to clearly separate out the early versus late burials – so for some burials, it remains unclear as to whether they belong to the

Woodland period or the later Mississippian one (Cole 1975). For example, it has been shown that Mississippian burials from the Dallas phase are intrusive into the top levels of the Hamilton mounds (Cole 1975), and the mounds were utilized by people from the Mississippian Hiwassee Island phase (A.D. 1100 – 1300) as well (Schroedl et al. 1990).

History repeated itself in the Late Woodland period, as similar to the Late Archaic period, archaeological evidence suggests that interregional interaction in the form of trade decreased, while warfare increased (Anderson 2001). The Late Woodland was typified by copious culture change, including the development of the bow and arrow, which certainly influenced not only subsistence but warfare as well (Anderson and Mainfort 2002). There was additionally a change in iconography with an increase in solar disk depictions in some areas suggesting the increasing importance of maize (Anderson and Mainfort 2002). Furthermore, population growth is indicated in part by the presence of intensive maize agriculture in some areas (Anderson 2001); although maize was a crop of minor importance in most areas (Nassaney 2000). In fact, Nassaney (2000) hypothesizes that the differential importance of cultivated crops, including maize, during the Woodland era led to the variation seen during the Mississippian period in terms of the relative importance of specific crops. The agricultural/horticultural intensification observed towards the end of the Woodland era was a sign of things to come in the ensuing Mississippian era.

The Mississippian period in eastern Tennessee dates to A.D. 900 – 1600 (Schroedl et al. 1990) and was characterized by maize and squash agriculture, and later in the period, beans; nucleated settlements in many areas with platform mounds and plazas; shared iconography, and shell-tempered pottery (Bogan 1983; Griffin 1967; King and Meyers 2002; Koerner 2005; B. Smith 1986; Sullivan 1986; VanDerwarker 1999). Mississippian societies were located across the interior Southeast, into the Midwest, the southern mid-Atlantic region and parts of the eastern Great Plains (King and Meyers 2002). Populations chose to mainly settle in river valleys due to the fertile soil and the large concentration of other resources, such as timber and wild animals (Smith 1978; Sullivan 1986).

For decades, the political and power organization of Mississippian societies was considered to be that of a chiefdom arranged into a hierarchy, determined based on the comparison with Polynesian society organization per the cultural evolutionary schemes of Fried (1967) and Service (1962). However, contemporary thought is now debating this simplistic view of Mississippian political organization across the Southeast (Cobb 2003; Knight and Steponaitis 2007; Pauketat 2007; Sullivan 2001, 2006; among others). The inter-regional variation among Mississippian societies and their organizational schemes also is becoming apparent. The model that included male-dominated, hereditary hierarchies is now being replaced by models that are based on ethnohistorical accounts of known native Southeastern cultures. These models emphasize

heterarchies rather than hierarchies (Cobb 2003; Crumley 1995). In essence, the power structure of Mississippian society is increasingly understood as one that included horizontal, rather than vertical links between social segments.

Furthermore, this viewpoint emphasizes the importance of individual agents, including the actions of commoners and other social groups, in the maintenance of the political economy (Cobb 2003).

Although some statuses in Mississippian society may have been ascribed at birth, most statuses likely were based on certain life accomplishments (Scott and Polhemus 1987; Sullivan 2001; VanDerwarker 1999). Some mortuary analyses that contrast mound burials with village burials suggest differences in social status, as evidenced by markers such as stature and stress indicators (Betsinger 2002; Hatch and Willey 1974; Hatch et al. 1983), but others that analyze similar markers do not show differences in mound and village burials (Vogel 2007). Our conception of social status and rank as experienced by Mississippian individuals likely needs reevaluation, as new ideas and interpretations of these societies are formulated. For example, Sullivan and Rodning (Sullivan 2001, 2006; Sullivan and Rodning 2001) have hypothesized that rank in Southern Appalachian Mississippian societies was attained in different ways depending upon gender, with men achieving prestige and power through skill in warfare, inter-community politics, and possibly trade; while

women's power and esteem increased with age as heads of households, families, and kin groups, and as controllers of agricultural production.

Vogel (2007) recently demonstrated that for the Late Dallas phase Cox Mound and Village site, located in Anderson County, East Tennessee, no significant differences skeletally existed between individuals buried in the mound versus the village. Harle (2003) also found few indicators of social inequality based on age and sex in the stress indicators of the Late Dallas phase mound population at the Fains Island site on the French Broad River in Jefferson County, Tennessee. These studies clearly demonstrate that further research into Mississippian status relationships is warranted.

Maize increased in importance between A.D. 800 – 1000 in the Southeast, and by A.D. 1000, improved strains of maize had been cultivated (Faulkner 1975; B. Smith 1986). In addition to paleobotanical evidence for the presence of maize, evidence of maize's relative importance to subsistence is seen in the extent of technological innovations specifically geared towards intensive agriculture. For example, hoes along with ceramic storage and processing vessels are present at many Mississippian sites, in addition to community food storage pits (B. Smith 1986).

While maize constituted the majority of the Mississippian diet, there were two additional crops that made up the "horticultural trinity" along with maize: beans (*Phaseolus* sp.) and squash (*Cucurbita pepo*) (Smith 1978: 483). Regional

variation in the crops present existed, as beans for example did not appear in the lower Little Tennessee River Valley until the Late Mississippian Dallas phase (Chapman and Shea 1981). Beans in general, while present by A.D. 1100, were differentially utilized by Mississippian groups, not even appearing in some areas until A.D. 1450 (B. Smith 1986: 61). Pumpkin, gourd, marshelder, and sunflower were farmed as well, but were of less importance (Smith 1978; Griffin 1967). The climate especially in the Southeast is ideal for growing a crop like maize (Griffin 1967), as spring starts early and the ground rarely freezes. In addition, climatic conditions regionally at the beginning of the Mississippian era were conducive towards agriculture in general (Anderson 2001).

Despite the fact that agriculture was the primary subsistence strategy, data from sites in the Southeast reveals that wild foods continued to constitute part of the diet. Bruce Smith (1978: 483) outlines the groups of wild foods that were of importance to the Mississippian diet: various fish species, migratory waterfowl, white-tail deer; raccoon; and turkey, nuts; fruits; and berries; and seed-bearing plants like *Iva annua* (sumpweed) and *Chenopodium berlandieri* (goosefoot). River mussels were exploited during Early Mississippian times as well (Schroedl et al. 1990). Analysis of paleobotanical and zooarchaeological remains from the Late Mississippian Dallas site and Middle Mississippian (Late Hiwassee Island phase) Hixon site, located in Hamilton County, East Tennessee,

showed that in addition to the corn/beans/squash triad and wild animals, nuts like hickory, walnuts, and butternuts were all present (Hatch and Geidel 1983).

The consumption of fish and birds probably accounted for about half of the protein intake (Smith 1978). While it is possible that the elites probably enjoyed preferential access to birds and prime cuts of animal meat (Hatch and Geidel 1983; Bogan 1983), current interpretations regarding the distributions of zooarchaeological ecofacts indicates that the proximity of prime cuts of meat (as evidenced by the animal bone remains) to the mounds was probably more related to community-wide feasting activity than to an overall representation of elite diet (Blitz 1993; Cobb 2003; VanDerwarker 1999). The previous discussion regarding Mississippian period political structure is relevant here, as feasting probably was a mechanism whereby the redistribution of food and material objects created reciprocal obligatory relationships between individuals (Cobb 2003).

The Mississippian cultural sequence for eastern Tennessee was defined by Lewis and Kneberg on the basis of their excavations in the Chickamauga Reservoir from 1936 – 1938 (Lewis et al. 1995). As radiocarbon dating was not invented until the late 1940's, archaeologists during the WPA excavations were limited to designating phases on the basis of stratigraphic associations, artifact typologies, and associating similarities in prehistoric and historic material

culture (the Direct Historical Approach) to assume shared cultural origins⁵.

Kneberg and Lewis identified three Mississippian phases: Hiwassee Island; Dallas; and Mouse Creek (Lewis and Kneberg 1946; Lewis et al. 1995).

Contemporary methods (e.g., radiocarbon dating and dendrochronology) have established the sequence for the Chickamauga Basin to be the following:

Hiwassee Island (A.D. 1100 – 1300); Dallas (A.D. 1300 – 1400); and Mouse Creek (late Dallas: A.D. 1400 – 1600) (Koerner et al. 2007; Sullivan 2007a, 2007b).

For Lewis and Kneberg, each phase was exemplified by a specific type of architecture, material culture, and mortuary pattern. The Hiwassee Island phase, (based on the Hiwassee Island type site located in present-day Meigs County), was typified by rectangular wall trench structures, flat-top habitation mounds, and shell-tempered pottery (Lewis et al. 1995). However, the Hiwassee Island type site had an absence of Hiwassee Island phase burials within the platform mounds and villages (Lewis et al. 1995). The Dallas phase was characterized by shell-tempered pottery and flat-top habitation mounds, but in contrast to the Hiwassee Island phase, had square and rectangular log-post structures and an abundance of flexed burials within the mound and village (Lewis et al. 1995). These two phases also fit in with the Southeastern Ceremonial Complex (c. A.D. 1000 – 1300), which consisted of a shared religious cosmology and trade between

⁵ The Direct Historical Approach today is seen as inaccurate due to the complexities of cultural diffusion and independent invention (Sullivan 1995).

people from the Great Lakes to the Gulf Coast and from the eastern Plains to the Atlantic Coast (King 2007; Sullivan 1986).

Lewis and Kneberg's final Mississippian phase, Mouse Creek, was based on three sites along the Hiwassee River: Mouse Creeks, Ledford Island, and Rymer, in present-day Bradley and McMinn Counties. The material culture differed from that of the Dallas phase, there were no mounds evident, houses were rectangular and semi-subterranean, and individuals were buried in an extended position (Lewis et al. 1995). By this time (c. A.D. 1400), the objects associated with the Southeastern Ceremonial Complex began to decrease in abundance, and mound building ceased in this area (Sullivan 1986). Elsewhere in eastern Tennessee mound building continued. Southeast Tennessee may have been affected by population influx from middle Tennessee as a result of drought in that area (Meeks 2006).

Excavations in later decades after those done by Lewis and Kneberg uncovered justification for the revision of the culture sequence as originally defined. For example, excavations at Martin Farm in Monroe County and part of the Tellico Reservoir project provided evidence for an emergent Mississippian component (Schroedl et al. 1985). Based on the new information, Kimball and Baden (1985) reorganized the Mississippian culture sequence for East Tennessee into the following chronological order: Martin Farm (A.D. 900 – 1000); Hiwassee Island (A.D. 1000 – 1300); Dallas/Mouse Creek (A.D. 1300 – 1600); and Overhill

Cherokee (A.D. 1600 – 1838). In addition, some issues with the interpretation of the chronology remained, especially for the Martin Farm and early Hiwassee Island phases as it is likely that the individuals associated with these phases continued the practice of burial mound use begun in the latter part of the Woodland period (Faulkner 1975; Schroedl et al. 1990). Sullivan (2007b) states that contemporary agreement regarding the chronology for East Tennessee revolves around the following: Martin Farm (A.D. 900 – 1100); Hiwassee Island (A.D. 1100 – 1300); and Dallas/Mouse Creek (A.D. 1300 – 1600) with Mouse Creek being distinct from Dallas due to differences in burial patterns (extended versus flexed burials) and stylistic pottery differences (fewer cordmarked pots, among other differences). In addition, we now know that in the Chickamauga Basin, the Mouse Creek phase (A.D. 1400 – 1600) is later than the Dallas phase (A.D. 1300 – 1400) (Sullivan 2007b).

Following the Mississippian culture, great changes were in store with the rise of the Cherokee culture (A.D. 1600 – 1838) and particularly with the arrival of Europeans in the 16th century. The Spaniard Juan Pardo arrived at the Mississippian town of Joara, in what is now North Carolina, in the upper Catawba River Valley in early 1567 (Beck et al. 2006). He and his garrison built Fort San Juan in this vicinity, the earliest fort this far interior into the United States (Beck et al. 2006). While the fort only lasted a year and a half before falling due to warfare with the natives (Beck et al. 2006), the presence of Pardo and his

men along with the Hernando de Soto exploratory expedition between A.D. 1539 – 1542 (Hudson 1976) was effectively the beginning of the end for native peoples in this region – indeed, this mission and others like it foreshadowed things to come, such as disease, death, and depopulation.

Previous Work: Bioarchaeology of Prehistoric Tennesseans

There have been a number of studies investigating prehistoric health and lifeways from a biological standpoint for the Southeastern United States. For example, there is a large body of work from places like Alabama (Bridges 1989a, 1991a, 1991b, 1994, 1996; Bridges et al. 2000; Powell 1991; Schoeninger et al. 2000), Florida (Hutchinson 1993, Miller-Shaivitz and İşcan 1991; Wentz 2006), Georgia (Larsen 1982a, 1982b, 1984, 1990a, 1990b, 1994; Larsen and Sering 2000; Larsen and Ruff 1991; Ruff et al. 1984; Williamson 2000), North Carolina (Hutchinson 2002; Driscoll and Weaver 2000), and Virginia (Gold 2000; Lambert 2000b) that has helped to clarify questions about the subsistence change impact on dental and skeletal health, the biological relatedness of populations, and the gender division of labor, among others. For prehistoric Tennessee, the majority of the work that has been done in these areas has focused on questions of health relating to subsistence strategy for the Mississippian people.

In general, the studies that have been done for prehistoric Tennessee that focus on Mississippian health reveal that most people were contending with serious health issues, such as nutritional deficiencies (evidenced by rates of cribra

orbitalia and porotic hyperostosis) (Boyd 1984; Parham 1982; Pippitt 2002), general malnourishment/illness in childhood (as evidenced by transverse growth arrest lines in the tibia) (Hatch et al. 1983), enamel hypoplastic defects (Harle 2003), and dental disease (Smith 1982, 1987), not to mention the hazard that trauma (either intentional or accidental) brought to overall health (Smith 2003; Kuemin Drews 2000; Smorynsky 2002).

Many of these studies, particularly those conducted between the mid 1970's and late 1980's, focused on testing two hypotheses. These were: 1) there are significant health differences between food collectors and maize dependent agriculturalists and 2) better health is predicted by high status (Smith 1993a). For example, Hatch and colleagues (1983: 60) found that individuals from the Dallas phase (A.D. 1300 – 1400) Dallas site and Late Hiwassee Island phase (A.D. 1150 – 1300) Hixon site from what is now the Chickamauga Reservoir in East Tennessee suffered high childhood mortality and that only 7% of individuals lived past age 40. They interpreted these numbers within the socio-political structure of Dallas society (i.e., two-tiered simple chiefdom level), and suggested that an individual's social standing contributed to their chances of being metabolically stressed (Hatch et al. 1983). More recently, Smith and Betsinger (2007a, 2007b) found a significant difference in dental pathology between low status and high status maize agriculturalists from the site of Citico in eastern Tennessee, with the

low status individuals having a higher disease expression than those of high status.

While the above argument is a common one in bioarchaeology in general, we now know that there are regional and even intra-regional patterns in community health status. As an example from within the Tennessee Valley, Boyd (1984) found that when the maize agriculturalists from the Dallas phase site of Toqua (Tellico Reservoir) was compared to the contemporaneous maize agriculturalists from the Mouse Creek phase sites (confined to the Hiwassee River Valley, Chickamauga Reservoir), there was no significant demographic stress evident for the latter group. In fact, individuals from the Mouse Creek phase sites enjoyed low mortality, a low probability of death, and a relatively high life expectancy, especially when compared to the more stressed Toqua population (Boyd 1984). Today we recognize that Dallas and Mouse Creek represent two socio-politically distinct cultures and this difference probably played a role in the health disparity between them.

In part due to the sheer number of skeletal remains available from the TVA/WPA projects and the good preservation in general of the Mississippian individuals, a number of studies have been conducted on osteological samples from several sites with a Dallas component, especially those from the Toqua site, located in Monroe County in East Tennessee. In the most recent study, Betsinger and Smith (2006, 2007) found that there was no difference by sex in terms of

dental pathology prevalence and therefore, males and females had access to an essentially identical diet. Parham (1982) found high rates of infant and child mortality for individuals from Toqua, as well as high rates of cribra orbitalia and porotic hyperostosis, especially in children. In addition, he discovered that individuals could not be separated on the basis of status by examining biological data from the skeleton alone (Parham 1982).

Similarly, in her comparative study of a collective Mouse Creek phase skeletal sample with that from Toqua, Boyd (1984) found that incidence of porotic hyperostosis and cribra orbitalia was higher for those from Toqua than for those individuals from the Mouse Creek phase sites, likely in part because the Toqua site was occupied for a longer period of time (Polhemus 1987), which implies compromised community sanitation and therefore, compromised hygiene. Betsinger (2002) revealed a similar result in her comparative study of three Late Mississippian Dallas phase sites from the same geographic area (Tellico Reservoir): individuals from Toqua had more skeletal markers of stress when compared to individuals from Citico and Tomotley, which had much shorter occupation sequences.

Betsinger (2002) also found that when the burials from the villages and the mounds were compared from these three sites, individuals from the mounds (i.e., high status) overall were less stressed than those buried in the villages (i.e., low status). In addition, biological markers of stress were not sex-biased, with

males and females being equally stressed. She used this biological information to corroborate information about the social structure of Mississippian chiefdoms: individuals of high status are typically buried in the mounds, versus the village (Betsinger 2002; but see Sullivan 2001 per mortuary patterning). However, in her comparative analysis of the Cox mound and village sites in Anderson County, Tennessee, Vogel (2007) found that there was no significant difference in terms of health (as observed by stress markers such as enamel hypoplasia, dental disease, and infectious disease, among others) between individuals buried in the mound and those buried in the village. These contrasting results indicate three things: 1: status differences may not always be tied to burial location; 2: social position may not always be differentiated by health status; and 3: cultural differences may exist within an archaeologically-defined phase.

Another Late Mississippian site that has received particular attention is the site of Averbuch, located in the Nashville Basin, Middle Tennessee. Berryman (1981) found evidence of chronic stress for individuals from Averbuch, including high infant mortality, enamel hypoplasia, transverse growth arrest lines, and shortened stature. He additionally found that the age group at highest risk of skeletal stress was adults who were 20-25 years old at death, females more so than males, probably due to the energy cost and hazards of pregnancy, childbirth, and lactation (Berryman 1981). Eisenberg (1986) found copious evidence for anemia, including high frequencies of porotic hyperostosis and

cribra orbitalia among children and young adults. Periostitis and osteomyelitis infections of the long bones (both healed and active) were also prevalent (Eisenberg 1986).

Furthermore, Eisenberg (1991) found for those individuals who survived childhood, there was a high probability of dying in the early 20's. In fact, life expectancy at birth for Averbuch individuals was among the lowest recorded for both prehistoric and historic sites: 17.4 years for males and 14.6 years for females (Eisenberg 1991: 85). Eisenberg (1991) interpreted these numbers in light of severe and chronic disease stress and social stratification which may have limited access to available natural resources. Hamilton (1999) came to similar conclusions in her study of oral pathology for the Averbuch population. She found that 77% of the individuals had carious lesions, which is 60% higher than the average for other Mississippian groups (Hamilton 1999: 40). Furthermore, 87% of individuals exhibited one or more enamel hypoplasias, evidence of a substantial amount of stress endured during childhood (Hamilton 1999: 41).

In addition, a handful of studies have focused on one or two specific aspects of life and death for prehistoric Tennesseans. Maria Smith (2003: 303) found that for the populations inhabiting the Chickamauga Reservoir area (East Tennessee), deliberate trauma was higher in individuals from the Mouse Creek Mississippian phase (8%) as compared to individuals from the contemporaneous Dallas phase (3.8%). Much of this trauma was non-lethal ectocranial which she

interpreted as interpersonal, rather than intergroup, violence (Smith 2003). She argued that the elevated gender-specific ectocranial trauma in the Mouse Creek sample was behavior associated with a mechanism of personal conflict resolution in the absence of centralized authority (i.e., chiefdom level) (Smith 2003; and see Schroedl 1986; Sullivan 1986). Lahren and Berryman (1984) found that for the West Tennessee Mississippian population at the Chucalissa site, high status males had more fractures than did either high status females or low status males or females. They argued that this difference reflects the cultural expectations of males above and beyond what was expected of other members of the group: warfare and/or hunting.

As far as research on health for other components is concerned, work on the Archaic period has mostly been limited to trauma studies (Smith 1993b, 1995, 1996, 1997), mortuary patterning (Magennis 1977; Higgins 1982), and the role of comparative studies using Archaic samples early on in the bioarchaeological paradigm (the biocultural approach) as a general basis of comparison for Mississippian agriculturalists (Smith 1993a). For instance, in a survey of a large Late Archaic osteological sample from west-central Tennessee, Smith (1993b, 1995, 1997) found that deliberate trauma was not only evident (e.g., inflicted projectile points), but it varied by geographic location (upland remote versus main channel sites) and included the status-enhancing practice of trophy-taking. This trophy-taking behavior included scalping and forearm removal. A window

into the ideology of Late Archaic people is evident by a case of the inclusion of burned animal bones to replace a removed forearm at the Robinson site and two cases of grave inclusions of a modified human femoral shaft from the Ledbetter Landing site (Smith 1993b, 1997).

Parry fractures (mid-shaft fractures of the ulna and radius), often interpreted as deliberate acts of violence, were examined in the same Archaic samples because they had been perceived to be more common in females. Female-directed violence was not indicated as the frequency was associated with female sample bias and an absence of corroborative cranio-facial trauma (Smith 1996). This evidence for interpersonal and intra-group violence clearly has implications for the overall health and well-being of populations.

Not much work has been done on health for Woodland populations from Tennessee, probably due to the poor preservation for the majority of the available Late Woodland sample and the dearth of skeletal remains from most of the earlier Woodland components. However, in a stable carbon isotope study, Buikstra et al. (1988) found that Hopewellian people (Middle Woodland: c. A.D. 600) from the Nashville Basin were not eating maize, even though it was present by this time in adjacent areas. However, there is a marked shift in the isotopic values for Middle Tennessee Mississippian groups, indicating that the transition to maize-dependency in this region was rapid (Buikstra et al. 1988). The poor health observed for many of these groups (e.g., Averbuch) is interpreted as

partially due to this dependency, however, Buikstra and colleagues (1988) caution that the relationship between diet and health is multifactorial, and other variables must be considered.

An Archaic, Woodland, and Mississippian sample was included in a comparison of dental stress indicators such as linear enamel hypoplasias, fluctuating dental asymmetry, and mean tooth size (Jablonski 1983). The comparison was made between Archaic period individuals from sites in west-central Tennessee, Late Woodland/Early Mississippian individuals from Hiwassee Island in East Tennessee, and Mississippian individuals from Toqua in East Tennessee. Jablonski discerned an increase in stress through time. She tentatively attributed this increase to population growth and subsistence shifts (Jablonski 1983).

Baseline subsistence differences were generated by many studies which compared various Tennessee Mississippian site samples with the west-central Tennessee Late Archaic sample. For example, Richardson (1988: 151) compared infant mortality between the sites of Cherry (Archaic; gatherer-hunters) and Ledford Island (Mississippian; agriculturalists) and found that the infant mortality rate had nearly doubled for the Mississippians (12.5% for Cherry compared to 28.6% for Ledford Island). Even though these two sites are geographically distant from each other (Cherry is located in West Tennessee and Ledford Island in East Tennessee), Richardson (1988) interprets these numbers to

indicate that the change through time in infant mortality is related to the change in subsistence strategy.

In the same light, Maria Smith (1982, 1986, 1987) examined markers of oral health for Archaic populations from East and West Tennessee (Anderson, Eva, Cherry) and a Mississippian population from East Tennessee (Toqua). She found that while there was a strong association between age and antemortem tooth loss, the Mississippians had a higher number of caries than did the Archaic individuals (Smith 1982, 1986, 1987), as maize is a cariogenic carbohydrate. In addition, the location of caries differed between the groups: Archaic individuals had more cervical caries (attributed to periodontitis) while Mississippians had more occlusal surface caries and lost more molars (via caries attributable to pulp exposure) (Smith 1982, 1986, 1987). Rates of attrition differed as well, and she attributed these differences to subsistence-related differences in food processing (e.g., consumption of raw foods versus the use of cooking pots) (Smith 1982, 1986, 1987).

The antiquity of treponemal disease (i.e., yaws and/or treponarid) is confirmed by Late Archaic cases from the west-central site of Eva (Powell et al. 2005). In a further survey of treponemal disease frequency for individuals from the Middle Archaic, Late Archaic and Early Woodland periods in West Tennessee, Smith (2006) found that frequency and patterns of morbidity changed through time. The Early Woodland period not only had the highest frequency,

but also exclusively exhibited subadult treponemal infection. She indicated that while this result was unexpected since treponemal disease has traditionally been associated with agriculturalists, high frequencies of treponemal disease also correlate with sedentism, one of the markers for the end of the Archaic and beginning of the Woodland period (Smith 2006). An ongoing survey of treponemal disease in the Tennessee Woodland and Late Mississippian components has further revealed important co-associations with status and settlement patterning (aggregate versus dispersed) (Robbins and Smith 2008; Smith and Betsinger 2008), as well as evidence of possible congenital transmission (Hutchinson et al. 2008).

The previous discussion illustrates the importance of comparing subsistence, sedentism, sex/gender, social status, and sociopolitical control and how it allows for the broader elucidation of patterns through time. However, the studies just discussed focused solely on indicators that reveal one aspect of health. The research done for this dissertation adds to the information regarding impact of subsistence change for Tennessee specifically by examining multiple indicators of health for sites through a range of culture periods. In addition, as there is not much information about skeletal markers of health for Woodland populations in Tennessee, this work aids in adding to the record in that regard.

Chapter 5

Materials

Northern Chile Sample

The prehistoric Chilean skeletal material studied here is curated at the *Museo Arqueológico* in La Serena, Chile. This museum houses skeletal remains of individuals belonging to the Archaic culture (7730 B.C. - A.D. 245) and the Chilean Diaguita culture (A.D. 1000 - 1536). Unfortunately, skeletal remains from the intermediate time periods of the El Molle and Las Animas have low sample sizes and are very poorly preserved, and therefore were not available for study. All individuals analyzed for this study came from Region IV of Chile, in the semi-arid North. See Figure 1.

Two of the sites included in the Archaic sample used in this dissertation were La Herradura and El Cerrito, located directly proximal to each other approximately two kilometers from the shore of Coquimbo Bay (Rosado 1994). In addition, one individual was analyzed from the site of Playa Blanca, also located in this vicinity. See Table 5.

El Cerrito was excavated in 1960 by Iribarren (Costa-Junqueira et al. 1998) and radiocarbon dating placed the site at 3780 +/- 550 years ago (c. 1830 B.C.), including it in the Archaic III phase (Castillo 1991; Kuzmanic and Castillo 1986; Rosado 1994). La Herradura dates to the Archaic II phase and was initially excavated in the 1940's by *Museo Arqueológico* archaeologists (Kuzmanic and

Castillo 1986; Alaniz 1973). At that time, the prevailing view was that the ceramics were of utmost importance with human bones being of no practical value scientifically and as a result, only the skulls were recovered from the stone box burials (Alaniz 1973; Rosado pers. comm. 2007). My personal data collection methodology called for preferentially scoring mostly complete skeletons when possible. Therefore, only five skulls from La Herradura were analyzed here.

The El Cerrito cemetery consisted of 99 individuals interred in a flexed position, several with limestone slabs covering the upper thorax and head (Rosado 1994). In addition, many of the individuals were interred with grave goods, including mortar stones, projectile points, shells, and bone artifacts (Rosado 1994; Costa-Junqueira et al. 1998). However, this cemetery lacked the variety and number of grave goods seen in other Archaic cemeteries and it appears that family members were interred with each other simultaneously (Ampuero pers. comm. 2007). From this evidence, it appears that the burials at El Cerrito were interred in a hurried fashion and perhaps within a relatively short time span of each other (Ampuero pers. comm. 2007). It is unclear as to whether this burial procedure was due to some sort of medical or social crisis.

Sixty-seven of the 99 skeletons from El Cerrito were analyzed for this study. Skeletons not analyzed included those for which few if any of the observations were possible due to incompleteness and/or preservation; and when there was commingling of skeletons in boxes.

The third Archaic site analyzed for this study was the site of Guanaqueros, located on the coast south of Coquimbo Bay. This site dates to the Archaic II and III phases (Kuzmanic and Castillo 1986). Guanaqueros was first excavated in the 1950's, and the cemetery was located on a terrace approximately 100 meters from the beach (Iribarren 1956). Numerous cultural artifacts were recovered on the surface, including projectile points, shells, and camelid and fish bones (Iribarren 1956). The burials themselves contain projectile points, bone objects, and marine shells (Iribarren 1956). Projectile points tended to be located proximal to the skulls, and Iribarren (1956) interpreted this as having spiritual meaning. The final sample size analyzed from Guanaqueros was 22, making the total number of Archaic individuals examined 95. See Table 5.

The Diaguita individuals represented in this study were excavated from the sites of Compañía Baja, Punta de Piedra, El Olivar, Illapel, Peñuelas, Peñuelas 21, Peñuelas 24, Puclaro, and Punta de Choros, all in the semi-arid North of Chile. See Table 6.

The site El Olivar is a coastal site located on the north side of the Elqui River from La Serena, in the La Compañía area, and it dates to the third Diaguita phase, known as Diaguita-Inca (Rosado 1994). The cemetery at El Olivar consisted of stone cists positioned no deeper than 80 centimeters from the ground surface (Cornely 1944). As a result, many of the graves had been disturbed due to agricultural activity in this area, and this disturbance had a

negative impact on the relative preservation of the remains (Rosado 1994). However, several of the graves were intact and contained a variety of burial goods, including ceramics, projectile points, mortar stones, bone artifacts, and camelid bones (Rosado 1994). A total of 12 individuals from El Olivar were analyzed for this study. In addition, one individual from Compañía Baja, located proximal to El Olivar, was analyzed as well.

The site Illapel dates to the first Diaguita phase, known as Transitional Diaguita (Rosado 1994). This site is located in the interior valley of Limarí, approximately 75 miles southeast of La Serena (Rosado 1994). The cemetery was located underneath a modern street intersection in the city of Illapel, and as a result, only six individuals were recovered (González 1992). All of the bodies were extended dorsally, with grave goods of projectile points and ceramics placed in the head region (González 1992). However, those buried directly in the dirt without a stone cist were lacking any burial goods (González 1992). The presence of mollusk shells in one of the stone cists indicates that the people here maintained contact with people on the coast, a pattern similar to what is seen at other interior valley Diaguita sites (González 1992). Four of the individuals from Illapel were analyzed for this study.

The Peñuelas sites are coastal, located just south of the city of La Serena and date to the Diaguita I and II phases (Biskupovic 1985; Biskupovic and Ampuero 1988, 1991). Peñuelas was among several sites excavated by *Museo*

Arqueológico archaeologists initially in the 1930's (Rosado 1994), and as previously mentioned, it was common during this time period to recover ceramics and skulls only. Therefore, only six skulls from that excavation were analyzed here. Peñuelas 21 and 24 are two adjacent parcels of land and these were excavated in 1972 and 1985, respectively (Biskupovic 1985; Biskupovic and Ampuero 1988, 1991).

Both cemeteries contained stone box graves located approximately 50 centimeters below the surface, and several of the cists contained multiple burials (Biskupovic 1985; Biskupovic and Ampuero 1988, 1991). Similar to other cemeteries in this region, many of the burials contained camelid bones as offerings and one of the graves from Peñuelas 24 had a complete camelid skeleton located directly underneath a human adult male skeleton (Biskupovic and Ampuero 1988, 1991). Ceramic bowls and projectile points were other common offerings (Biskupovic 1985; Biskupovic and Ampuero 1988, 1991). Twenty-three individuals from Peñuelas 24 and 17 individuals from Peñuelas 21 were analyzed for this study.

The site of Puclaro is located near the city of Vicuña, along the Elqui River in the interior valley, approximately 30 miles east of La Serena. Excavated in 1999, the site dates to the Classical Diaguita phase and consisted of 11 graves, including three that had been looted and destroyed (Ampuero pers. comm. 2007). Similar to other Diaguita sites, the graves consisted of stone cists; however,

not all of the graves had individual covers, with about six of them sharing a cover (Ampuero pers. comm. 2007). Some of the cists contained two or three individuals and most graves included ceramics and bone artifacts (Ampuero pers. comm. 2007). Six of the individuals from Puclaro were analyzed here. Two individuals from Punta de Piedra, another valley site located near Puclaro, were analyzed as well.

The final Diaguita site used for this study was Punta de Choros, located coastally approximately 100 miles north of La Serena, just south of the Atacama region. Skeletal remains were found and brought by the police to the *Museo Arqueológico* in the winter of 2006 (Rosado pers. comm. 2007). Therefore, no contextual information is available. Museum archaeologists assume that these individuals are Diaguita based on the site location and relative preservation of the remains. However, a cursory examination reveals that their craniofacial morphology does not resemble that of the Diaguita and therefore it is possible that these individuals represent a different population entirely (Rosado pers. comm. 2007; Rosado et al. 2007). This is a question that needs further investigation; however, for the purposes of this study, these individuals will be included as part of the Diaguita sample size. All four of the individuals recovered were analyzed, making the final Diaguita sample size 75. See Table 6.

Tennessee Sample

The Frank H. McClung Museum at The University of Tennessee houses the skeletal material excavated by the Works Progress Administration (WPA) under the auspices of the Tennessee Valley Authority (TVA) in the 1930's and 1940's. This museum curates the remains of approximately 5700 individuals ranging from the Archaic to Late Mississippian periods (Chapman 1988).

Archaeological investigations were undertaken in the Tennessee Valley region as a result of planned dams and resultant flooding by the TVA for the purposes of controlling flooding and bringing electricity to the Tennessee Valley (Milner and Jacobi 2006). As a result, in order to avoid losing the archaeological record for the prehistoric Tennessee Valley, a number of sites were excavated on a scale not seen before nor since in the United States (Milner and Jacobi 2006).

This dissertation focuses on sites dating to the Archaic (11,450 – 3200 BP), Woodland (3200 – 1000 BP) and Mississippian (A.D. 1000 – 1600) periods. See Table 4. The Archaic sample utilized here came from the Cherry site, 84BN74 (2500 – 1000/500 B.C.) (Magennis 1977), which was located in Benton County, West Tennessee. The Cherry site was excavated in 1941 by Douglas Osborne as part of the Kentucky Reservoir Project, and contained 73 burials (Chapman 1988; Osborne n.d.). Cherry was situated in a remote location, between two streams of the Big Sandy River and approximately 22 kilometers north of where the Big Sandy converged with the Tennessee River (Smith 1982). Based on its remote location away from the resources of the main channel and the presence of storage

pits at the site, it is most likely that this site was primarily a winter occupation (Smith 1982). Since I coded preferentially complete individuals, 46 individuals were analyzed here. See Table 7.

In addition, skeletons from sites dating to the Late Woodland/Early Mississippian period: A.D. 700 – 1150 (Schroedl 1973) from the sites of Alford (Roane County), Hampton (Rhea County), McDonald (Rhea County), Montgomery (Roane County), Smith (Rhea County), and Wilson (Roane County) were analyzed with a total sample size of Woodland individuals of 57. See Table 7. As discussed in Chapter 4, these sites contain Hamilton mounds and therefore contain both Late Woodland and Early Mississippian components. For most of these sites, a larger number of burials were excavated, but many were in such poor condition that all that remained of several bones were soil stains (cf. Burroughs' site report, 76RE8). For those remains that were complete enough to justify excavation, many of these were fragmentary as well. As a result, the sample analyzed here is limited to those remains for which at least a designation of age and one other indicator were possible. All of these sites were located in East Tennessee and with the exception of McDonald, were excavated as part of the Watts Bar Reservoir Project (Chapman 1988).

Alford (4, 10RE4) was excavated in 1940 by Wendell C. Walker. The site was located on the Alford farm, two miles south of the town of Kingston in Roane County, and consisted of five Woodland burial mounds located on the

west bank of the Tennessee River. Burial mound #4 contained 30 burials, and three of those were analyzed here. Burial mound #10 contained 28 burials, and two of those were analyzed here.

The Upper Hampton site (89, 93RH41; 85VT2RH41) was excavated in 1940 by Charles H. Nash and Wendell C. Walker, and while it contained both Woodland and Mississippian components, only those individuals from the Woodland phase were analyzed here. The Upper Hampton site was located in Rhea County, about 8-10 miles east of Spring City, Tennessee and halfway between two tributaries of the Tennessee River, Piney and Whites Creek. The Hampton farm had several sites located on it, and consequently was divided into upper and lower divisions by TVA archaeologists. Of five burial mounds located on a bluff situated along the west bank of the Tennessee River and overlooking the upper division of Hampton farm, Mound 89RH41 was the largest, with nine individuals recovered. Two of those individuals were analyzed here. Site 93RH41 was located in the upper division of Hampton farm, and was an occupation site with both Early and Late Woodland components. Of the 11 burials excavated, eight were utilized for this study.

The burial mound and cemetery site of 85VT2R41 was located on the lower division of Hampton farm, about 200 feet inland from the west bank of the Tennessee River. It was situated approximately half a mile away from the five Woodland burial mounds mentioned previously, and about 700 feet away from

an Early Woodland village (86RH41). While 65 burials were encountered during excavations, not all of these burials contained bone (Walker n.d.a.), and consequently a smaller number of these were returned to the laboratory. Eleven of these individuals were analyzed here, totaling 21 individuals from the Hampton sites.

Located about a mile from the Hampton sites was the Smith site, 122RH41, which consisted of a burial mound located about nine miles south of Spring City in Rhea County, Tennessee on the bank of the Tennessee River (Rowe 1952). Seventeen burials were excavated from this mound, of which one was analyzed here.

The McDonald site (40RH7) was excavated in 1971 as part of the Watts Bar Nuclear Plant project. It was located in Rhea County, two miles downstream from the Watts Bar Dam on the western shore of the Tennessee River, northeast of Yellow Creek (Schroedl 1978). Of the 50 burials from the five excavated burial mounds, many of these were in poor, fragmentary condition. Four individuals from McDonald were analyzed here. Radiocarbon dates were obtained from this site, and were published by Schroedl (1973): A.D. 700 – 1150, which fits into the Late Woodland and Early Mississippian Hiwassee Island phase.

The Montgomery site (73, 76, 77, 78RE8) was excavated in 1941 by Charles H. Nash and Carroll A. Burroughs (Chapman 1988). Located on the Montgomery farm, eight miles south and west of Rockwood, Tennessee, the site contained

seven Woodland burial mounds, of which three were excavated (76, 77, 78) (Nash n.d.a.). Of the five individuals contained in burial mound #76, one individual was analyzed here. Burial mound #77 originally contained 17 individuals, four of which were accidentally destroyed in a fire during excavation (Burroughs 1941). Four of the remaining burials were analyzed here. Five of the nine individuals from burial mound #78 were analyzed in this study. Along with the one individual (of two excavated) from the village site (#73), the total number of individuals from Montgomery was 11.

The Wilson site (17, 23RE6) was excavated in 1940 by Alden Hayes and Carroll A. Burroughs. The Wilson farm was located on the Tennessee River in Roane County, about a mile upriver from Rockwood Landing. A total of seven burial mounds were located on this site. Burial mound #17 was the largest, and contained a total of 19 burials which were in poor condition (many bones, including the pelves, were only represented by bone dust) (Hayes n.d.). However, four individuals were complete enough to allow inclusion in this analysis. Of the 20 burials from burial mound #23, 12 individuals were analyzed here, making the final Late Woodland/Early Mississippian sample 57. See Table 7.

Individuals dating to the Mississippian time period from the Ledford Island site (16BY13, Bradley County), located in East Tennessee were analyzed. This site was excavated over an 11 month period in 1938 – 1939 and was part of

the Chickamauga Reservoir Project (Chapman 1988). It was excavated by George Lidberg, Charles H. Fairbanks, Stuart Neitzel, John Alden, and William Beatty and was located on the Hiwassee River, about 12 miles above its junction with the Tennessee River. The island itself was about a mile and a half long and less than a mile wide and was located near the left bank of the Hiwassee River (Lewis et al. 1995). Two occupation components were identified, with the second component (Mouse Creek) being the major one with the longest occupation (Lewis et al. 1995). Several hundred graves were excavated (459) and these contained 462 individuals. Some of these burials were located in cemeteries, with others spread out through the village. Approximately 29% of the burials had grave goods interred with the individuals (Sullivan 1986; Lewis et al. 1995). One hundred sixty of the individuals from Ledford Island were analyzed here. See Table 7.

Chapter 6

Methods

The Western Hemisphere Health Index: Statistical Methodology

The index developed by Steckel et al. (2002a: 68) is defined as: “the sum of the quality adjusted life years lived by a synthetic cohort of individuals whose mortality experience was specified by a Model West level 4 life table.” Life tables are constructed from populations with good vital statistics, are a tool used to estimate age-at-death distributions and life expectancy at birth for unknown populations with similar characteristics (Coale and Demeny 1983), and have practical utility for several disciplines, including history, economics, epidemiology, and bioarchaeology. The reference population used for the health index was based on a Model West Level 4 life table, which was calculated using vital statistics from late nineteenth and early twentieth century populations from Western and Eastern Europe, Australia, Canada, the United States, Asia, and South Africa (Coale and Demeny 1983).

The concept of quality-adjusted life years depicts health status over an individual’s lifetime. It is calculated by adding up scores given to attributes of health for each year of life. Steckel et al. (2002a, 2002b) have adapted the index for use in skeletal data collection, so that it adjusts for age distribution while incorporating the severity of paleopathological lesions. There are seven basic

indicators of health that are scored, and these were chosen based on when in life people are affected by them – e.g., three attributes apply mainly to children (linear enamel hypoplasias, stature, and anemia); two attributes apply mainly to adults (dental disease and degenerative joint disease) and two apply to children and adults (trauma and infection) (Steckel et al. 2002a). For further information about the relevance of the chosen indicators, refer to Chapter 2 in this work. The scores for any particular attribute are function values, ranging from 0 to 1. In essence, the index value for a population that indicates health status is the sum of these function values.

This method is aggregate or site-specific instead of being based on an individual level – it integrates every attribute recorded for each skeletal element for which age-at-death is available⁶ (Steckel et al. 2002a). An aggregate score is necessary because if the method were based on an individual level, then individuals for which not every attribute could be observed would be excluded due to differential preservation/recovery. For the majority of skeletal series, there will be only a small percentage of individuals for which all observations are possible. It would be to the detriment of the sample to limit the data collection only to those individuals for which all observations were possible, even though the possibility exists of missing data on pathology, trauma, and/or stress indicators as a result of differential preservation (Steckel et al. 2002a).

⁶ A different approach is taken by Boldsen and Mollerup (Boldsen 2001, 2005, 2007; Boldsen and Mollerup 2006) who utilize an individual-based approach towards the diagnosis of leprosy, as they found the presence of leprosy lesions was irrespective of age-at-death.

Each attribute has a range from severely compromised to normal, which translates as a scale of 0% for the severely compromised condition to 100% for the not present condition. Stature is scored as continuous between 0 and 100, while the other attributes are discrete. For example, enamel hypoplasias have three categories: none equals a score of 100% (1); moderate equals a score of 50% (.5); and severe equals a score of 0%. The scores given to each attribute translate into a single index number which is a measure of the health-related quality of life (Steckel et al. 2002a).

There are some assumptions that Steckel et al. (2002a) account for in the index. Stature is obtained from femur length, and a score of 100% is given if the individual attained modern femur standards for their age based on Maresh (1955). Those individuals below three standard deviations are given a score of 0. In addition, a high weight is given to childhood health and nutrition, which can be reflected in stature, the presence or absence of enamel hypoplasias, and cribra orbitalia or porotic hyperostosis. For simplicity, Steckel and Rose (2002a) assume that lesions on bones persisted for ten years prior to death;⁷ and dental disease and degenerative joint disease is presumed to be absent during childhood. In addition, the estimated age-at-death is adjusted via the method of Lovejoy et al. (1985a) so that a little more than a year is subtracted from the age of young adults (18-29) and older adults are aged slightly.

⁷ Healed and active lesions are not differentiated and the assumption taken is that lesions existed for ten years before death. Steckel and Rose (2002a) allow that further research is needed before these assumptions can be modified.

Calculating the index for a site first involves constructing age-specific rates of attribute scores. These rates are essentially a ratio, with the score for a particular attribute for each year of life divided by the number of years lived. For example, a person who died at age 40 and had a stature score of .5 or 50% would have a ratio of: .5 (stature score) multiplied by 40 (age-at-death) – [because the score counts for each year of life lived] divided by 40, which is the number of years lived. The ratios for the attributes of stature, anemia, and hypoplasias are constructed in this way. Ratios for dental disease, infection, degenerative joint disease (DJD), and trauma are done similarly, but with the assumption that the condition only existed for ten years prior to death (for juveniles under ten years, the actual age-at-death is used). For example, a person who was 40 at death and is given a score of 100 for periosteal reaction would have a ratio of: 100% (1.0) (periosteal reaction score) multiplied by 10 (years presumed condition existed) / divided by 40 (age-at-death). Furthermore, individuals are assigned to age categories (0-4; 5-14; 15-24; 25-34; 35-44; 45+) in order to account for sites with few individuals (Steckel et al. 2002a). Each individual's ratio, or age-specific rates for each attribute, is summed within each age category for each population.

Steckel et al. (2002a) wrote a program in FORTRAN to compute the age-specific attribute scores. Average scores for each attribute are calculated by multiplying the ratios within each age category by a weighted age-at-death from the reference population of a Model West Level 4 life table (Steckel et al. 2002a).

The products of this multiplication are summed for each age category, and then divided by life expectancy at birth in this reference population (26.4 years). This result is the attribute score as a percentage of the maximum attainable life expectancy for the tested population. To obtain the health index value, the scores obtained for the seven attributes are averaged, which gives the overall score as a percentage of the maximum attainable life expectancy (Steckel et al. 2002a). The closer this value is to 100, the less stressed the population was, because the value serves as an indicator of fewer markers of stress. These percentages represent quality of health and length of life and can be compared across populations. Refer to Steckel et al. (2002a: 71-72) for further description of the methodology.

The program that runs the health index calculations is available online at <http://global.sbs.ohio-state.edu/healthIndex/>. When a data file is uploaded, it generates the values for quality-adjusted life years, the percentage of the maximum attainable life expectancy for the tested population, and health index values for stature, hypoplasia, anemia, dental disease, infection, degenerative joint disease, and trauma. In addition, the output contains general frequency statistics including age distributions by age cohort, and mean values for age, stature, total number of teeth, caries, and abscesses.

Data for each population (Archaic Chile, Archaic Tennessee, Woodland, Mississippian, and Diaguita) were run through the health index program. The statistical package SPSS 15.0 was used to generate within-population frequencies

for each of the following indicators: cribra orbitalia, porotic hyperostosis, auditory exostosis, tibial infection, skeletal infection; degenerative joint disease of the cervical, thoracic, and lumbar vertebrae; degenerative joint disease of the hip/knee, shoulder/elbow, wrist, hand, and temporomandibular joints; and trauma of the arm, leg, nasal bones, face, skull, hand, and weapon wounds. Basic age and sex distributions for each population were devised as well. Pearson chi-square ($p < .001$) was also used to test for significant differences in these attributes between the five examined populations. However, no tests of significance were run on any of the trauma attributes because of the low incidence of trauma overall. Additionally, the mean age-at-death and standard deviation for individuals by score in each attribute was also calculated.

Chi-square and Fisher's exact test (since there were cells with low counts) were utilized in order to assess if enamel hypoplasia occurrence and population were independent. A new ratio variable was created (i.e., number of caries/number of teeth) for the caries, premortem tooth loss, and abscesses attributes, and these values were further tested. The Kruskal-Wallis rank order test was used to rank these values from the culture with the lowest value to the culture with the highest value. This test was appropriate because these numbers were percentages and not counts. A univariate ANOVA was then used to test for differences in these ranks between the populations.

Data Collection Protocol

Data collection followed the method outlined by Steckel et al. (2002a). The data recording form includes an area for inventory of observable skeletal components, in addition to the age and sex designations of each skeleton. With the exception of age, stature, and dental disease, the scores for the attributes were categorical, ranging from 0-5 depending upon the attribute. See Table 8. The skeletons in the sample were aged using standard methods including Brooks and Suchey's (1990) pubic symphysis aging method; Lovejoy and colleagues' (1985b) auricular surface aging method and Brothwell's (1981) dental wear aging technique. Subadults were aged using standards of growth and development, such as tooth eruption and epiphyseal closure (Baker et al. 2005; Scheuer and Black 2000). For the age category, there are three columns: summary age; dental age; and age range. The summary age is the midpoint of the age range. The dental age category was used for subadults. There are six possibilities in the sex category: 1: definite female; 2: probable female; 3: definite male; 4: probable male; 5: subadult and therefore sex uncertain; and 6: unknown. The data coding form for this analysis was created in Microsoft Excel with columns created for each indicator per Steckel et al. (2002a).

Stature was the first health indicator measured. Height in relation to dental age is a good indicator of nutrition in subadults. To account for this relationship, maximum diaphyseal length is taken from the femora in

millimeters. For adults, maximum femur or tibia length was measured, and then adult height was calculated using the formulae for Native Americans found in Sciulli et al. (1990).

The second health indicator scored was presence/absence of linear enamel hypoplasias. Four teeth were scored for hypoplasias: 1: deciduous maxillary central incisor; 2: deciduous maxillary or mandibular canine; 3: permanent maxillary central incisor; and 4: permanent maxillary or mandibular canine. Scoring was as follows: 0=unobservable (due to wear or absence of tooth); 1=no hypoplasia; 2=one hypoplasia; 3=two or more hypoplasias.

Dental disease was the third health indicator recorded. Dental caries were recorded for the permanent dentition only. There were three fields for the recording of dental caries, with the total number of teeth present in the first field; number of teeth lost antemortem in the second; and total number of teeth with lesions in the third. The presence of abscesses were recorded as well, with total number of observed sockets in the first field and total number of observed abscesses in the second.

The fourth health indicator scored was cribra orbitalia and porotic hyperostosis. Anemia can present itself on the skeleton in different ways, either as cribra orbitalia, seen in the orbit of the frontal bone, or as porotic hyperostosis, typically observed on the parietal bone. Cribra orbitalia was scored as follows: 0=no observable orbits; 1=absent on at least one observable orbit; 2=presence of a

lesion; 3=gross lesions with clear expansion diplöe. Porotic hyperostosis was scored as: 0=no observable parietals; 1=absent on at least one observable parietal; 2=presence of a lesion; 3=presence of gross lesions.

Infection and periosteal reactions were the fifth variable recorded. Only major lesions of the long bones were recorded, with the tibia getting its own category since it is the most common site for infection. Tibiae were scored as follows: 0=no tibia(e) present; 1=no lesions on at least one present tibia; 2=slight periosteal reaction on less than one quarter of the surface of one or both tibiae; 3=moderate reaction on less than one half of one or both tibiae; 4=severe periosteal reaction involving more than one half of one or both tibiae. The rest of the skeleton was recorded as: 0=no periosteal reaction on any bone other than the tibia(e); 1=periosteal reaction on any bone other than the tibia(e) not caused by trauma; 2=evidence of systemic infection involving any of the bones, including the tibia(e).

Degenerative joint disease is the sixth health indicator. Eight different joints were scored: shoulder and elbow; hip and knee; cervical vertebrae; thoracic vertebrae; lumbar vertebrae; temporomandibular joint; wrist; and hand. The scoring for each joint differs slightly (see Table 8), but essentially the scoring is as follows: 0=joints not available for observation; 1=no sign degenerative disease; 2=initial destruction of the joint; 3=major destruction of the joint; 4=joint immobilization.

The seventh and final indicator of health that was measured is trauma. Seven areas of the skeleton were scored: arm; leg; nasal bones; face; skull vault; hands; and weapon wounds in any location. Each area is scored slightly differently (see Table 8), but the basic scoring system is as follows: 0=no elements present for scoring; 1=no fracture; 2=healed fracture.

Chapter 7

Results

Age and sex distributions for each of the five tested populations are presented in Figures 3 – 12, and the calculated health index results are presented in Tables 9 and 10. The frequencies for each tested attribute are shown in Tables 11 – 33 and Figures 13 – 20. There are no major differences evident between the five cultures, as indicated by the health index values, which range from 62.1% (Tennessee Archaic) to 70.8% (Chilean Archaic and Diaguita). However, the results do reveal a few stark differences in terms of the attribute values, when compared by continent and through time, outlined below.

In terms of a comparison between the tested Chilean cultures, the health index value (percent of maximum attainable) was identical (70.8%). When further comparisons were made between the attribute values for the Diaguita and Chilean Archaic, the Diaguita had slightly higher (indicating fewer lesions and therefore a better level of health) values for stature (5.7 versus 1.1) and anemia (90.2 versus 87.3); and had a much higher value for infections (70.3 versus 51). The Archaic populations tested fared better with hypoplasias (95.4 versus 88.3), dental disease (87.7 versus 81.3), degenerative joint disease (82.5 versus 73.8), and trauma (90.7 versus 85.8). Refer to Table 10. However, most of these values are relatively close, with the most dramatic difference between the

attribute value for hypoplasia, with the agriculturalist Diaguita scoring lower than the maritime gatherer-hunter Archaic.

When compared to the 65 sites included in the Western Hemisphere health index (cf. Steckel et al. 2002a), the values for Archaic Chile and Diaguita were closest to the historic samples, while the Mississippian and Woodland populations were closest to foragers and agriculturalists from Mesoamerica. The Archaic Tennessee sample from the Cherry site was most similar to an agricultural Mayan population, and was comparatively within the lower third of ranked health index sites. There is no real pattern to be elucidated here, other than health patterns do not necessarily associate with subsistence strategy.

When the cultures from Tennessee were examined, the assigned health index values ranged from the lowest at 62.1% for Archaic, to 67.6% for Mississippian, and Woodland with the highest value at 68.9%. This order in which the values were arranged was surprising, the implication of which will be interpreted in the discussion chapter to follow.

As far as each attribute value was concerned, the values for stature, dental disease, infection, and trauma were all similar to each other, with the differences between the values ranging from about one to five (see Table 10). In contrast, the values for hypoplasia, anemia, and degenerative joint disease displayed much larger differences. For anemia, the order for the attribute values was first the Archaic population with the lowest value (62.1) followed by Mississippian (83.3)

and then Woodland with the highest value (95.5). The order for degenerative joint disease was the same, with the Archaic value at 63.2, Mississippian at 76.4, and Woodland at 97. This pattern changed with hypoplasia, with Woodland scoring the lowest (50.1), followed by Archaic (66.3) and then Mississippian with the highest value (71.2). See Table 10.

When the populations were compared cross-continentially, the overall pattern revealed was that the health index values for Tennessee (c. 62-68%) are less than those for Chile (70.8%) but only slightly so. The most dramatic difference lies in the values for stature, with the Chilean populations much lower (1.1 and 5.7) than the Tennessee populations (12 - 14.4). For skeletal infection, the Diaguita had the lowest incidence, with an attribute value of 70.3 compared to 49.9 - 53.3 for the remaining four groups. The Tennessee Archaic sample suffered the most degenerative joint disease (63.2) and anemia (62.1) which is reflected by its status as having the lowest health index value for the populations tested here (62.1%). The Woodland sample suffered the highest amount of childhood stressors, as reflected by the hypoplasia attribute value (50.1) with the Chilean Archaic population suffering the least from these stressors (95.4). As far as a comparison between the dental disease and trauma values, they were all within a range of about six or so differences between the calculated values (see Table 10).

The chi-square statistic was used to compare the nominal/ordinal data from the observed attributes, with the assumption that the samples are

independent. The p value used was .001 in order to decrease the chance of having a false significant value (Type 3 error) since twelve different tests were performed. Significant differences were seen with porotic hyperostosis, tibial infection, skeletal infection, and degenerative joint disease of the shoulder/elbow, hip/knee, and wrist ($p < .001$) when each attribute was compared by culture utilizing the Pearson chi-square statistic. See Table 34. Essentially, this analysis revealed that both Archaic populations had a significantly higher disease load than did the other populations. The Archaic Tennessee sample had the most attributes with departures from expected counts when attributes and culture were considered independent. The Mississippian population had significantly higher amounts of two attributes: porotic hyperostosis and tibial infection.

Both the Archaic Tennessee and Mississippian populations had significantly more porotic hyperostosis than did the others, with residual values of 6.0 and 3.1, respectively. See Table 35. For tibial infection, there were several departures from expected: Archaic Chile had the significantly highest rate of severe tibial infection (residual = 3.6), Archaic Tennessee had the highest rate of moderate infection (residual = 2.6), and Mississippian had the highest rate of slight tibial infection (residual = 2.5). See Table 36. The Archaic Chilean population also had a significant departure from expected regarding the presence of systemic infection (residual = 2.8), as did the Archaic Tennessee

population with the presence of infection of any bones other than the tibia (residual = 3.4). See Table 37. For joint disease, the Archaic Tennessee population had a significantly higher count of initial shoulder, elbow, hip, knee, and wrist degenerative changes (residuals = 5.4, 4.7, 4.4, respectively). See Tables 38 and 39.

In addition, the mean ages-at-death for individuals by score in each attribute was also calculated. Comparisons of the mean ages between populations for attributes with significant p values are shown in Tables 40 – 45. Most of these mean ages were similar between the populations for each score. However, while sample sizes were small, those individuals from the Archaic Tennessee population with severe porotic hyperostosis (gross lesions with expansion of the *diplöe*) were on average 10 years older than those individuals with the same disease expression in the other cultures (Table 40). There was also an interesting pattern with systemic infection, as there did not appear to be a common age at which infection was prevalent: those individuals exhibiting this marker from the Archaic Chilean population (which was significantly more than expected) were a mean age of 41, while those from the Archaic Tennessee, Woodland, Mississippian, and Diaguita populations were an average age of 15, 28, 39, and 22, respectively (Table 42).

For hip and knee degenerative joint disease, the Archaic Tennessee individuals with initial degenerative changes were a mean age-at-death of 38, which is approximately seven years younger than individuals with the same

feature in the other populations (Table 44). Furthermore, a similar pattern is seen with the Archaic Tennessee individuals with evidence of degenerative joint disease of the wrist; while they share a similar age-at-death with those from the Archaic Chilean population with wrist DJD (c. 45 years), they are on average 10 years younger than those individuals with degenerative wrist changes in the other tested populations (Table 45).

When the occurrence of enamel hypoplasia was analyzed by culture using Pearson's chi-square and Fisher's exact test, the results revealed a significant association (Figure 21). Specifically, Archaic Chile has fewer occurrences of hypoplasia than expected, and while the results for the Diaguita population were not statistically significant, cursory examination of the results reveals a similar pattern (Figure 22). In addition, both Archaic Tennessee and Woodland populations displayed more occurrences of hypoplasia than expected (Figure 22).

For the caries, premortem tooth loss, and abscesses attributes, the Kruskal-Wallis rank order test was used to examine significant differences on ranks by culture. The results showed significant differences for the caries attribute only, using an alpha of .05. See Figures 23 and 24. There were no significant differences between the rank order by culture for the remaining tested attributes, premortem tooth loss and abscesses.

Chapter 8

Discussion and Conclusion

The hypotheses presented at the outset of this research were that a difference in health would be seen between the foragers and agriculturalists, demonstrated by a decrease in health through time; and that the Northern Chilean populations would exhibit better health overall than their Tennessee counterparts possibly as a result of a more varied subsistence base. The Western Hemisphere Health Index along with Pearson chi-square analyses were used to test these hypotheses and the results revealed intriguing patterns.

The health index values indicate an *increase* in health through time for the tested Tennessee populations, with the Archaic sample having the lowest health index value, followed by the Mississippian in the middle, and finally, the Woodland sample with the highest value. This pattern was unexpected and contrary to most prevailing wisdom that has demonstrated a *decrease* in health accompanying subsistence change for a multitude of populations. In general, Woodland populations are characterized as transitional horticulturalists, still maintaining foraging activities but not quite completely dependent on cultivated crops. In this light, assuming that the Woodland population tested here had a varied subsistence base, it makes sense that they had a higher health index value than did the fully agricultural Mississippians. Early Mississippian individuals were included in the Woodland sample (see Chapters 4 and 5), and therefore it

would be expected that the comparison between the Mississippian and Woodland samples would be similar. However, the overall Woodland sample in this case was very poorly preserved and in most cases, it was not possible to score every attribute for each individual. Therefore, I think this high value for the Woodland population is an artifact of the differential preservation. Ultimately, the results from the Woodland analysis here should be interpreted with caution.

There are numerous possible reasons why the Archaic Tennessee population analyzed here from the Cherry site exhibits a greater number of stress markers than the analyzed Mississippian population from Ledford Island. These two temporally distinct populations are also geographically distinct, presenting the possibility that some of the comparative value is lost, as there may have been factors specific to each unique environment which affected health. Further, in her analysis of Ledford Island in tandem with other Mouse Creek sites and the Toqua site, Boyd (1984) found that the individuals from the Mouse Creek sites had fewer markers of stress such as porotic hyperostosis and cribra orbitalia and a lower mortality when compared to the Toqua site, a Mississippian site also in eastern Tennessee. Individuals from Mouse Creek phase sites possibly had fewer stress episodes than other Mississippian populations in eastern Tennessee, which could partially explain the disparity between the sample from Cherry and that from Ledford Island – i.e., had Cherry been compared with Toqua, perhaps the health status of the two would have appeared more similar.

However, the occupation at Toqua spanned the entire Mississippian period (c. A.D. 1100 – 1600), while Mississippian occupation at Ledford Island was limited to the Mouse Creek phase component (A.D. 1400 – 1600). Previous studies investigating differences in health between Toqua inhabitants and individuals from other Mississippian sites found a higher incidence of stress markers for those from Toqua (Boyd 1984; Betsinger 2002; and refer to Chapter 4 in this work). The possibility of compromised sanitation from long-term human occupation likely contributed to the higher amount of stress observed on individuals from the Toqua sample as compared to other analyzed Mississippian samples (Boyd 1984; Betsinger 2002). In this instance, since Ledford Island was occupied for a much shorter period of time (c. 200 years as compared to several centuries for Toqua) there was a decreased chance of infectious disease transmission due to poor sanitation compounded over time.

It is clear that there were certain factors inherent to either the physical or sociopolitical environment (or both) at Cherry that contributed to the observed high stress load. Cherry was a remote upland site and while it was situated between two streams of the Big Sandy River, the site was nevertheless located about 22 kilometers away from the resources of the main channel, the Tennessee River (Smith 1982). Smith (1982) hypothesizes that Cherry's remote location in addition to the presence of storage pits indicates that it was primarily used as a winter occupation site. If this is true, then those individuals interred at Cherry

died in the wintertime, typically a season of scarcity. While bony manifestations of iron-deficiency anemia take time to appear, the high amounts of porotic hyperostosis seen in individuals from Cherry may therefore partially be attributable to dietary insufficiency added up over a lifetime of winter seasons.

In fact, Cherry had the lowest health index value among the other tested populations and exhibited the most number of significant departures from expected counts with the chi-square analyses. For example, when compared to the other four tested populations, the health index score for anemia is the lowest for Cherry. This score indicates that the individuals from Cherry suffered a high amount of anemia. The significant chi-square result with porotic hyperostosis supports that finding that Cherry had more departures from expected counts with severe changes on the parietal bones, attributable to anemia.

This result was surprising in light of the earlier discussion regarding anemia: it is an illness caused by iron-deficiency, and since maize (the primary crop of prehistoric agriculturalists in the Southeast) is deficient in iron, the expectation is that evidence of anemia would be higher in agriculturalists. In this case, maize was not present at Cherry as its earliest appearance in Tennessee is A.D. 465 – 500 (Crites 1978) and the occupation at Cherry is much earlier, about 2500 – 500 B.C. (Magennis 1977). So the question this result raises is why porotic hyperostosis was so prevalent in this population. It is important to remember here that an iron-deficient diet is not the only causal factor of anemia. Blood loss,

parasites, and diarrhea are also contributing factors. Rosado (1994) found cribra orbitalia and porotic hyperostosis rates approaching 30% for both the Diaguita and Chilean Archaic populations, regardless of the fact that trace element analysis showed that their diets were high in iron. Therefore, dietary insufficiency was not a factor in the etiology of anemia for those populations.

Similarly, for coastal populations from California, Walker (1986) found an increase in iron-deficiency anemia as population size and density increased. He interprets this finding in the context of increased population density leading to potential water contamination by parasites. While fish (the primary staple) are high in iron, the increased likelihood of parasitic infection essentially would have negated the dietary contribution (Walker 1986). Perhaps the individuals from Cherry were in a similar situation: subsisting upon an iron-sufficient diet, but simultaneously suffering from an abnormally high level of parasite infestation or from some other factor that resulted in iron loss. Dietary insufficiency during the wintertime is plausible as well. Whatever the cause, it is clear that the Cherry population does not fit the stereotypic picture of “healthy” foragers.

Furthermore, the analyses revealed that those individuals from Cherry exhibiting initial arthritic changes (i.e., osteophyte formation) on the shoulder and elbow joints had an average age-at-death of about seven years younger than did individuals in the other populations with a similar pathology. While the length of time before death that the changes developed cannot be ascertained, as

these changes were initial ones, it is possible to conclude that the people from Cherry were developing degenerative joint disease at an earlier age than were people from the other populations. In addition, a similar pattern is seen with degenerative changes of the wrist. Although the people from Cherry with this marker share an average age-at-death with the individuals from the Chilean Archaic population (c. 45 years), this age is 10 years younger than those with wrist degeneration in the other populations. Again, this observation further reinforces the fact that these changes were probably developing at earlier ages. This finding indicates these foraging peoples were participating in strenuous, repetitive activities with the arms and hands, leading to arthritic changes. Future analysis of this pattern should include sorting the attributes not only by age, but by sex and status as well to determine if differential activity patterns existed.

When the populations between the continents were compared, the pattern revealed was that both Chilean populations not only had a higher health index value than did any of the Tennessee populations, but this value was identical (70.8%) for both Chilean populations. This finding indicates that there was neither a decrease nor an increase in health between the time of the Archaic people and the later Diaguita. This pattern is the same one that Rosado (1994) found in her earlier study of these two populations and therefore was not very surprising. However, it does reinforce the assertion that it is not an absolute that the transition to an agricultural subsistence strategy is accompanied by an

attendant decline in overall health. In this specific case, the Diaguita, while adopting maize, beans, and squash agriculture, did not abandon the marine resources utilized so heavily by their predecessors. I argue that this fact is in part responsible for the identical health index values between the Chilean Archaic and Diaguita samples analyzed here.

While each attribute value was not identical between these two populations, the identical health index value essentially reflects a “leveling out” of health attributes comparatively – while the Diaguita have a lower value for hypoplasia for example (88.3 versus 95.4 for the Archaic), the Archaic have a lower value for infection (51 versus 70.3 for the Diaguita). In fact, it is infection that sets the Archaic Chilean sample apart from not only the Diaguita, but the other populations as well. The Pearson chi-square analysis revealed a significant departure from expected counts for systemic skeletal infection. The intensive reliance on the marine environment, while providing ample food, ironically probably contributed to this elevated infection load. The collection of shellfish and other small marine animal resources probably represented a relatively easy activity in which even children could participate. However, these resources are located in tidal pools, which consist of rocky environments laden with sharp-edged stones, broken shells, and slimy seaweed. Rosado and Vernacchio-Wilson (2006) discuss this risk, and managing to collect enough food for the day under such conditions without slipping, falling, and cutting oneself (thus opening the

door for bacterial invasion) would have been an accomplishment. The Diaguita, while maintaining such practices, were not as reliant upon them because of their practice of agriculture, and therefore, it is not surprising that a similar skeletal infection pattern is not seen in the Diaguita.

The comparison between the Archaic samples on both continents revealed a much higher health index value for the coastal Chilean Archaic population than the interior Tennessee Archaic population. In addition, the sample from the Cherry site (Tennessee Archaic) had more hypoplasias, porotic hyperostosis, and degenerative joint disease than did the contemporaneous Chilean population. These results indicate better health on at least some levels for the Chileans. The answer to why may lie in the fact that the Chileans inhabited a coastal environment.

Coastal living provides several advantages, not least among them the possibility of a varied diet and subsistence strategy. The marine resources consumed by prehistoric Chileans likely included fish, shellfish, and sea mammals; as such remains are present in archaeological middens and in grave contexts. However, as discussed in Chapter 2, dietary reconstruction from ecofacts alone is flawed, as error due to variation with shellfish nutrition and shell midden construction is likely. Claassen (1998) discusses that variation is present in the nutritional content of each individual mollusk species and that this nutritional content varies even within a species by season of the year, age and sex

of the organism. Additionally, ethnographic observation and archaeological investigations have shown that shell middens can result from processes related to non-food procurement (such as processing shells for pottery temper and tools) (Claassen 1998; Bonomo 2007) and from non-human taphonomic processes (Claassen 1998). Furthermore, while there is variation in the mollusk species people choose to collect for food versus other purposes, it is probable that all shellfish remains regardless of use will be discarded into the same midden (Claassen 1998).

As a result, Claassen (1998) concludes that reconstruction to determine the relative importance of shellfish to the diet should proceed along the lines of human bone stable isotope analysis and not by applying formulae to shell midden samples to determine the amount of meat per shell and its overall contribution to the diet. Even though figures exist on caloric, protein, and other nutrient contents of several shellfish species (e.g., Klippel and Morey 1986; Erlandson 1988; Claassen 1998), these figures can vary widely depending on numerous factors (season of collection, etcetera) and therefore they should be used in interpretations with care.

In this instance, the Cherry site was a shell midden site, as were all the Archaic Chilean sites studied here. A cursory comparison of the protein content of five North American (U.S.) freshwater mussel species to five Eastern Pacific Ocean mollusk species (data in Claassen 1998: 184-5) reveals a generally lower

protein content for the U.S. species (7.8-11.1 grams of protein/100 grams weight – 9.56 g average) versus the Eastern Pacific Ocean species (9.6-22 grams of protein/100 grams weight – 15.76 g average). However, interpretations regarding the differences in health between the Tennessee and Chilean sample simply based on the above would be weak since exact data regarding shellfish species consumption are not currently available for each site. Stable isotope analyses (barium/strontium) on the Chilean Archaic sample showed that their diet consisted of a large proportion of marine foods (Rosado 1994).

Unfortunately, however, while the barium/strontium ratio works well to differentiate between a marine diet and a terrestrial one, it cannot differentiate relative dietary contribution to the level of types of marine foods consumed, e.g., mollusks versus fish (Claassen 1998). Just as unfortunate is the fact that no equivalent data exist for the Cherry site sample. Ultimately, my interpretation regarding the difference in health seen here between the Chilean and Tennessee Archaic samples remains tied to general differences between the respective environments and subsistence strategies. Future work should further investigate this question of shellfish contribution to the diets of both populations and what effect, if any, its consumption had on health.

The chi-square analyses of hypoplasia occurrence showed that the Archaic Chile population had fewer occurrences than would be expected when all five tested populations were compared. This result also mirrors the health index

results, with the Archaic Chile population having the highest score for hypoplasia (95.4) among the other populations, indicating few occurrences of hypoplasia. The implication is that these individuals suffered few physiological-disrupting events during childhood while the teeth were forming. While the chi-square result does not additionally isolate the Diaguita as having significantly fewer occurrences, the Diaguita do have the second highest attribute value for hypoplasia (88.3) when compared to the other populations. This observation serves as further support for certain factors which contributed to the low incidence of hypoplasia being inherent to the coastal environment these prehistoric Chileans inhabited. Furthermore, both the Archaic Tennessee and Woodland populations had significantly more hypoplasia than would be expected when the populations were compared. This pattern indicates relatively high levels of physiological stress during childhood for these populations.

The Kruskal-Wallis test run on the caries, premortem tooth loss, and abscesses attributes revealed that only the caries attribute was significantly different in terms of rank by culture. However, when the health index dental attribute value was compared between all populations, there was very little difference in scale between the values. This result is probably related to the combination of three different observations (caries, premortem tooth loss, and abscesses) into one category. The analysis of each of these categories individually can be a powerful tool towards discerning particular differences between

populations in terms of diet, and therefore, lumping them all into one category loses some of that specificity⁸.

When the Diaguita and Mississippian populations are compared, the overall trend observed is that the Diaguita have a higher health index value and attribute values for almost every category, with the exception of stature and trauma. The dental attribute and degenerative joint disease values are also lower for the Diaguita, but only slightly so. Essentially, the picture that emerges is that while the Diaguita did not have statures that met modern standards for height-for-age, they suffered fewer hypoplasias, bouts of chronic anemia, and infections than did the Mississippians. Trauma, however, appears to have been most prevalent among the Diaguita compared to the other populations, with an attribute value of 85.8 compared to scores in the 90s for the others. Perhaps the Diaguita suffered from higher amounts of accidents and bouts of interpersonal violence. This avenue is one that can be explored in future research. However, the sample size of identified trauma for each population was low, and therefore, a firm conclusion as to why the Diaguita exhibited more traumatic injury cannot be firmly stated.

A more important question is why the Diaguita seemingly had better health than their Mississippian contemporaries. Again, the fact that their subsistence was not solely agricultural in its nature is a neat explanation.

⁸ Refer to review by Hillson (1996) who discusses, for example, the differing etiologies of caries and periodontal disease.

However, a more complex explanation that incorporates contextual analysis of previous studies is required. Of the 15 self-described coastal populations in the health index (Steckel et al. 2002a), two of them (coastal Brazil and coastal South Carolina) have health index values placing them as the top two of all 65 analyzed sites, and most of the remaining 13 have health index scores of 80 and above. The lowest score for a coastal population is 69.8, for coastal California (Steckel et al. 2002a). This comparison seems to indicate that there are certain advantages from a health-related standpoint to living in a coastal environment.

For example, Hutchinson and colleagues (2000) demonstrated via stable isotope analysis that for the coastal Georgia Bight region, there was a shift from a diversified maritime adaptation to an increasingly narrow agricultural one. As a result, Larsen and Harn (2000) observed an increase in caries rates and a significant increase in periostitis with the adoption of agriculture in the Georgia Bight. While this finding was not surprising given that multiple studies have shown similar results (cf. Cohen and Armelagos 1984), Larsen and Sering (2000) found a low incidence of cribra orbitalia and porotic hyperostosis for both the preagricultural and agricultural populations from the same region. Therefore, the coastal subsistence strategy utilized by prehistoric Georgia Bight inhabitants likely contributed to the low rates of severe iron-deficiency anemia, as following the earlier discussion from Chapter 2, the consumption of maize and fish together increases iron availability and absorption.

The results that I obtained in this study, in addition to Rosado's (1994) earlier results regarding health and subsistence strategy for the Diaguita and preceding Chilean Archaic populations, seem to fit well within a model that proposes better health for groups subsisting upon marine resources. The maritime hypothesis discussed earlier states that maritime biomes can support large populations due to the nutrient content of marine resources. Furthermore, in certain areas of high resource biomass and availability, such as Pacific coastal South America, this subsistence strategy led to sedentism and increasingly complex systems of social organization (Moseley 1975). It is also possible that the protein inherent to many of these maritime faunal resources possibly contributed to low rates of stress seen among the coastal Archaic and Diaguita. Although sedentism and its effects have been linked to increased stress for other coastal populations (Hutchinson 2006; Lambert 1993), it does not seem to have affected the Diaguita to the same degree.

While it appears that the Chilean Archaic and Diaguita populations suffered from fewer stress episodes than did the analyzed Tennessee populations, a blanket statement regarding the health benefits to subsisting on marine resources is not warranted since additional studies contradict this assertion. For prehistoric populations from the Santa Barbara Channel Islands of coastal California, Walker (1986) and Lambert (1993) have demonstrated an increase in stress markers such as porotic hyperostosis and periostitis in tandem

with increasing population size and sedentism, even though these groups maintained a strong attachment to marine resources. In fact, these populations experienced a shift from a generalized marine gathering-hunting strategy to one that was increasingly reliant upon fish only (Lambert 1993; Walker 1986).

Lambert (1993) asserts that such a heavy dependence on fish (even though rich in protein, iron, and other nutrients) essentially created health issues similar to those seen in populations heavily dependent upon mono-crop agriculture. She interprets these results by emphasizing the factors that occurred in association with the change in subsistence strategy - namely, increasing population density and size, sedentism, and contact with outsiders; and states that it was these factors that perhaps were more important in the development of detrimental health effects than the change in subsistence strategy itself.

In addition, for prehistoric populations from coastal North Carolina, Hutchinson (2006) found higher rates of porotic hyperostosis for those foragers from the outer coast (subsisting primarily on marine foods) versus the inner coast (subsisting primarily on terrestrial foods). Similar to Walker (1986), he concluded that water contamination from increased population density or infection due to treponematosi s was likely the cause rather than dietary deficiency (Hutchinson 2006). Therefore, it appears that a simple pattern of coastal living = better health does not exist. Rather, other features of the physical (location of water sources, contaminated or not) and sociopolitical (amount of

population density, relative access to resources) environments are major contributors to health patterns in coastal populations.

A secondary purpose of this research was to evaluate the health index methodology. Since the health index is a relatively new method, assessment of its utility is warranted. The development of this method was necessary to enable comparisons of populations on a gross scale. Before development of this methodology, large-scale comparisons were only possible where data collection protocol for each population was standard, which was unlikely. This method is the first attempt to standardize data collection in a way that allows for population comparison with health status in mind. While in general the method is a good tool for comparing health between populations, there were a few drawbacks that probably are attributable to the relatively new nature of the method – i.e., not being utilized by a broad range of researchers as of yet.

Several changes may be useful for fine-tuning the method. For example, the nature of the chosen indicators themselves deserves revision. In her application of the health index to prehistoric foragers from Florida, Wentz (2006) noted that the trauma category especially was problematic, as it allowed for observation of the skull and limbs only, ignoring the torso and other bones. Clearly, fractures of the ribs, clavicles, and other bones can be important in terms of identifying patterns such as interpersonal violence, which may have a bearing on community health. Anecdotally, during data collection I observed a few

individuals with such fractures, but the limitations within the data collection methodology precluded accounting for them. It is important to include observations for bones like the ribs even though the likelihood of good preservation of such bones is slim, as these observations can reveal patterns related to interpersonal violence and accidents.

Another limitation with the method is that degenerative joint disease is scored for several categories of joints, lumping joints like the hip and knee and shoulder and elbow together. These joints obviously work in tandem with each other and identifying arthritis for these joint combinations reveals a little about work, activity patterns, and repetitive motions. However, more refined questions about the exact nature of those activity patterns can only be answered if there is more specific information regarding which exact joints are affected and to what degree. Kennedy (1989) reviews evidence for skeletal markers of occupational stress, and most of these are discernable only through patterns in specific joints affected.

The health index method also calls for assessment of wrist degenerative joint disease but not of the ankle. Yet, I noted several cases of osteophyte formation and/or eburnation of the tibio-talar articulation. This observation deserves inclusion. Regarding the observation of hand degeneration called for in the method, for the vast majority of skeletons I observed, the hands were either not present at all or there were only a few finger bones. Ultimately, this problem

meant that any data I collected on this indicator is meaningless because the sample was not nearly representative. I suggest the method could be strengthened by adding observations on trauma for all bones, degenerative joint disease of the ankle, and thereby decreasing the dependence on the observation for degeneration of the hands.

A few discrepancies between the published methodology from 2002 and the actual software that runs the health index program (not available online to a wide audience until the summer of 2007) also created problems. For example, the method protocol includes observations for robusticity, taken via measurements of the humerus and femur. However, there is no column for these observations in the form file that gets uploaded for analysis, and therefore, these measurements are disregarded. Moreover, the initial data collection protocol called for inclusion of ecological variables such as climate, subsistence plants, topography, and elevation, among others. While these variables may have been used for organization and data collection of the 65 sites presented by Steckel and Rose (2002), these variables are not included in the current version of the program. These discrepancies should be addressed in some form to make the program more user-friendly, especially since one intention of the index was for widespread use by scholars.

Perhaps the principal matter of importance where evaluation of the health index is concerned is the nature of the statistical methodology. The description

that Steckel and colleagues (2002a: 71-2) provide of specifically how the program devises the attribute and health index scores is vague. The inclusion of simple step-by-step examples in future publications would be beneficial. One of the principal authors, Richard Steckel (personal communication 2008) was kind enough to provide me with the weighted scores used on the ages-at-death from the reference population when constructing the index, but these weights are not currently published. Further, the unclear description in the 2002 publication made it impossible to replicate the steps of the statistical methods, even when these weights were provided. It is likely that other researchers attempting to work out examples will have a similar predicament.

Wentz (2006) raised a parallel objection in her application of the health index program. She suggested that the nature of the program, whereby data is uploaded blindly and the calculated values appear after the click of a button, make it difficult to know if said values were calculated correctly or not. It is imperative that statistical methods used for any analysis are described in a clear and straightforward manner in order to heighten replicability. The health index methodology will be significantly strengthened once this issue is addressed.

Pearson chi-square analyses were used to compare the observed attributes between the tested populations to evaluate the usefulness of the index in its current form. A question arose as to what other statistical tests would reveal when the observed indicators from the populations were compared in a similar

way, as the utility of the index lies in its ability to compare health between populations. The Archaic Tennessee sample from Cherry not only had the lowest health index value, but had the most significant departures from expected counts with the chi-square analysis as discussed earlier. Cherry also had the lowest attribute value for anemia, and the chi-square identified this population as being significantly different from the others in terms of porotic hyperostosis.

Furthermore, the Mississippian population had the second lowest attribute value for anemia and was also significantly different in terms of severe porotic hyperostosis from the other populations. The Cherry sample also had the lowest attribute score for degenerative joint disease, and as discussed earlier, had significantly different amounts of shoulder/elbow and wrist degeneration when compared to the other populations. While the health index and chi-square are two different kinds of statistical analyses, when the results are compared, similar patterns emerge. While the health index methodology deserves further refinement, even in its current state it represents a suitable mechanism for comparing populations and for making interpretations regarding changing trends in health status.⁹

The overall patterns revealed here were that health and subsistence are not necessarily tied together in what has been the assumed traditional relationship – namely, that there is a decrease in health between foraging and

⁹ A new version of the health index has been developed for use in the Old World, and it incorporates a number of changes (Steckel et al. n.d.)

farming. Such a simplistic explanation ignores the complexities inherent in not only the subsistence strategy itself, but in the local environment and the resources it has to offer. It also ignores the role that human agents play as participators (individually and collectively) in decisions that have a direct bearing on health (i.e., where to live, which foods to eat, how to prepare them, whether or not to engage in risky activities, and so on).

The population comparisons reported here revealed that forager groups inhabiting different environments with different food resource availability exhibited different health patterns. The population that inhabited the coastal environment (Chilean Archaic) appeared to have fewer markers of stress than did the interior population (Cherry). In addition, there was an increase in health between the interior, riverine forager population (Cherry site - Tennessee Archaic) and the interior riverine agricultural population (Mississippian). Clearly, there were factors other than subsistence that negatively affected the health of the residents of the Cherry site. In contrast, the stress level of both forager and agricultural populations from Chile appears to be similar, indicating that the addition of agriculture in this region did not affect health to the same extent that has been demonstrated for other regions. The diverse subsistence strategy in addition to the diversity of resources available in a coastal, marine environment were probably contributors. Questions regarding the nature of the socio-political environment in each population and the role it played in behavior

and adaptation, insofar as this context related to experiential and functional health, is an avenue that deserves future exploration.

These results in addition to the results from the sites presented by Steckel et al. (2002a) reveal that native peoples in the Americas did not enjoy an equal experience of health – neither all bad nor all good. For the sites contained in the 2002 publication, there are several Native American groups with high health index values, but also many with low values. This distribution indicates that there was a very diverse experience of health prior to European contact in the Americas. Steckel et al. (2002a) discuss this issue and hypothesize that the diversity of patterns seen may in part be due to population size. Smaller populations may have a lesser chance of contracting and maintaining communicable diseases, yet have increased access to resources. Nonetheless, there are clear problems with this interpretation because Archaic groups typically have low population sizes and the Archaic Tennessee sample analyzed here had the lowest health for this tested sample. Thus it is indicated that factors other than subsistence and population size clearly are contributors to health status.

This finding serves to reinforce the assertion that broad generalizations stating that a change in subsistence inevitably leads to bad health – or to better health, for that matter, should not be made. Ultimately, while one or another situation may be demonstrated for certain populations, it is important to

remember that each population is a distinct entity, affected by environmental, social, and biological factors differentially. Factors that may be detrimental to one population (such as an increased population size leading to increased communicable disease due to increased contact with waste) may not be as consequential in another population, where perhaps a better social system exists for the disposal of waste.

Hutchinson (2006: 164-5) states even though it appears broad patterns do not exist,

“We must extract patterns and explain cases that do not fit the patterns, while using variation in the patterns to explore potential insights into the processes of adaptation [and]....while the attainment of universal laws does seem distant, documenting the variation within and between regions is a first step to understanding the process by which changes in economy, behavior, and sociopolitical organization occurred”.

It is increasingly clear that subsistence strategy alone cannot explain the patterns in health status seen. Diet and health have an undeniable, definite relationship, but this relationship is more complicated than previously postulated. Rather, a combination of subsistence, physical environment, behavior, and sociopolitical organization (including status) all appear to have a direct bearing on health. Future work must give carefully calculated weight to each of these factors if Hutchinson’s “universal laws” are to be attained.

Our task as skeletal investigators lies not only in collecting osteological data, but in teasing out the factors which contributed to what we observe on the skeleton. This task is complicated by the fact that these factors are myriad in

number and intertwined. Comparative studies are invaluable for examining each population within its unique context, followed by a step-by-step comparison of the observed similarities and differences between groups. Such studies may help elucidate not only what these operating factors were, but which of them were consequential for each prehistoric population in terms of health.

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Appendix

Table 1. North and South American Culture Chronology

Years	North American Culture	South American Culture
8000 BC	Archaic ¹⁰	Archaic ¹¹
7000 BC		
6000 BC		
5000 BC		
4000 BC		
3000 BC		
2000 BC		
1000 BC	Woodland ¹²	Ceramic Period Cultures: El Molle ¹³
500 BC		
AD 0		
AD 500		Las Animas ¹⁴
AD 1000	Mississippian ¹⁵	Diaguita ¹⁶
AD 1500		
AD 1536		
AD 1600		

¹⁰ 8000-1000 BC (Anderson 2001)

¹¹ 7730 BC-AD 245 (Kuzmanic and Castillo 1986)

¹² 1000 BC-AD 1000 (Anderson 2001)

¹³ 300 BC-AD 700 (Ampuero 1986)

¹⁴ AD 800-1000 (Ampuero 1986)

¹⁵ AD 1000-1600 (Anderson 2001)

¹⁶ AD 1000-1536 (Rosado 1994)

Table 2. Chilean Archaic Chronology*

Phase #	Dates
Phase I	7730-7450 B.C.
Phase II	5500-1800 B.C.
Phase III	2955-500 B.C.
Phase IV	A.D. 30-245

*from Kuzmanic and Castillo (1986)

Table 3. Chilean Diaguita Chronology*

Phase Name and Number	Dates
Transitional (I)	A.D. 1000-1200
Classic (II)	A.D. 1200-1450
Diaguita-Inca (III)	A.D. 1450-1536

*from Rosado (1994)

Table 4. Tennessee Culture Chronology*

Culture period	Dates
Archaic	8000-1000 B.C.
Woodland	1000 B.C.-A.D. 1000
Mississippian	A.D. 1000-1600

*from Anderson (2001)

Table 5. Archaic Sites Analyzed

Site Name	Phase	Location	N
El Cerrito	III	Coquimbo Bay	67
Guañeros	II, III	South of Coquimbo Bay	22
La Herradura	II	Coquimbo Bay	5
Playa Blanca	?	Coquimbo Bay	1

Table 6. Diaguita Sites Analyzed

Site Name	Phase	Location	N
El Olivar	III	N side Elqui River (coastal)	12
Illapel	I	Limarí Valley (valley)	4
Peñuelas	II	South of La Serena (coastal)	6
Peñuelas 21	II	South of La Serena (coastal)	17
Peñuelas 24	I, II	South of La Serena (coastal)	23
Punta de Choros	?	North of La Serena (coastal)	4
Puclaro	II	Elqui Valley (valley)	6
Compañía Baja	?	N side Elqui River (coastal)	1
Punta de Piedra	?	East of La Serena (valley)	2

Table 7. Tennessee Sites Analyzed

Site Name	Type	Phase	Location	N
Cherry (84BN74)	Occupation	Archaic	West TN	46
Alford (4RE4)	Burial Mound	Woodland	East TN	3
Alford (10RE4)	Burial Mound	Woodland	East TN	2
Hampton (85VT2R41)	Burial Mound	Woodland	East TN	11
Hampton (89RH41)	Burial Mound	Woodland	East TN	2
Hampton (93RH41)	Occupation	Woodland	East TN	8
McDonald (40RH7)	Burial Mound	Woodland	East TN	4
Montgomery (73RE8)	Occupation	Woodland	East TN	1
Montgomery (76RE8)	Burial Mound	Woodland	East TN	1
Montgomery (77RE8)	Burial Mound	Woodland	East TN	4
Montgomery (78RE8)	Burial Mound	Woodland	East TN	5
Wilson (17RE6)	Burial Mound	Woodland	East TN	4
Smith (122RH41)	Burial Mound	Woodland	East TN	1
Wilson (23RE6)	Burial Mound	Woodland	East TN	12
Ledford Island (16BY13)	Occupation	Mississippian	East TN	160

Table 8. Data Collection Protocol for Categorical Variables

Variable	Score					
	0	1	2	3	4	5
Cribra Orbitalia	Not observable	Absent	Present	Gross lesions		
Porotic Hyperostosis	Not observable	Absent	Present	Gross lesions		
Auditory Exostosis	Not observable	Absent	Present			
Tibial Infection	Not observable	Absent	Slight	Moderate	Severe	
Skeletal Infection	No infection	Present	Systemic			
Shoulder and Elbow DJD	Not observable	No DJD	Initial	Severe	Immobilization	Systemic
Hip and Knee DJD	Not observable	No DJD	Initial	Severe	Immobilization	Systemic
Cervical Vertebrae DJD	Not observable	No DJD	Initial	Extensive	Body Fusion	
Thoracic Vertebrae DJD	Not observable	No DJD	Initial	Extensive	Body Fusion	
Lumbar Vertebrae DJD	Not observable	No DJD	Initial	Extensive	Body Fusion	
Temporomandibular DJD	Not observable	No DJD	Present			
Wrist DJD	Not observable	No DJD	Present			
Hand DJD	Not observable	No DJD	Present			
Arm Trauma	Not observable	No Fracture	Healed	Healed; malaligned	Healed with joint fusion	Healed, alignment Unknown
Leg Trauma	Not observable	No Fracture	Healed	Healed; locomotion Loss	Healed; major locomotion loss	Healed, alignment Unknown
Nasal Bones Trauma	Not observable	No Fracture	Healed			
Face Trauma	Not observable	No Fracture	Healed			
Vault Trauma	Not observable	No Fracture	Healed			
Hands Trauma	Not observable	No Fracture	Healed			
Weapon Wounds		Absent	Present			

Table 9. Calculated Health Index Results

Culture	Quality-adjusted life years	% of maximum attainable
Archaic Chile	18.68	70.8
Archaic Tenn	16.38	62.1
Woodland	18.18	68.9
Mississippian	17.83	67.6
Diaguita	18.67	70.8

Table 10. Calculated Health Index Attribute Values

Culture	Stature	Hypoplasia	Anemia	Dental	Infection	DJD	Trauma
Archaic Chile	1.1	95.4	87.3	87.7	51	82.5	90.7
Archaic Tenn	13.1	66.3	62.1	83.3	53.3	63.2	93.2
Woodland	14.4	50.1	95.5	84.8	49.9	97	90.7
Mississippian	12	71.2	83.3	83.9	51.7	76.4	94.5
Diaguita	5.7	88.3	90.2	81.3	70.3	73.8	85.8

Table 11. Cribra Orbitalia Frequency

Culture	Present		Absent		n observed	n total
	Frequency	Percent	Frequency	Percent		
Archaic Chile	18	34%	35	66%	53	95
Archaic Tenn	3	6.5%	25	54.3%	28	46
Woodland	2	3.4%	24	41.4%	32	58
Mississippian	14	8.8%	58	36.3%	88	160
Diaguita	15	20%	30	66.7%	45	75

Table 12. Porotic Hyperostosis Frequency

Culture	Present		Absent		n observed	n total
	Frequency	Percent	Frequency	Percent		
Archaic Chile	4	7.7%	48	92.3%	52	95
Archaic Tenn	20	64.5%	11	23.9%	31	46
Woodland	3	9.4%	29	90.6%	32	58
Mississippian	29	28.4%	73	71.6%	102	160
Diaguita	4	10.3%	35	89.7%	39	75

Table 13. Auditory Exostosis Frequency

Culture	Present		Absent		n observed	n total
	Frequency	Percent	Frequency	Percent		
Archaic Chile	8	14.8%	46	85.2%	54	95
Archaic Tenn	5	17.2%	24	82.8%	29	46
Woodland	2	5.4%	35	94.6%	37	58
Mississippian	19	15.2%	106	84.8%	125	160
Diaguita	6	14.3%	36	85.7%	42	75

Table 14. Tibial Infection Frequency

Culture	Absent		Slight		Moderate		Severe		n observed	n total
	n	%	n	%	n	%	n	%		
Archaic Chile	16	29.1%	10	18.2%	20	36.4%	9	16.4%	55	95
Archaic Tenn	5	13.2%	14	36.8%	19	50%	0	0%	38	46
Woodland	17	51.5%	5	15.2%	8	24.2%	3	9.1%	33	58
Mississippian	34	24.5%	55	39.6%	44	31.7%	6	4.3%	139	160
Diaguita	18	54.5%	12	36.4%	3	9.1%	0	0%	33	75

Table 15. Skeletal Infection Frequency

Culture	No infection ¹		Infection ²		Systemic infection		n observed	n total
	N	%	n	%	n	%		
Archaic Chile	29	42%	28	40.6%	12	17.4%	69	95
Archaic Tenn	11	26.8%	27	65.9%	3	7.3%	41	46
Woodland	17	40.5%	18	42.9%	7	16.7%	42	58
Mississippian	80	53.3%	62	41.3%	8	5.3%	150	160
Diaguita	39	76.5%	11	21.6%	1	2%	51	75

¹Absence of infection any bones other than tibia(e)

²Presence of infection any bones other than tibia(e)

Table 16. Shoulder and Elbow Degenerative Joint Disease Frequency

Culture	No DJD		Initial DJD		Extensive DJD		n observed	n total
	N	%	n	%	n	%		
Archaic Chile	34	79.1%	7	16.3%	2	4.7%	43	95
Archaic Tenn	9	34.6%	16	61.5%	1	3.8%	26	46
Woodland	14	100%	0	0%	0	0%	14	58
Mississippian	56	69.1%	14	17.3%	11	13.6%	81	160
Diaguita	23	79.3%	4	13.8%	2	6.9%	29	75

Table 17. Hip and Knee Degenerative Joint Disease Frequency

Culture	No DJD		Initial DJD		Extensive DJD		n observed	n total
	N	%	n	%	n	%		
Archaic Chile	43	89.6%	1	2.1%	4	8.3%	48	95
Archaic Tenn	12	44.4%	13	48.1%	2	7.4%	27	46
Woodland	13	100%	0	0%	0	0%	13	58
Mississippian	79	80.6%	12	12.2%	7	7.1%	98	160
Diaguita	22	61.1%	11	30.6%	3	8.3%	36	75

Table 18. Cervical Vertebrae Degenerative Joint Disease Frequency

Culture	No DJD		Initial DJD		Extensive DJD		Fusion		n observed	n total
	n	%	n	%	n	%	n	%		
Archaic Chile	21	70%	7	23.3%	2	6.7%	0	0%	30	95
Archaic Tenn	10	55.6%	4	22.2%	3	16.7%	1	5.6%	18	46
Woodland	6	100%	0	0%	0	0%	0	0%	6	58
Mississippian	45	86.5%	4	7.7%	2	3.8%	1	1.9%	52	160
Diaguita	8	50%	4	25%	2	12.5%	2	12.5%	16	75

Table 19. Thoracic Vertebrae Degenerative Joint Disease Frequency

Culture	No DJD		Initial DJD		Extensive DJD		Fusion		n observed	n total
	n	%	n	%	n	%	n	%		
Archaic Chile	27	75%	9	25%	0	0%	0	0%	36	95
Archaic Tenn	14	58.3%	9	37.5%	0	0%	1	4.2%	24	46
Woodland	8	88.9%	1	11.1%	0	0%	0	0%	9	58
Mississippian	54	76.1%	12	16.9%	5	7%	0	0%	71	160
Diaguita	10	58.8%	5	29.4%	1	5.9%	1	5.9%	17	75

Table 20. Lumbar Vertebrae Degenerative Joint Disease Frequency

Culture	No DJD		Initial DJD		Extensive DJD		Fusion		n observed	n total
	n	%	n	%	n	%	n	%		
Archaic Chile	21	58.3%	8	22.2%	6	16.7%	1	2.8%	36	95
Archaic Tenn	8	28.6%	10	35.7%	9	32.1%	1	3.6%	28	46
Woodland	10	83.3%	2	16.7%	0	0%	0	0%	12	58
Mississippian	46	65.7%	10	14.3%	11	15.7%	3	4.3%	70	160
Diaguita	7	46.7%	3	20%	4	26.7%	1	6.7%	15	75

Table 21. Temporomandibular Joint Degenerative Disease Frequency

Culture	Absent		Present		n observed	n total
	n	%	n	%		
Archaic Chile	47	88.7%	6	11.3%	53	95
Archaic Tenn	10	58.8%	7	41.2%	17	46
Woodland	17	100%	0	0%	17	58
Mississippian	54	78.3%	15	21.7%	69	160
Diaguita	29	69%	13	31%	42	75

Table 22. Wrist Degenerative Joint Disease Frequency

Culture	Absent		Present		n observed	n total
	n	%	n	%		
Archaic Chile	32	88.9%	4	11.1%	36	95
Archaic Tenn	11	47.8%	12	52.2%	23	46
Woodland	7	100%	0	0%	7	58
Mississippian	52	88.1%	7	11.9%	59	160
Diaguita	13	76.5%	4	23.5%	17	75

Table 23. Hand Degenerative Joint Disease Frequency

Culture	Absent		Present		n observed	n total
	n	%	n	%		
Archaic Chile	32	97%	1	3%	33	95
Archaic Tenn	22	95.7%	1	4.3%	23	46
Woodland	3	100%	0	0%	3	58
Mississippian	69	100%	0	0%	69	160
Diaguita	7	87.5%	1	12.5%	8	75

Table 24. Arm Trauma Frequency

Culture	No fracture		Healed fracture		Healed with poor alignment		n observed	n total
	N	%	n	%	n	%		
Archaic Chile	52	96.3%	2	3.7%	0	0%	54	95
Archaic Tenn	33	71.7%	0	0%	1	2.9%	34	46
Woodland	23	88.5%	3	11.5%	0	0%	26	58
Mississippian	119	95.2%	4	3.2%	2	1.6%	125	160
Diaguita	32	94.1%	1	2.9%	1	2.9%	34	75

Table 25. Leg Trauma Frequency

Culture	No fracture		Healed fracture		Healed with some loss of locomotion		n observed	n total
	N	%	n	%	n	%		
Archaic Chile	56	98.2%	1	1.8%	0	0%	57	95
Archaic Tenn	34	94.4%	0	0%	2	5.6%	36	46
Woodland	34	97.1%	1	2.9%	0	0%	35	58
Mississippian	148	99.3%	0	0%	1	0.7%	149	160
Diaguita	42	93.3%	2	4.4%	1	2.2%	45	75

Table 26. Nasal Bones Trauma Frequency

Culture	No fracture		Fracture		n observed	n total
	n	%	n	%		
Archaic Chile	40	97.6%	1	2.4%	41	95
Archaic Tenn	11	100%	0	0%	11	46
Woodland	7	100%	0	0%	7	58
Mississippian	22	95.7%	1	4.3%	23	160
Diaguita	39	97.5%	1	2.5%	40	75

Table 27. Facial Bones Trauma Frequency

Culture	No fracture		Fracture		n observed	n total
	n	%	n	%		
Archaic Chile	42	100%	0	0%	42	95
Archaic Tenn	9	100%	0	0%	9	46
Woodland	12	100%	0	0%	12	58
Mississippian	22	100%	0	0%	22	160
Diaguita	39	100%	0	0%	39	75

Table 28. Skull Vault Trauma Frequency

Culture	No fracture		Fracture		n observed	n total
	n	%	n	%		
Archaic Chile	50	96.2%	2	3.8%	52	95
Archaic Tenn	29	100%	0	0%	29	46
Woodland	28	100%	0	0%	28	58
Mississippian	83	100%	0	0%	83	160
Diaguita	38	92.7%	3	7.3%	41	75

Table 29. Hands Trauma Frequency

Culture	No fracture		Fracture		n observed	n total
	n	%	n	%		
Archaic Chile	35	100%	0	0%	35	95
Archaic Tenn	24	96%	1	4%	25	46
Woodland	4	100%	0	0%	4	58
Mississippian	76	100%	0	0%	76	160
Diaguita	12	100%	0	0%	12	75

Table 30. Weapon Wounds Frequency

Culture	No Weapon Wounds		Weapon Wounds		n observed	n total
	n	%	n	%		
Archaic Chile	75	100%	0	0%	75	95
Archaic Tenn	28	87.5%	4	12.5%	32	46
Woodland	31	96.9%	1	3.1%	32	58
Mississippian	123	100%	0	0%	123	160
Diaguita	55	96.5%	2	3.5%	57	75

Table 31. Dental Caries Frequency

Culture	Total # teeth	# teeth with caries	Percent	n observed	n total
Archaic Chile	1075	63	5.86%	55	95
Archaic Tenn	684	82	11.9%	33	46
Woodland	961	92	9.57%	46	58
Mississippian	2471	345	13.96%	122	160
Diaguita	976	120	12.29%	57	75

Table 32. Premortem Tooth Loss Frequency

Culture	Total # teeth	# lost premortem	Percent	n observed	n total
Archaic Chile	1075	112	10.42%	55	95
Archaic Tenn	684	50	7.3%	33	46
Woodland	961	90	9.36%	46	58
Mississippian	2471	287	11.6%	122	160
Diaguita	976	191	19.56%	57	75

Table 33. Abscesses Frequency

Culture	Total # sockets	# abscesses	Percent	n observed	n total
Archaic Chile	1422	73	5.13%	56	95
Archaic Tenn	804	41	5.09%	36	46
Woodland	581	41	7.05%	31	58
Mississippian	2963	33	1.1%	129	160
Diaguita	1309	40	3.05%	59	75

Table 34. Calculated Significant Pearson Chi-Square Values

Tested Attribute	Pearson Chi-Square Value	df	Significance
Porotic Hyperostosis	59.723	8	.001
Tibial Infection	51.266	12	.001
Skeletal Infection	37.999	8	.001
Shoulder/Elbow DJD	37.239	8	.001
Hip/Knee DJD	37.751	8	.001
Wrist DJD	21.711	4	.001

Table 35. Significant Crosstabulation for Porotic Hyperostosis

Culture		Porotic Hyperostosis			Total
		absent	present	severe	
Archaic Tenn	count	11	20	0	31
	expected count	23.7	6.2	1.1	31
	% within culture	35.5	64.5	.0	100%
	adjusted residual	-5.8	6.6	-1.1	
Mississippian	count	73	21	8	102
	expected count	78.1	20.3	3.6	102
	% within culture	71.6	20.6	7.8	100%
	adjusted residual	-1.5	.2	3.1	

Table 36. Significant Crosstabulation for Tibial Infection

Culture		Tibial Infection				Total
		absent	slight	moderate	severe	
Archaic Chile	count	16	10	20	9	55
	expected count	16.6	17.7	17.3	3.3	55
	% within culture	29.1	18.2	36.4	16.4	100%
	adjusted residual	-.2	-2.5	.9	3.6	
Archaic Tenn	count	5	14	19	0	38
	expected count	11.5	12.2	12	2.3	38
	% within culture	13.2	36.8	50	0	100
	adjusted residual	-2.4	.7	2.6	-1.7	
Mississippian	count	34	55	44	6	139
	expected count	42	44.8	43.8	8.4	139
	% within culture	24.5	39.6	31.7	4.3	100%
	adjusted residual	-2.0	2.5	.0	-1.2	

Table 37. Significant Crosstabulation for Skeletal Infection

Culture		Skeletal Infection			Total
		absent	present	systemic	
Archaic Chile	count	29	28	12	69
	expected count	34.4	28.5	6.1	69
	% within culture	42	40.6	17.4	100
	adjusted residual	-1.5	-.1	2.8	
Archaic Tenn	count	11	27	3	41
	expected count	20.4	17	3.6	41
	% within culture	26.8	65.9	7.3	100%
	adjusted residual	-3.1	3.4	-.4	

Table 38. Significant Crosstabulation for Shoulder/Elbow and Hip/Knee Degenerative Joint Disease

Culture		Shoulder/Elbow DJD			Total
		absent	initial	severe	
Archaic Tenn	count	9	16	1	26
	expected count	18.3	5.5	2.2	26
	% within culture	34.6	61.5	3.8	100%
	adjusted residual	-4.3	5.4	-.9	
		Hip/Knee DJD			Total
		absent	initial	severe	
Archaic Tenn	count	12	13	2	27
	expected count	20.6	4.5	1.9	27
	% within culture	44.4	48.1	7.4	100%
	adjusted residual	-4.1	4.7	.0	

Table 39. Significant Crosstabulation for Wrist Degenerative Joint Disease

Culture		Wrist DJD		Total
		absent	present	
Archaic Tenn	count	11	12	23
	expected count	18.6	4.4	23
	% within culture	47.8	52.2	100%
	adjusted residual	-4.4	4.4	

Table 40. Mean Age by Score for Porotic Hyperostosis*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	Absent	48	33	15.3
	Present	4	26	5
Archaic Tenn	Absent	11	16.4	16.6
	Present	20	36.9	13.9
Woodland	Absent	29	27.7	13.2
	Present	3	30.6	4
Mississippian	Absent	73	29.1	17.1
	Present	21	27.9	14.6
	Severe	8	23.3	15.4
Diaguita	Absent	35	36.1	14.8
	Present	3	24	20
	Severe	1	25	

Table 41. Mean Age by Score for Tibial Infection*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	Absent	16	17.2	15.9
	Slight	10	30.9	8.4
	Moderate	20	38	14.5
	Severe	9	41.6	10.6
Archaic Tenn	Absent	5	4.7	4.1
	Slight	14	32.2	14.7
	Moderate	19	35.8	17.2
Woodland	Absent	16	30.5	16
	Slight	5	32	7.5
	Moderate	8	32.6	6.8
	Severe	3	35	8.6
Mississippian	Absent	34	12.4	13.8
	Slight	55	30.1	13.6
	Moderate	44	34.2	13
	Severe	6	44.1	9.1
Diaguita	Absent	18	29	15.2
	Slight	12	39.6	16.6
	Moderate	3	37	13

* Bolded values are mean ages for scores with significant differences between cultures.

Table 42. Mean Age by Score for Skeletal Infection*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	No infection	29	22.3	13.8
	Infection any bones other than tibiae	28	36.5	14.8
	Systemic infection	12	41.2	10.6
Archaic Tenn	No infection	11	16.1	15.3
	Infection any bones other than tibiae	27	35.5	16.1
	Systemic infection	3	15	21.7
Woodland	No infection	17	24.3	15.9
	Infection any bones other than tibiae	17	34.6	8.2
	Systemic infection	7	28	14.4
Mississippian	No infection	78	18.7	15.3
	Infection any bones other than tibiae	62	34.7	13
	Systemic infection	8	39.1	13.7
Diaguita	No infection	39	31.9	15.5
	Infection any bones other than tibiae	11	40.1	16.8
	Systemic infection	1	22	

Table 43. Mean Age by Score for Shoulder/Elbow Degenerative Joint Disease*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	No DJD	34	31.7	14
	Initial degeneration	7	47.5	9.4
	Severe degeneration	2	40	
Archaic Tenn	No DJD	9	27.8	8.8
	Initial degeneration	16	43.1	10.4
	Severe degeneration	1	65	
Woodland	No DJD	14	32.7	9.5
Mississippian	No DJD	56	32.2	7.2
	Initial degeneration	14	44.6	9.7
	Severe degeneration	11	45.4	15.5
Diaguita	No DJD	23	35.3	12.6
	Initial degeneration	4	52.5	15
	Severe degeneration	2	55	7

* Bolded values are mean ages for scores with significant differences between cultures.

Table 44. Mean Age by Score for Hip/Knee Degenerative Joint Disease*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	No DJD	43	32.5	13.1
	Initial degeneration	1	45	
	Severe degeneration	4	49.5	7.1
Archaic Tenn	No DJD	12	34.9	16.9
	Initial degeneration	13	38.8	7.4
	Severe degeneration	2	52.5	17.6
Woodland	No DJD	13	33.4	8.9
Mississippian	No DJD	79	32.6	8.6
	Initial degeneration	12	44.5	11.7
	Severe degeneration	7	42.8	9
Diaguaita	No DJD	22	35	11.7
	Initial degeneration	11	45.9	12.2
	Severe degeneration	3	50	10

Table 45. Mean Age by Score for Wrist Degenerative Joint Disease*

Culture	Score	N	Mean Age	Std Dev
Archaic Chile	No DJD	32	31.8	14
	DJD	4	43.7	6.2
Archaic Tenn	No DJD	11	32	9.5
	DJD	12	45	10
Woodland	No DJD	7	31.5	10
Mississippian	No DJD	52	33.8	7.7
	DJD	7	52.8	11.8
Diaguaita	No DJD	13	36.4	13
	DJD	4	57.5	12.5

* Bolded values are mean ages for scores with significant differences between cultures.



Figure 1. Archaeological Sites of the Chilean Semi-arid North

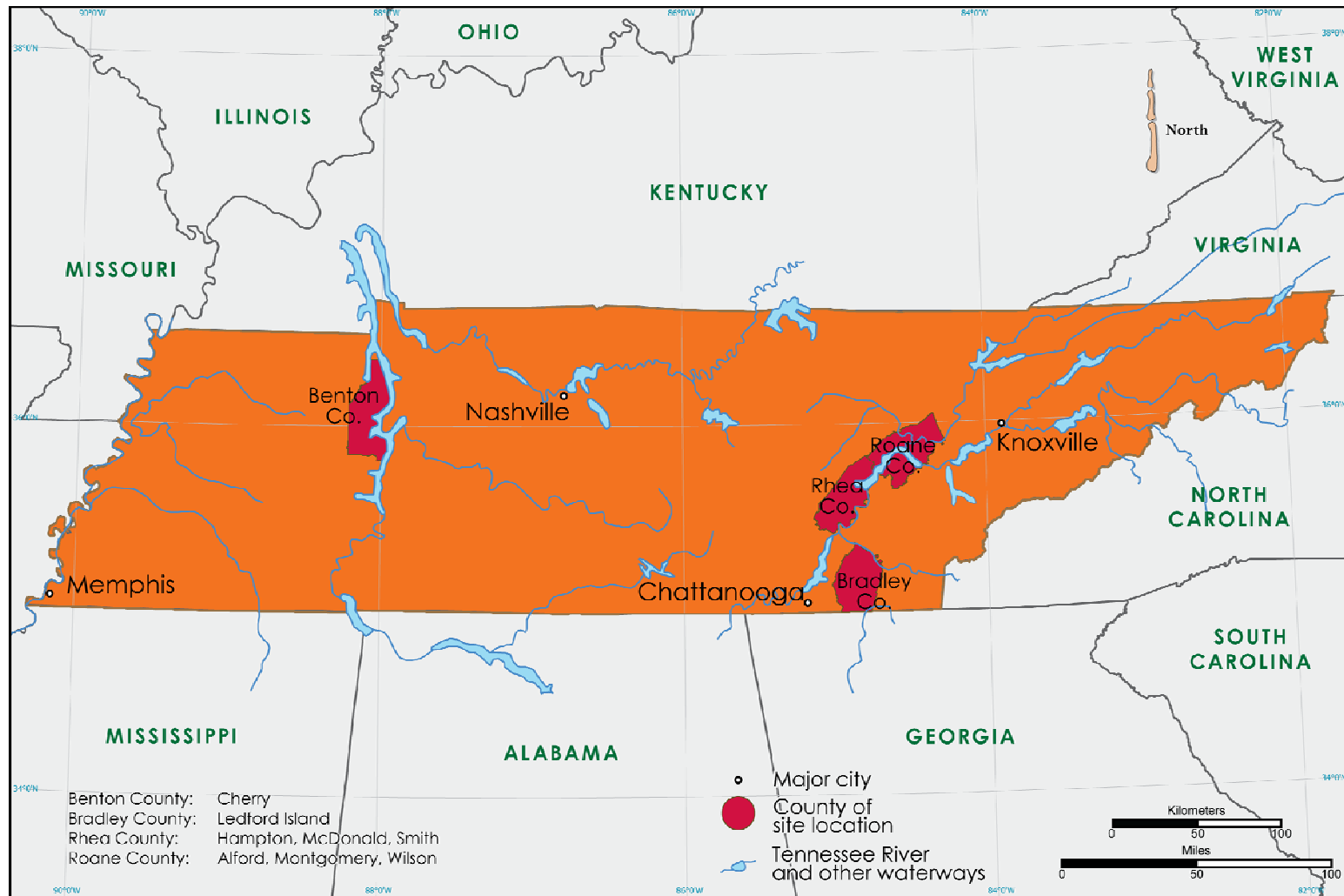


Figure 2. Analyzed Archaeological Site Locations in Tennessee

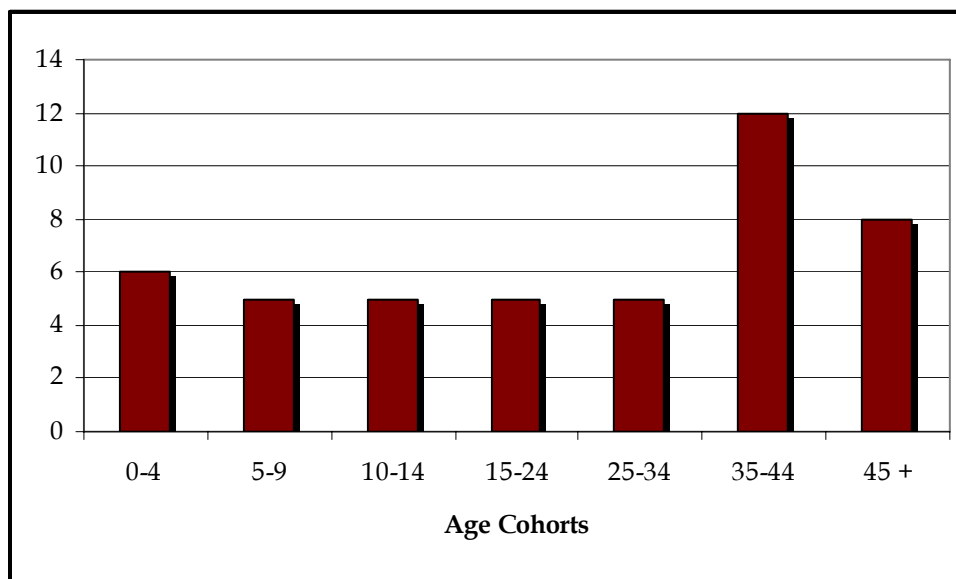


Figure 3. Cherry Age Distribution

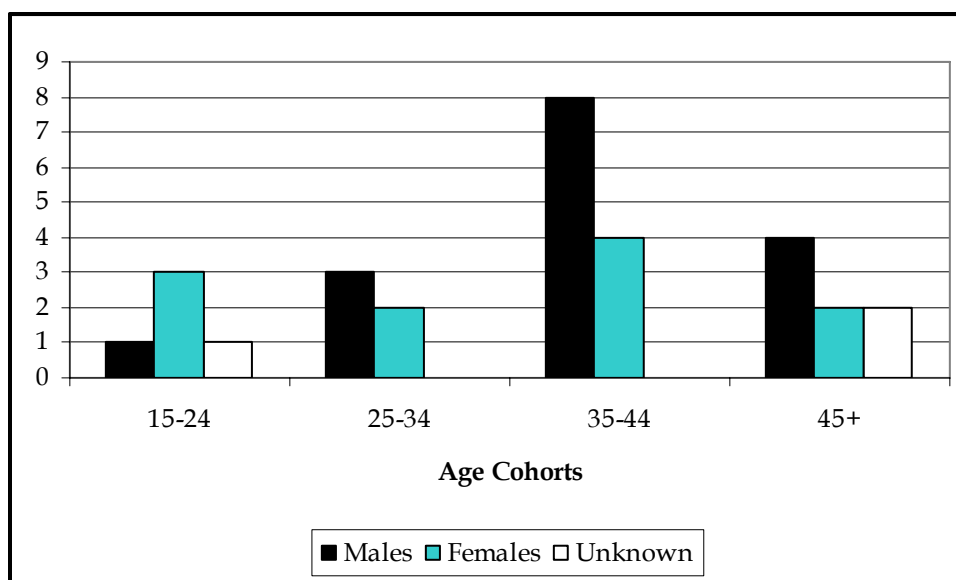


Figure 4. Cherry Age Distribution, Adult Males and Females

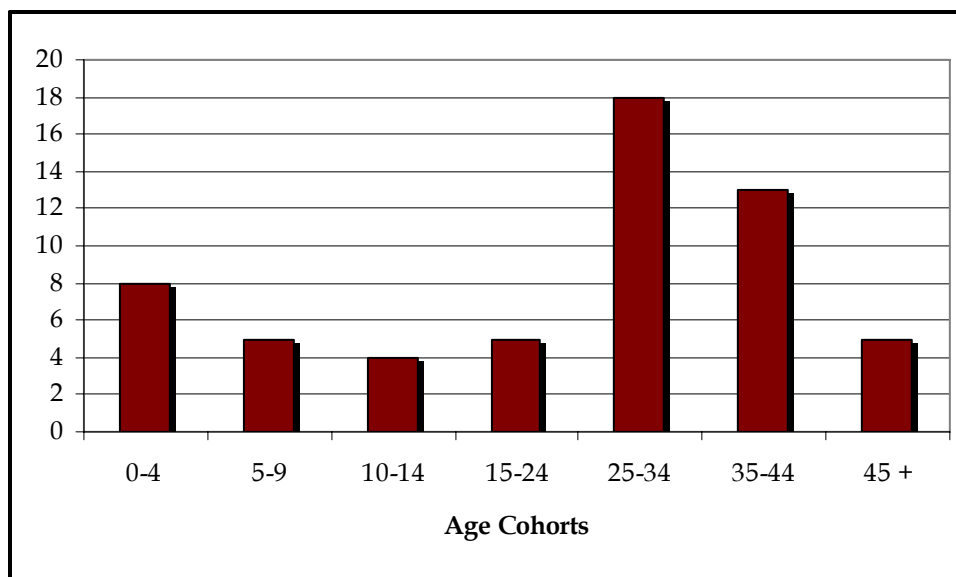


Figure 5. Woodland Age Distribution

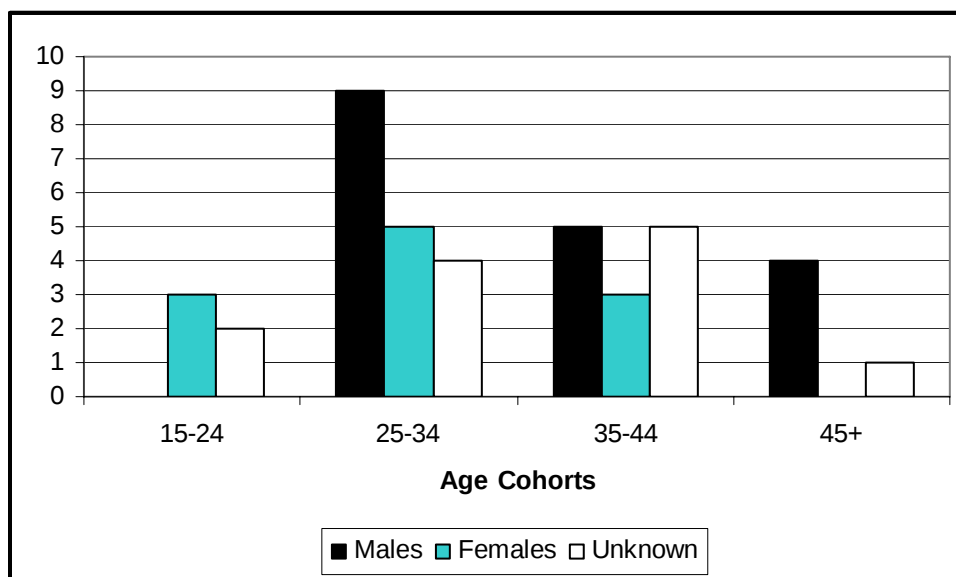


Figure 6. Woodland Age Distribution, Adult Males and Females

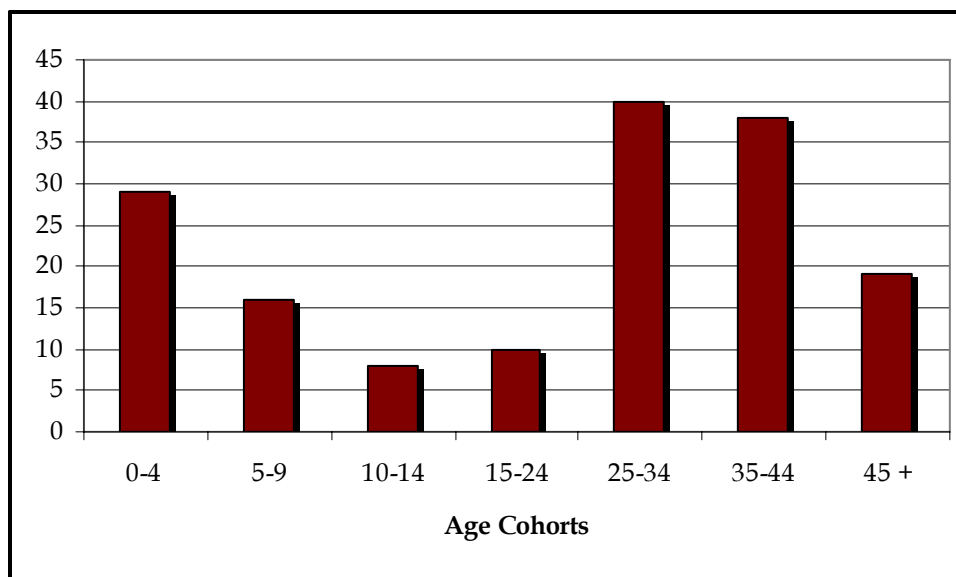


Figure 7. Ledford Island Age Distribution

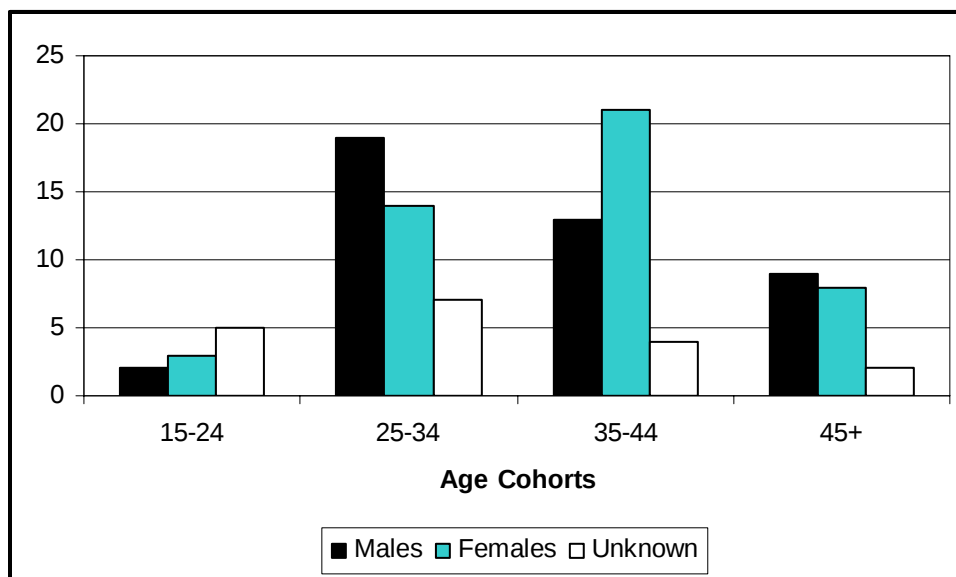


Figure 8. Ledford Island Age Distribution, Adult Males and Females

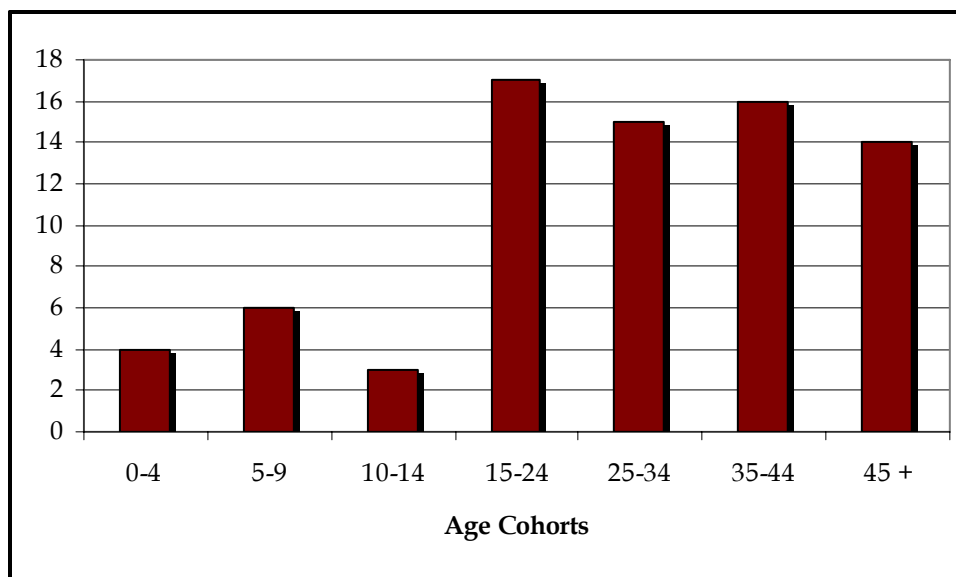


Figure 9. Diaguia Age Distribution

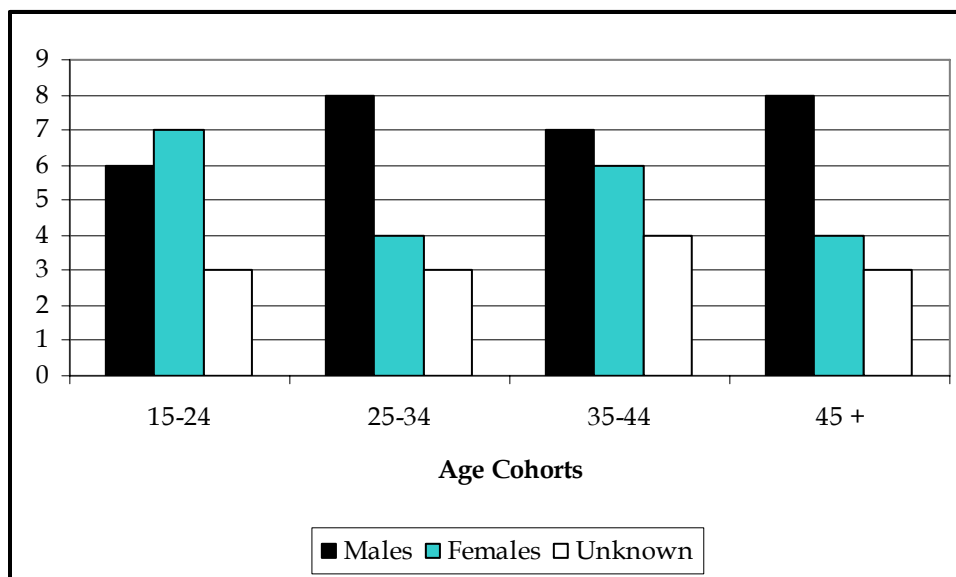


Figure 10. Diaguia Age Distribution, Adult Males and Females

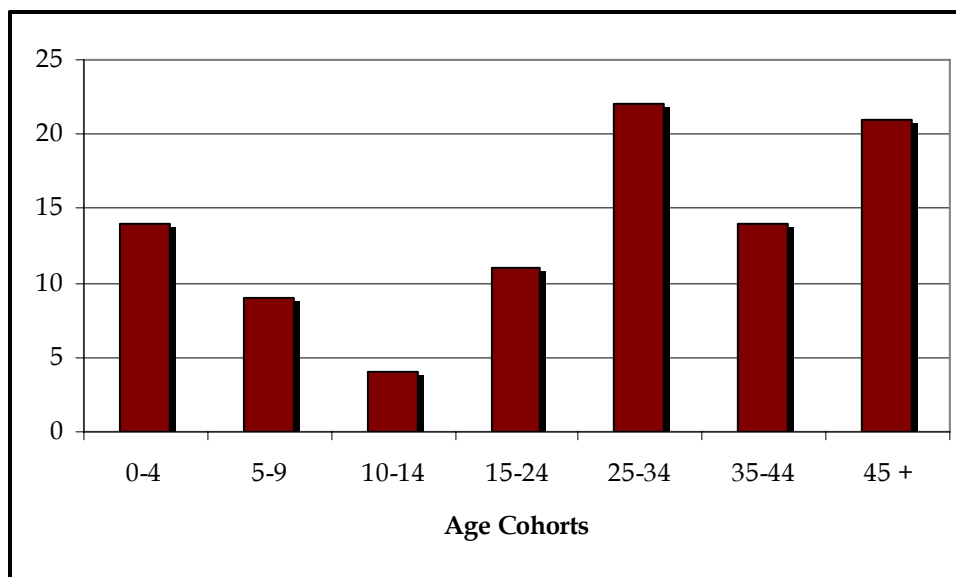


Figure 11. Chilean Archaic Age Distribution

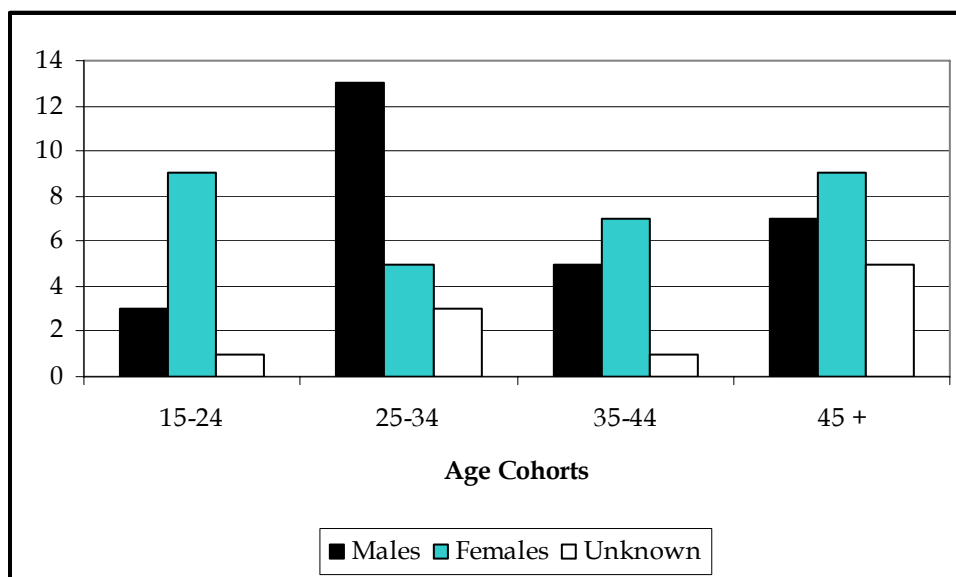


Figure 12. Chilean Archaic Age Distribution, Adult Males and Females

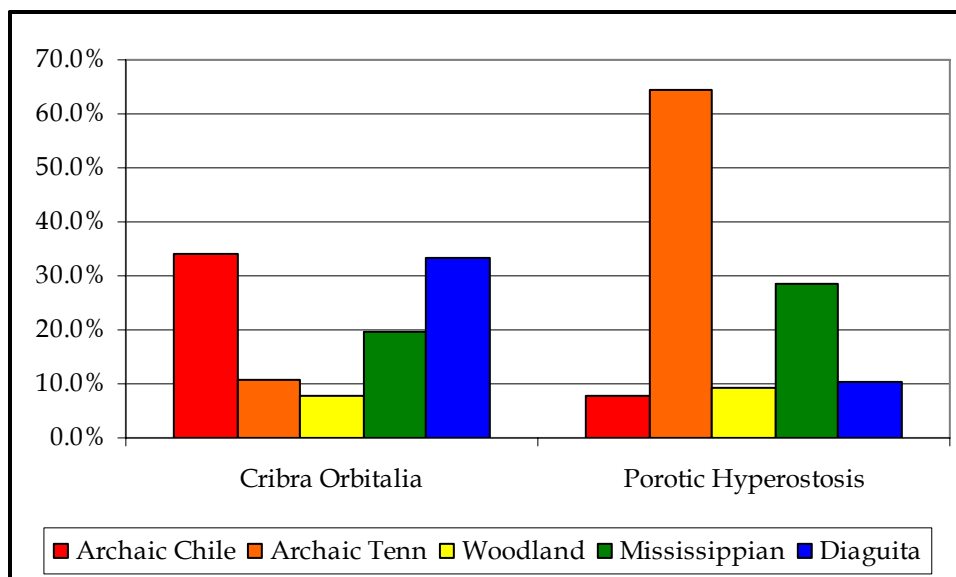


Figure 13. Cribra Orbitalia and Porotic Hyperostosis Frequency

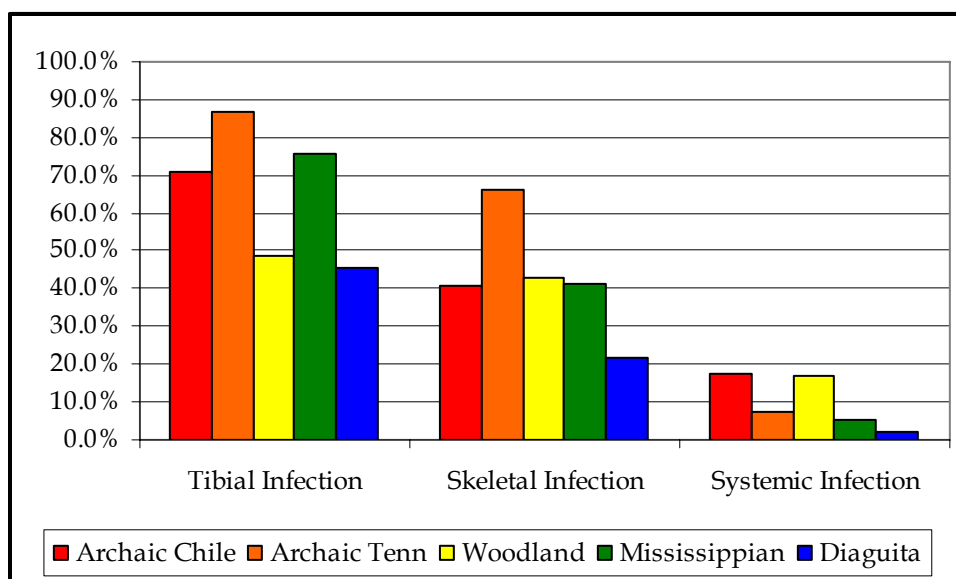


Figure 14. Infection Frequency

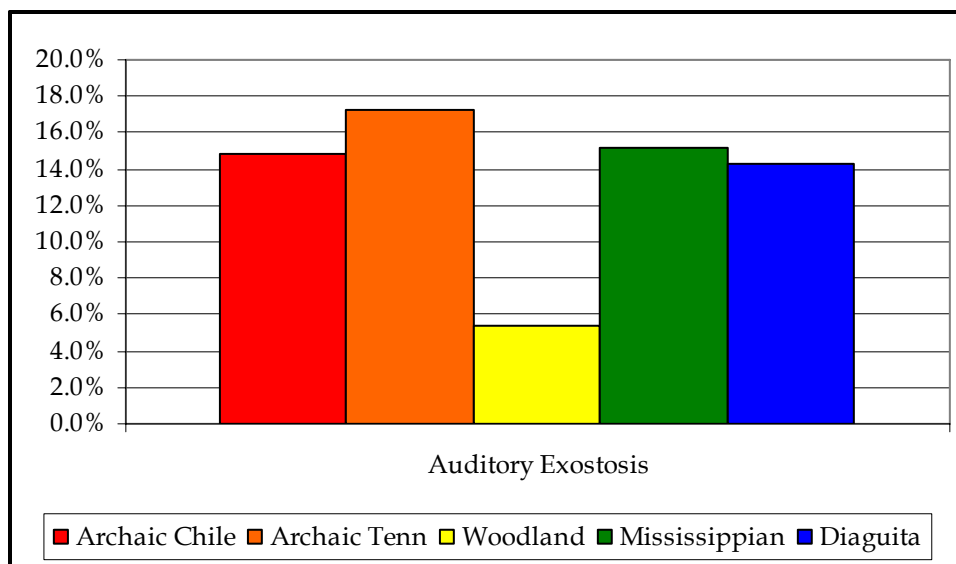


Figure 15. Auditory Exostosis Frequency

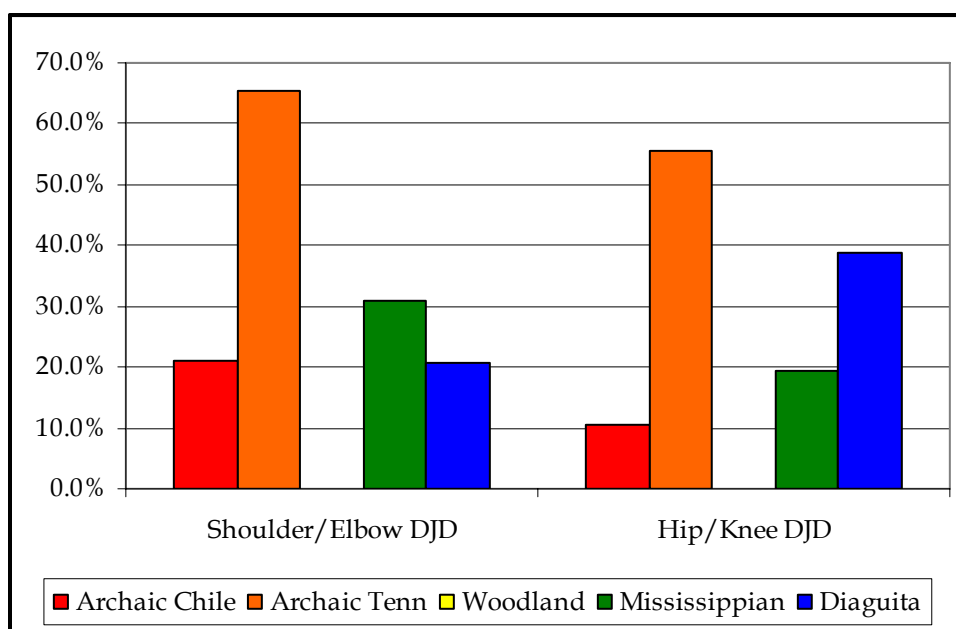


Figure 16. Arm and Leg Degenerative Joint Disease Frequency

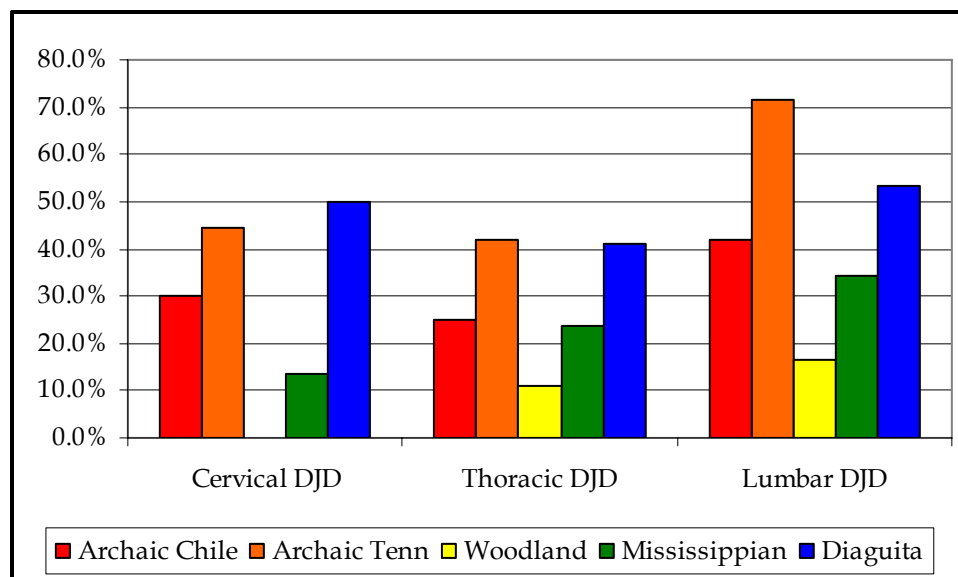


Figure 17. Vertebral Column Degenerative Joint Disease Frequency

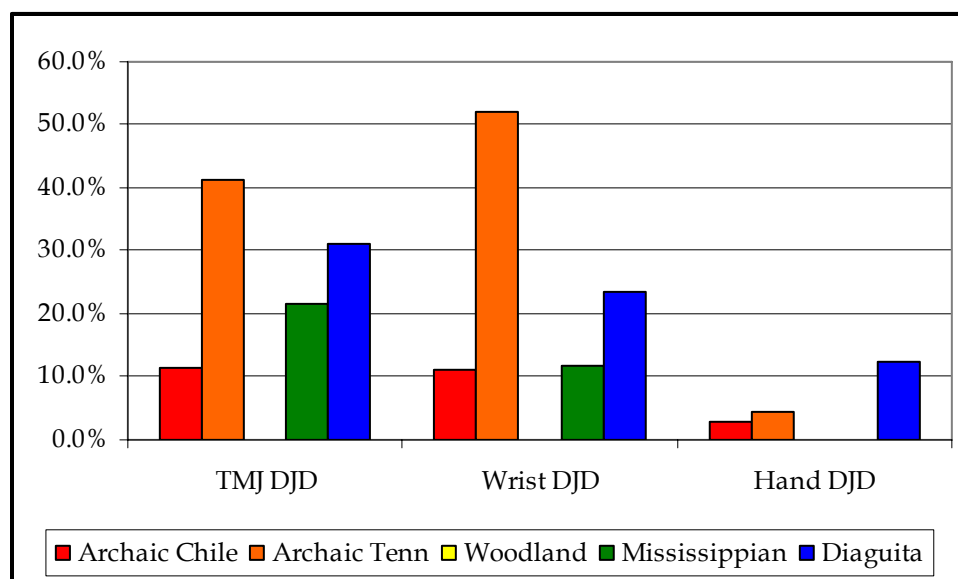


Figure 18. TMJ, Wrist, and Hand Degenerative Joint Disease Frequency

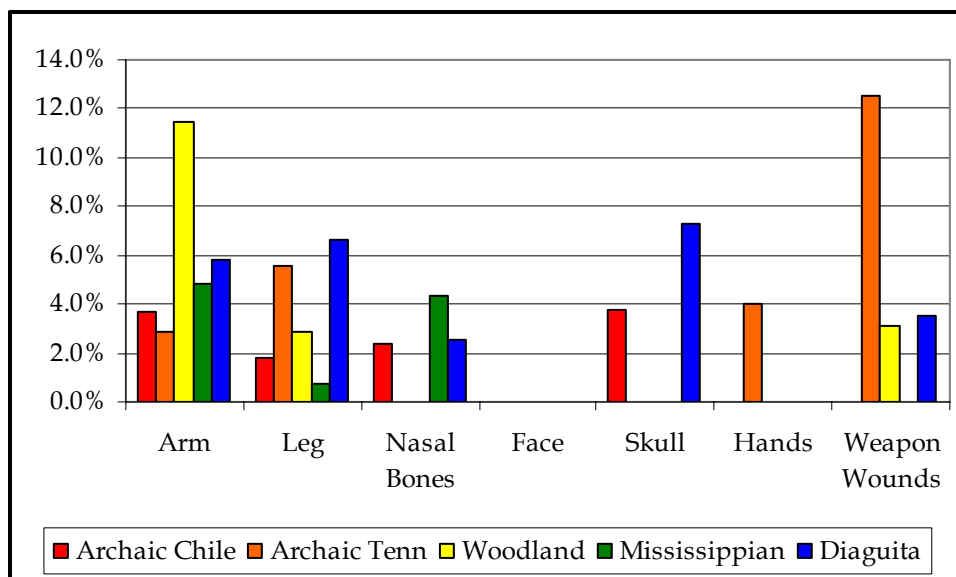


Figure 19. Trauma Frequency

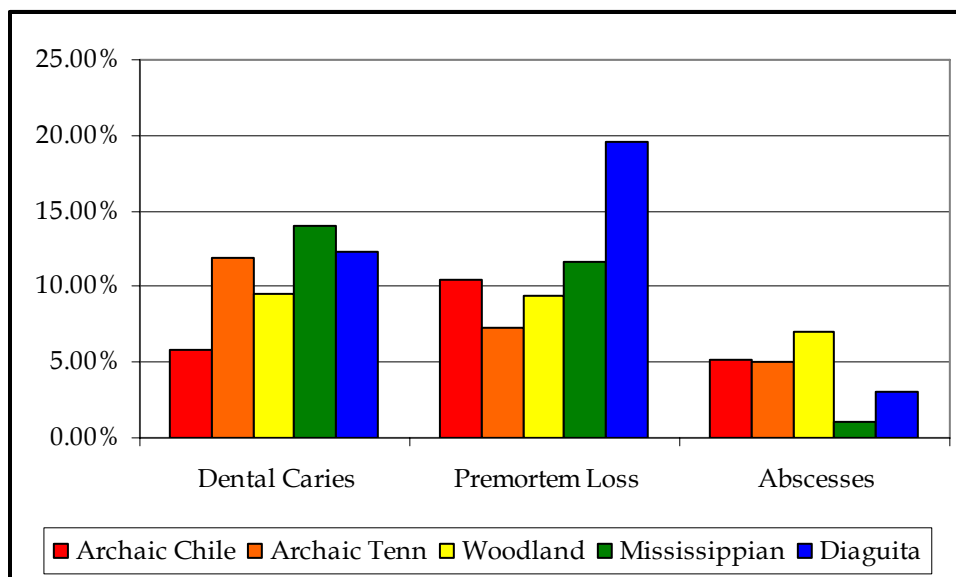


Figure 20. Dental Disease Frequency

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
				Sig.	99% Confidence Interval		Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound		Lower Bound	Upper Bound
Pearson Chi-Square	25.716 ^a	8	.001	.002 ^b	.001	.003			
Likelihood Ratio	28.669	8	.000	.001 ^b	.000	.001			
Fisher's Exact Test	25.200			.001 ^b	.000	.002			
Linear-by-Linear Association	.650 ^c	1	.420	.428 ^b	.415	.441	.231 ^b	.221	.242
N of Valid Cases	236								

a. 4 cells (26.7%) have expected count less than 5. The minimum expected count is 2.31.

b. Based on 10000 sampled tables with starting seed 957002199.

c. The standardized statistic is .806.

Figure 21. Pearson Chi-square Results, Enamel Hypoplasia Occurrence

culture * hypo Crosstabulation

			hypo			Total
			no hypo	one occurrence	two occurrences	
culture	Archaic Chile	Count	33	3	0	36
		Expected Count	24.1	8.7	3.2	36.0
		% within culture	91.7%	8.3%	.0%	100.0%
		Adjusted Residual	3.4	-2.4	-2.0	
	Archaic Tenn	Count	12	11	3	26
		Expected Count	17.4	6.3	2.3	26.0
		% within culture	46.2%	42.3%	11.5%	100.0%
		Adjusted Residual	-2.4	2.3	.5	
	Woodland	Count	16	6	6	28
		Expected Count	18.7	6.8	2.5	28.0
		% within culture	57.1%	21.4%	21.4%	100.0%
		Adjusted Residual	-1.2	-.4	2.5	
	Mississippian	Count	66	30	11	107
		Expected Count	71.6	25.8	9.5	107.0
		% within culture	61.7%	28.0%	10.3%	100.0%
		Adjusted Residual	-1.6	1.3	.7	
	Diaguaita	Count	31	7	1	39
		Expected Count	26.1	9.4	3.5	39.0
		% within culture	79.5%	17.9%	2.6%	100.0%
		Adjusted Residual	1.8	-1.0	-1.5	
Total	Count	158	57	21	236	
	Expected Count	158.0	57.0	21.0	236.0	
	% within culture	66.9%	24.2%	8.9%	100.0%	

Figure 22. Pearson Chi-square Crosstabulation, Enamel Hypoplasia Occurrence

Ranks			
culture		N	Mean Rank
rcaries	Archaic Chile	55	121.41
	Archaic Tenn	36	150.35
	Woodland	46	140.37
	Mississippian	121	184.43
	Diaguita	56	153.43
	Total	314	

Figure 23. Kruskal-Wallis Ranks, Dental Caries by Culture

Test Statistics ^{b,c}			
			rcaries
Chi-Square			22.166
df			4
Asymp. Sig.			.000
Monte Carlo	Sig.		.000 ^a
Sig.	99% Confidence Lower Bound		.000
	Interval Upper Bound		.001

a. Based on 10000 sampled tables with starting seed 299883525.

b. Kruskal Wallis Test

c. Grouping Variable: culture

Figure 24. ANOVA Test Results on Dental Caries Kruskal-Wallis Ranks

Vita

Elizabeth A. DiGangi was born in June of 1977 on Long Island, New York. After graduating from Roosevelt High School in Yonkers, New York, she decided to brave the snow and attended the University at Buffalo where she joint majored in Anthropology and History, earning a Bachelor of Arts degree with the overall honor of *magna cum laude* and with highest distinction honors for the History major. She remained at UB, earning the Master of Arts degree in Anthropology in 2002. Having been bitten by the forensic anthropology bug, she decided to pursue a Ph.D. in physical anthropology at The University of Tennessee, where she was privileged enough to gain valuable hands-on experience with skeletal analysis at home and abroad, archaeology in the Caribbean, teaching undergraduates, and in the forensic realm as well. Elizabeth graduated with a Ph.D. in Physical Anthropology from The University of Tennessee in May of 2008, with future plans including further research into the health of prehistoric Chileans and Tennesseans, teaching anthropology, becoming a board-certified forensic anthropologist, traveling the world, and insisting that everyone she knows (from students to family members) address her as “Dr. DiGangi”.