THE SENESCENT MIMBRES POPULATION: AN APPLICATION OF THE TRANSITION ANALYSIS TO THE NAN RANCH RUIN SKELETAL SAMPLE

A Thesis

by

ALINE A. LOVINGS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

December 2011

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Lori Wright
Committee Members,	Suzanne Eckert
	Rogelio Saenz
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ABSTRACT

The Senescent Mimbres Population: An Application of the Transition Analysis to the NAN Ranch Ruin Skeletal Sample. (December 2011)

Aline A. Lovings, B.A., Texas A&M University

Chair of Advisory Committee: Dr. Lori E. Wright

This study uses Transition Analysis on the Mimbres skeletal remains of the NAN Ranch Ruin to provide a more complete picture of its demography. Previous attempts to reconstruct the demographic structure of prehistoric populations have been hindered by aging methods that provide biased age distribution. Early methods had a tendency to produce age distribution similar to that of the reference sample that was used to create them. In addition, they often overlooked sexual dimorphism and left out the senescent portion of the population which in turns produced inaccurate population structures. Transition Analysis is a multifactorial approach to estimate the age-at-death of adult skeletons that focuses on the cranium, the pubic symphysis and the auricular surface of the ilium. The method relies heavily on the Bayesian probability that a given trait or a given combination of traits is displayed at a given age; it recognizes sexual dimorphism, performs well on fragmentary skeletons and allows for the age estimation of older individuals.

The NAN Ranch Ruin sample consists of over 240 individuals, including 185 from the Classic Period. A previous study focused on the 81 individuals from the Classic

period that were collected during the first five years of excavations. Following age estimation of adult skeleton I constructed composite abridged life tables. For the Classic Period, I found a high infant mortality rate (47%) and low life expectancy at birth (21.14 years) as expected. However, this analysis produced different mortality patterns than older demographic studies, where mid adult mortality increases only slightly, decreases in late adulthood (40-55 years old) and increases again in senescence (55-80 years old), instead of increasing steadily in adulthood to culminate at age 50. This difference is a consequence of the aging methods that have been used to analyze other southwestern prehistoric samples. Finally, while I was not able to confirm different mortality patterns between males and females, I found that people from the east roomblock enjoyed greater longevity than those from the south roomblock, though the difference is not statistically significant.

DEDICATION

To my parents Jean-Marie and Geneviève Villeminey for their eternal love and unconditional support.

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CHAPTER I

INTRODUCTION

Research Goals

The Mimbres lived along the river of the same name in New Mexico and within surrounding drainage systems from about A.D. 200 to 1180 A.D. They are particularly famous for their exquisite Classic Black-on-White pottery often associated with funerary remains. The Classic Period (900 A.D. to 1180 A.D.) represents the apogee of Mimbres society in terms of population aggregation and ceramic production. In the mid twelfth century they dispersed into small more mobile groups, replacing their renowned pottery tradition with other styles, but essentially maintaining the same way of life.

The transition to the Classic Period from Pithouse periods as well as the more sudden transition to the Post Classic Period has been at the heart of Mimbres research for decades. Among those investigations, population studies at the valley and at the site level were conducted. Specifically, at the site level, the interest in Mimbres ceramics often associated with burials has allowed the careful and systematic excavation of skeletal remains, which are usually well preserved. Once excavated, skeletal remains can provide valuable information on the overall health and nutrition of a particular population as well as provide information on its demography, such as fertility and mortality patterns. The first step in analyzing skeletal remains is to estimate the sex and age of each skeleton. Sex estimation is not possible on juvenile skeletons, but is

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performed regularly on adult skeletons. Conversely, age estimates of juvenile skeletons are fairly accurate because they are based on the developmental changes of the bones; whereas age estimates for mature skeletons is more problematic. Age estimates on adult skeletons relies on unidirectional degenerative changes that are harder to analyze with precision because they are more heavily influenced by other factors than age alone, including health, nutrition, activity and environmental factors.

Estimating the age of adult skeletons is an important part of skeletal analysis in both archaeology and forensics, yet it is still a contentious topic. During the majority of the twentieth century, scientists focused on creating and refining existing aging methods, mainly based on the cranium and pelvis, but on other skeletal components as well. However, vivid critiques in the last few decades of the century have prompted the questioning of older methods and motivated the refinement of aging methods that now rely more heavily on computer assisted Bayesian statistics, as inspired from work in other biological fields, hence seeking more of a consensus within paleodemography.

Despite well excavated skeletal remains in the Mimbres Valley, very few studies have focused on the demography of those skeletal populations. At NAN Ranch Ruin, which is the subject of this case study, a paleodemographic study was performed by Suzanne Patrick (1988) on the 95 burials collected during the first five years of excavation. She used aging methods that have since come under fire and have some limitations, particularly in terms of estimating the age of older adults, which are often grouped within one open-ended interval (50 years and older) that is not very informative and offers an erroneous picture of adult mortality.

The purpose of the study is twofold. First, I have analyzed the age of all excavated adult skeletons, hence bringing the sample size of my study to over 240 burials as compared to the 95 burials that were available to Patrick. Secondly, my analysis relies on Transition Analysis (Boldsen et al. 2002), which draws from previous work on the cranium and pelvis, combined in a multifactorial approach and that relies on Bayesian statistics to offer a maximum likelihood age estimates. This approach is more reliable than older methods and less subject to constraints from the reference samples used to establish the method.

With this case study, my goal is to provide a more complete demographic profile of the NAN Ranch population and to compare it to other North American Southwest populations as well as to continue to contribute to the questions surrounding the Mimbres, their health, population growth and decline.

With the new method, I intend to refine the work of Patrick (1988). In addition, I hope to determine if there are significant differences in demographic indicators between males and females, between room blocks as well as between time periods as the sample allows it. Finally, I intend to try to determine how much an aging method can influence our understanding of ancient populations, especially in terms of old adult mortality, which is often overshadowed by the weaknesses of older aging methods.

Organization of the Thesis

First in Chapter II , I review the evolution of Mimbres archaeology, through its history, and material culture as well as through issues of human behavior that have driven Mimbres research in the past decades, specifically Mimbres population movement and connectivity. Then in Chapter III, I discuss paleodemography, its challenges and recent advancements, especially as it relates to Mimbres demography. Paleodemography differs from demography in that it focuses on a population of deceased individuals that are believed to be representative of a once living population, as opposed to dealing with a living population directly. Thus the discipline requires certain assumptions and faces challenges, particularly in terms of the methods used to estimate the age of an individual based on skeletal indicators only, as well as challenges with the statistical representation of population dynamics. In the following chapter, I describe the sample for this case study, its history of excavations, history of occupation and archaeological findings in terms of architecture, ceramic production and mortuary patterns. I specifically review the skeletal sample, its excavation, conservation and bioarchaeological findings. In Chapter V, I describe Transition Analysis (Boldsen et al. 2002). I address skeletal observations and the scoring system which I used to estimate the age of adult skeletons. In Chapter VI, I discuss the building of NAN Ranch life tables and compare my findings with those of Patrick’s (1988). Finally, in Chapter VII, I discuss NAN Ranch demography, specifically the senescent portion of the population which is often overlooked. I will also compare my results to other prehistoric Southwest populations. In my final chapter, I summarize my findings and investigate future research prospect.

CHAPTER II

MIMBRES ARCHAEOLOGY

The American Southwest has been populated by several cultures throughout the last 10, 000 to 15,000 years; it is divided into three major cultural traditions: the Ancestral Pueblo to the north, the Hohokam to the west and the Mogollon in the southeast. Each cultural tradition developed within the different environments of the region. The Ancestral Pueblo lived in the northern plateau, on and around mesas. Sandstone was readily available, and was commonly used as building material, as we can see from the remarkable architecture the Ancestral Pueblo left behind. The Hohokam lived in desert areas and built single-unit dwellings. They are known for their extensive irrigation systems, mound platforms, ball courts and their active involvement in the shell bead trade. Finally, the Mogollon occupied a more diverse environment with rugged mountains to the north, foothills, basin and ranges to the south; located mainly in southwestern New Mexico, eastern Arizona and northern Chihuahua in Mexico. The many rivers with low alluvial terraces and year round streams offered adequate water supply to sustain larger groups of people than in other parts of the Southwest (LeBlanc 1983).

The Mimbres culture belonged to the Mogollon tradition. Its name is derived from the Spanish word for willow, which grows abundantly near the river of the same name (Shafer 2003). The Mimbres occupied the most densely populated area of the Mogollon region, primarily owing to the availability of good arable land and water in and around the Mimbres and upper Gila River valleys. Figure 1 shows the location of the

Mimbres cultural region within the American Southwest. The Mimbres exerted a cultural continuity from 200 to about 1150 AD, which included a long ceramic tradition that culminated with the exquisite Classic Black-on-White pottery with naturalistic designs.

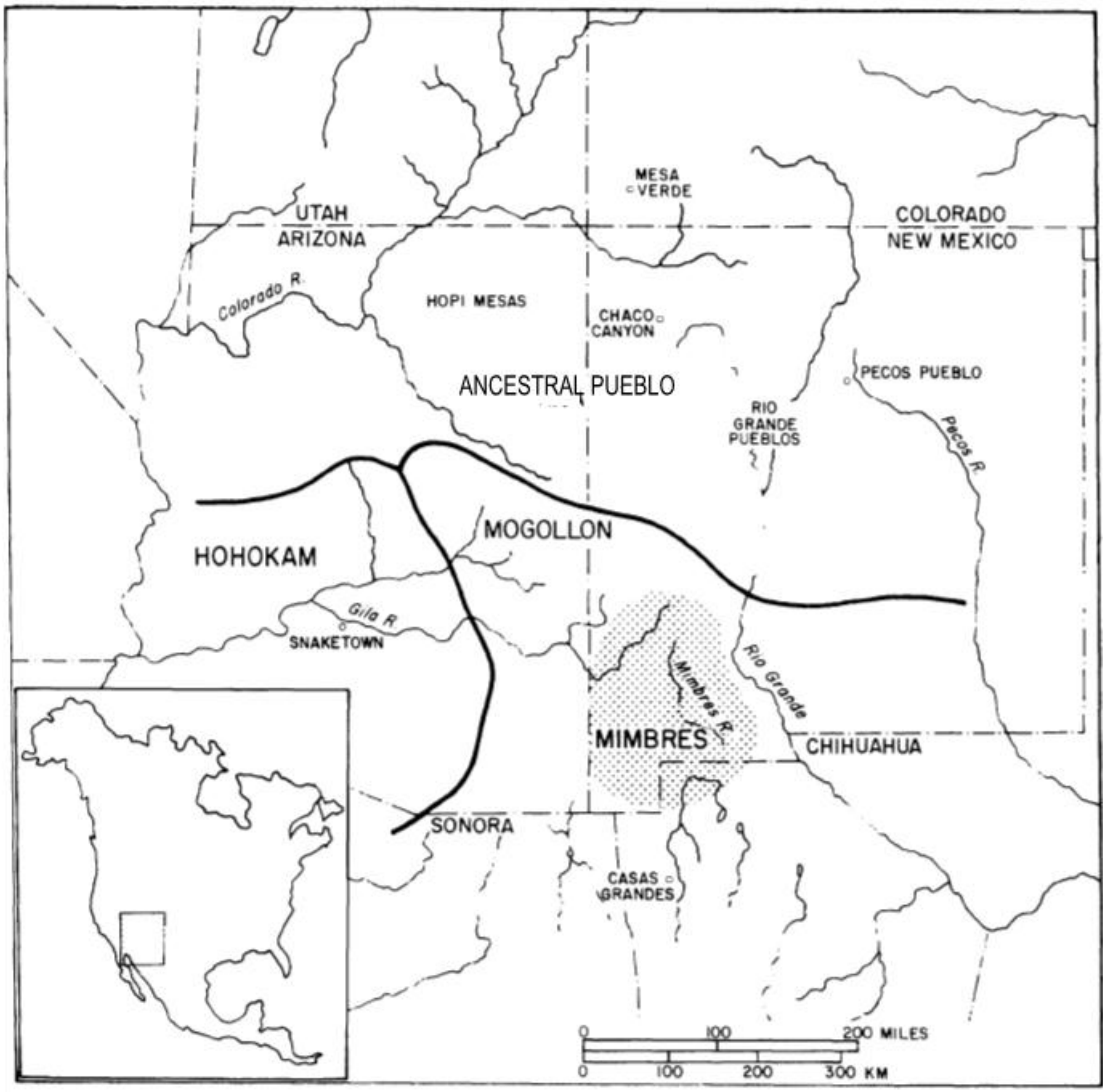

Fig. 1. Location of the Mimbres region within the major North American Southwest cultural traditions (after LeBlanc 1983: Figure I).

History of Mimbres Archaeological Studies

The American Southwest became a U.S. territory after the war with Mexico in the mid 1800's, and true archeological studies began just a few decades later. The bulk of early southwest archaeology focused mainly on the northern territories where indigenous people still lived and where major architectural edifices still stand. Adolph Bandelier, Clement Webster, Walter Hough and Nes Nelson all visited the Mimbres Valley and made mention of the Mimbres ruins they encountered, but the region did not capture people's interest as early as elsewhere. It is not until the early 1900's that people became fascinated with the area, when a New Mexico rancher invited Smithsonian scientists to look at them (Fewkes 1914; Fewkes 1916; Fewkes 1923; LeBlanc 1983; Shafer 2003).

The first major wave of excavations ensued, beginning in the 1930s with the work of Bradfield, the Cosgroves, Haury, Nesbitt and Bryan, among others, at Cameron Creek, Swarts Ruin, Harris Village, Mattocks Ruin and Galaz Ruin, respectively (Bradfield 1929; Bryan 1931a; Bryan 1931b; Cosgrove and Cosgrove 1932; Haury 1936; Nesbitt 1931). The Cosgroves provided the first model of Mimbres culture, while Haury determined the first temporal phases of the Mogollon tradition and how the Mimbres culture fit within them (Shafer 2003). Those early archaeologists took detailed notes of their various excavations and surveys but not all were published. In addition, a clearly defined chronology had not been established, which made interpretation of the data difficult at that time (Shafer and Taylor 1986). During the following three decades, there were hardly any organized scientific excavations of Mimbres ruins, save some salvage expeditions. Looters, however, visited the area, frequently destroying many sites in the quest for the coveted Classic Black-on-White Mimbres pottery. In 1974, as a response to the rapid destruction of Mimbres vestiges, the Mimbres Foundation conducted a number of surveys and excavations that allowed scholars to redefine the chronological sequence for the area and provide the first explanatory models (Anyon et al. 1981).

Chronology

Pre-Mimbres chronology

The American Southwest has been inhabited for at least the past 12,000 years. From 10,500 B.C. to about 7500 B.C. Paleoindians occupied the region, though the population was small and mostly dispersed. Very little is actually known about the Paleoindian Period in that area (Fagan 2000; Lekson 2006). Around 6000 B.C, the climate began to warm up, making for a dryer environment. Early Holocene forests were slowly replaced with scrubs and grasslands. Archaic southwestern inhabitants adapted their subsistence strategies to the changing environment, relying mainly on hunting smaller game and gathering plant food. The Archaic Southwest is not well documented either because it consisted mainly of widely scattered, small provisional sites, except in the highlands were some long term use or reuse of Archaic pithouses and rockshelters has been reported, especially in the latter part of the Archaic Period (Lekson 2006; Wills 1996). Archaic people left behind lithic material that allows for some distinction of regional variation, especially towards the end of the Archaic Period when territorial control of resources became more prominent (Fagan 2000; Lekson 2006; Vierra 2011; Wills 1989). They did not produce any ceramics or much in a way of buildings. Some basketry, fiber and fur materials have been retrieved from dry caves or rockshelters or in the highlands, but in all, few organic artifacts have been recovered, especially from the valley and desert areas.

Archaic hunter-gatherers of the Mimbres Valley maintained a similar way of life until about 200 A.D. At that time a major shift was underway in the region towards more permanent housing in the river valleys, longer site occupation (although people still remained somewhat mobile), and the appearance of clay containers (Hunter-Anderson 1986; LeBlanc 1983; Wills 1989). Thus began the Mimbres cultural tradition.

Mimbres chronology

> When the Mimbres first appear in the archaeological record, their hunting practices and use of desert plants were much the same as the earlier Archaic people of the Chihuahan Desert; only the use of corn, pottery and more permanent pithouses separate them materially from their Archaic ancestors (Shafer 1995:42).

The Mimbres flourished from about 200 A.D to about 1180 A.D. The chronology of their occupation has been secured using tree ring, archaeomagnetic, radiocarbon and obsidian hydration dating from various sites and it is also based on settlement, architectural, ceramic evolution, as well as stratigraphy (Lekson 2006; Shafer 2003). Initial Mogollon-Mimbres chronological sequences were based on excavation reports from sites that were investigated in the early parts of the twentieth century (Haury 1936), but the renewed interest in Mimbres archaeology in the 1970s allowed for the more refined chronology that is commonly used today (Anyon et al. 1981; LeBlanc 1983).

Mimbres chronology is composed of three periods: the Early Pithouse Period (A.D. 200-550), the Late Pithouse Period (A.D 550-1000) and the Classic Mimbres

Period (A.D. 1000-1150). The change from one period to another is characterized by a major adaptive shift in settlement location or architecture, respectively. During the Early Pithouse Period, the Mimbres settled on isolated knolls overlooking the floodplains. Later they moved down to the first river terraces, hence beginning the subsequent Late Pithouse Period. Similarly, the sudden architectural change from subterranean pithouses to above ground adobe pueblo villages characterizes the beginning of the Classic Mimbres Period.

Throughout all periods there was a continuous evolution of the material culture of the Mimbres, and scientists have broken down the broader periods into phases, when appropriate, that capture this cultural evolution. Table 1 shows the details of Mimbres chronology. The Early Pithouse Period is sometimes referred to as the Cumbre Phase, but unlike the Late Pithouse Period phases, this is not to temporally distinguish the material cultural evolution from the period, but rather to geographically distinguish it from contemporaneous Mogollon settlements in other areas of the American Southwest. The Late Pithouse Period has been broken down into three phases as follows: the Georgetown Phase, characterized by San Francisco Red pottery, the San Francisco Phase, famous for its Mogollon Red-on-Brown ceramics and finally the Three Circle Phase typified by Three Circle Red-on-White and Mimbres Boldface Black-on-White (Style I) pottery (Anyon et al. 1981). Finally, the Classic Period is divided into two phases: the Classic Phase and the Terminal Classic Phase.

TABLE 1. Mimbres chronology

Period		Phase	
Paleoindian	8000-9500 B.C.	Clovis	8880-9500 B.C.
		Folsom	8880-8000 B.C.
Archaic	8000-200 A.D.	Early Agricultural	1200 B.C – 200 A.D.
Early Pithouse	220 A.D. - 550 A.D.	Cumbre	
Late Pithouse	550 A.D. - 1000 A.D.	Georgetown	550-650 A.D.
		San Francisco	650-750 A.D.
		Three Circle	750-1000 A.D.
Classic	1000 A.D.- 1180 A.D.	Classic	1000-1130 A.D.
		Terminal Classic	1130-1180 A.D.
Postclassic	1150-1450 A.D.	Black Mountain	1150-1300 A.D.
		Cliff	1300-1450 A.D.
Apache	1650-1880 A.D.	Historic	

Around 1150 A.D. there is evidence of widespread abandonment or dispersal throughout the valley. Although people returned shortly after, the continuation of the Mimbres material culture had dissipated and had been replaced by a seemingly distinct material culture during the following periods of occupation: the Postclassic Period (Black Mountain Phase A.D. 1200-1300 and Cliff Phase A.D. 1300-1450) and the Apache Period (A.D. 1650 -1880) (Shafer 2003). This distinction between the Classic Period and the subsequent Black Mountain and Cliff phases was based on the disappearance of Mimbres Black-on-White pottery, but there is a notable continuity during that time in other aspect of material culture and technology. The Terminal Classic and Postclassic overlap slightly depending on the area (Hegmon et al. 1999).

The transition from pithouse to pueblo that occurred around 900 A.D. is a subject of contention. Some have seen the change as a sudden shift from hunter gatherers to full blown agriculture (Gilman 1987), while others argue for a transitional phase (of 150-200 years) between the Late Pithouse and Classic Periods (Diehl 1997; Lekson 1988; Lekson 2006; Shafer 1995). Such a phase has been referred to as Mangas (in the Gila river valley) or Late Three Circle or Transitional. The transition relies on changes in architectural patterns, ceramics and mortuary customs. Between 900 and 1000 A.D. the first small surface pueblo emerged as well as Mimbres Black-on-White (Style II) pottery. It is possible that these single small surface pueblos were outside storerooms for the adjacent pithouses that were lacking inside storage. But Style II pottery has been found equally in modified pithouses with extended or blocked entrances, and in early surface pueblos. At the same time, subfloor inhumations with "killed" pottery became more common than the preceding extramural burials with smashed vessels and more secondary cremations have been reported (Lekson 1988; Shafer 1995).

Subsistence

Environmental context

Topography and climate. The Mimbres occupied an area that is very diverse, including desert, grasslands and mountains (Minnis 1985). It is located at the junction of three of the four American deserts, the Great Basin, Chihuahua and Sonora (Bettison et al. 1996). The desert area consists of wide plains with occasional mountain ranges and ephemeral waterways, while the mountain areas peak at 2900 m above sea level. The Mimbres river and some small drainages are the only year round sources of water in the region (Minnis 1985). The Mimbres people lived along several river branches, mainly the Gila and Mimbres rivers and their tributaries, which provided adequate water supply for crops. The climate is arid to semi-arid, which translates into low annual precipitation, hot summers and cold winters with some snowfall. Rain falling between July and September, accounts for about 40% of the annual precipitation. But it is rather unpredictable, in the form of localized heavy thunderstorms. In the winter, snow storms can provide sufficient water supply for successful germination and growth, if high winds in the spring do not compromise early growth (LeBlanc 1983; Minnis 1985).

Vegetation and fauna. The amount of annual precipitation and the length of the growing season vary greatly depending on the terrain and elevation. Parts of the Mimbres region are mountainous where ponderosa pine, gambel oak, juniper with open grass understory, douglas fir and spruce trees grow above 2135 meters in the Transitional Zone. This area receives most of the rain or snow but has a short frost free period that makes it inadequate for agriculture. In contrast, the desert areas of the Lower Chihuahuan Zone that lie below 1650 meters, have a longer frost free period, but the low annual rain fall and high evaporation rate makes it inadequate to sustain any type of agriculture. Any drainage is ephemeral and only desert shrubs and some mesquite and cottonwood survive there. The pigmy woodland area of the Upper Chihuahuan Zone, that lies between the Transitional and Lower Chihuahuan zones, provides the most adequate mix of sufficient rainfall and lengthy growing period, which allowed the Mimbres people to settle and begin farming (LeBlanc 1983; Minnis 1985).

In much of the area populated by the Mimbres, the vegetation consisted mainly of pine, shrubs, piñon and juniper forests in higher elevation and of grassland, sage brush, open piñon and juniper woodland in the lower areas. Agave, sotal, yucca, cactus, mesquite, cholla, wild onions and potatoes grow well (Fagan 2000; Minnis 1985; Shafer 2003). Today the area is populated by a variety of animals such as mule deer, bear, wolf, beaver and muskrats in high elevations and bighorn sheep, pronghorn antelope, jackrabbits, cottontail rabbits, gophers, prairie dogs, reptiles, insects and many species of birds in the floodplains and desert areas (Fagan 2000; Minnis 1985; Shafer 2003; Wills 1996).

Diet

The Southwest subsistence strategy remained almost the same for a very long time. Although no Paleoindian sites have been reported in the Mimbres Valley, we know from surrounding areas that they relied mainly on gathering foods and hunted small and large Pleistocene fauna such as mammoths and bisons. Once the climate warmed up and the area became more arid, small bands of Archaic hunter-gatherers remained mobile, aggregating and dispersing occasionally. They covered large distances to overcome food shortage due to unpredictable rainfall, intense summer heat and sometimes harsh winters. They continued to gather a variety of plants, seeds, tubers, nuts and fruits (mainly agaves, acorns, mesquite beans and piñon nuts) and hunted large game (deer, pronghorn) as well as migratory fowl (Lekson 2006; Vierra 2011).

Around 1500 B.C. maize was introduced into the North American Southwest from Mexico, but it did not become a big part of the Archaic southwest diet. Initially, it was likely an occasional complement to wild plants. It could not have become a substantial part of the Archaic diet until the cultivation of squash and beans (1000 B.C. and 500 B.C. respectively) became more widespread and with the appearance of a new variety of corn, *maiz de ocho* (500/700 A.D), which was better adapted to the dryer conditions of southwestern New Mexico (Diehl 1996; Galinat 1988; Minnis 1985; Tagg 1996; Upham et al. 1988).

The importance of maize in the Mimbres diet and the timing of its use in the American Southwest is a much debated subject. As a matter of fact, the mere presence of corn in the archaeological record does not necessarily mean full reliance on the cultigen. Increased dependence on corn varied greatly from region to region. Based on pollen analysis and the recovery of burned corn cobs, maize appeared in the region early on but before the Mimbres inhabited the valley. The intensification of its use has been linked to the appearance of specialized storage rooms and the evolution of ground stone morphology (Diehl 1994; Diehl 1996; Hard et al. 1996; Wills and Huckell 1994).

The increased need for agriculture in the Southwest coincided with a change in climate, but also with a change in population pressure from surrounding areas (Northern Mexico, California and Western Plains). Southwestern natives could no longer travel great distances to sustain their growing population and that of their neighbors and had to adapt their subsistence strategy to be more flexible but less mobile. Plant diversity in the Mimbres Valley could not sustain large groups of individuals year round (Minnis 1985). Under these conditions, the cultivation of maize, although difficult in that environment, became essential to the survival of the people (Wills 1989; Wills 1992). Though the transition to full blown agriculture was not as sudden and as stressful on the remaining foragers, as it was previously thought (Kohler et al. 2008).

Hence, around 200 A.D. Mimbres peoples likely began a more sedentary life style. From then on, people continued to grow corn, squash and beans, to hunt and gather food. The reliance on corn grew overtime to be at least half of the caloric intake during the Classic Mimbres Period (LeBlanc 1983). Ultimately, as populations grew, new species of corn appeared and new irrigation techniques were developed, settlement moved further away from the river valleys and higher up in the mountains, where agriculture was harder but eventually became possible.

Hunting and gathering continued to supplement the cultivation of the corn squash and beans triad. Gathered plants consisted of goosefoot, pigweed, purslane, sunflower, tansy mustard, knotweed, mesquite, prickly pear, banana yucca and grasses. Small animals were most widely hunted or trapped: jackrabbits, cottontail rabbits, rodents, gophers and birds, while larger game, like deer, pronghorn and mountain sheep, was occasionally hunted and may have been quickly depleted (Schollmeyer 2005; Schollmeyer 2010; Schollmeyer 2011; Shafer 2003).

Settlement Patterns and Architecture

Settlement location

During the Archaic Period, ancestors of the Mimbres people were mostly mobile and appear to have stayed mainly in the desert areas where a limited amount of water was available. It is not clear how much Archaic people traveled to higher elevations because Archaic sites in the mountains are sparse, but the scarcity of sites does not exclude mountainous occupation (Minnis 1985; Wills 1996). Evidence of short term settlements from the Late Archaic consists of some small shallow structures, with no formal entrances, small posts and round tops covered with grass and possibly mud (LeBlanc 1983; LeBlanc 1989; Minnis 1985) and seasonal cave occupation occurred in the highlands (Wills 1996).

Around 200 A.D. the Mimbres began to build more permanent housing, in areas adjacent to good farmland, concentrated along major river valleys in the Upper Chihuahuan and Transitional zones. The first pithouses were built on high mesas overlooking the streams. Access to these areas was difficult and it is not clear why the Mimbres chose to settle there. It is difficult to fully interpret the significance of such location when we know so little about the settlement patterns of previous periods (Lekson 2006). The location points to a need to protect food reserves and defend the settlement, although there is no evidence of warfare in the area (LeBlanc 1983; Rice 1975; Shafer 1995). Dielh (2001) also argues for a demographic need to locate villages on hilltops where travelers could spot them from afar, which would have favored social cooperation between groups. Others have put forth theories on the ritual need for such a location or mentioned the deterring cold winter air within the drainage areas (Haury and Sayles 1947; Hoggs 1977). Early Pithouse villages were small, counting on average 5-20 small structures and one large communal structure or great kiva.

At the beginning of the Late Pithouse Period, around 550 A.D., the Mimbres left the high points for the well watered river valley. Multiple settlements began to develop in the lower alluvial terraces and remained inhabited until the end of the Classic Period around 1150 A.D (Nelson 1999). These settlements were generally three miles apart along the river, far enough from each other to accommodate irrigation and a buffer zone for hunting and gathering food (LeBlanc 1983; Shafer 2003). Towards the end of the Late Pithouse Period and Classic Mimbres Period, small clusters of rooms were also present in between large settlements, but they did not show signs of continuous occupation (such as hearths, artifacts and midden accumulation). They likely served as temporary fieldhouses (LeBlanc 1983; Minnis 1985). As populations grew in the valley, people settled increasingly in surrounding areas (Brown 1996). This is particularly true for the mountainous areas where agriculture was more difficult but may have become easier with adapted crops, or more appealing at a time of population expansion (Stokes and Roth 1999).

Architecture

There were two major functions for architectural structures in the Mimbres Valley. Structures were either domestic residence or ceremonial in nature. Other structures were used for storage and as well as seasonal fieldhouses. The distribution of structures throughout settlements seems to have been random and unplanned for the most part (Minnis 1985). However, Creel found evidence of Three Circle pithouses organized around a common court or plaza at the Old Town site and Cameron Creek, as well as evidence for an ancient road leading to a main kiva from outside the village at Old Town and possibly NAN Ruin (Anyon and LeBlanc 1980; Creel 1997; Creel and Anyon 2003; Creel and Anyon 2010; Lucas 1996; Shafer and Brewington 1995).

Residential architecture. During the Early Pithouse Period, the Mimbres built semi subterranean houses that were generally round or oval shaped, dug about 1 meter into the ground and were 7 to 15 square meters in area. They had a large center pole to support the round earth roof (built with the earth that was dug out) and a long slopped entry way, usually at the south or southeast end of the house. A hearth with a deflector stone was usually located midway between the entry way and the center post.

During the Late Pithouse Period, pithouses remained similar in size and orientation, their shape changed however, from D-shaped during the Georgetown Phase, to rectangular with rounded corners in the San Francisco Phase, and finally rectangular or square during the Three Circle Phase (Creel and Anyon 2003; LeBlanc 1983; Shafer 1995; Shafer and Taylor 1986; Wills 1996).

Originally pithouses were believed to be entirely sedentary housing (Anyon and LeBlanc 1984; LeBlanc 1980), but in the early years of Mimbres settlements, pithouses were likely used seasonally, as we can see from the presence or absence of hearths, the lack of burials, middens or artifacts in certain areas (Gilman 1987; Jewett and Lightfoot 1986; Lekson 1988; Shafer 1990b). Dielh (1997) looked at the evolution of different attributes throughout the Late Pithouse phase and demonstrated that there was a slow transition between semi sedentism and sedentism in the Mimbres Valley. Hearths originally were directly on the floor, and over time became more formal with clay lining and later with slab stones making them easier to maintain and clean. Wall plaster to reinforce interior walls became increasingly common especially towards the end of the San Francisco Phase and Three Circle Phase. Post density per pithouse doubled between 550 and 800 A.D., and while infrequent, there was also an increasing amount of pithouse remodeling towards the end of the Late Pithouse Phase. The use of masonry was also increasingly common, but usually occurred in the event a new pithouse was built where an old one once stood, where the soil was already loose and disturbed. The increased effort in pithouse maintenance that occurred through the Late Pithouse Period parallels the increasing dependence on maize as people were less mobile and population grew (LeBlanc 1983; Shafer and Taylor 1986). By the end of the Three Circle Phase, from 900 to 1000 A.D., extended entrances to pithouses were blocked and new ceiling hatchways became common on flat roofs. Wall ventilation was added by the hearth and sometimes the hearth itself was moved to a different location to accommodate the increasing amount of poles needed. The deflector stone between the hearth and the entrance was no longer needed and disappeared (Shafer 1995).

Around 950/1000 A.D., in response to increased population and consequently increased agriculture, the Mimbres no longer built subterranean housing, but instead built more adaptable above ground pueblos with cobble and adobe walls, sunken floors, large poles and crossbeams for flat roofs and ceiling entryways (Gilman 1987). The Classic Mimbres village consisted of clusters of rooms to accommodate the growing population and increased need for storage and cooperation (Feinman 2000a; Shafer 1995). Most major villages had up to 20 rooms per room block and there were up to 8 room blocks per villages (LeBlanc 1983; LeBlanc 1989).

In the end, domestic architecture, did not change much in size or overall form, it was first round, then oval and rectangular, it was first subterranean and then above ground to accommodate a quickly growing population and agriculture intensification (LeBlanc 1983).

Storage. Originally, storage was informal in the form of pits or cysts within pithouses or large unmovable jars, but during the Classic Period living and storage space became formally separated in different structures. Thus, pueblo rooms were built adjacent to one another and became either entirely dedicated to storage or living, with storage room usually in the north end of the room block and living rooms in the south end (LeBlanc 1983). Cobble floors allow for better rodent and moisture protection in storage rooms and granaries. Most storage rooms were located within a room block, but Shafer (1995; 1986) has identified isolated storage rooms with reinforced floors and significant amount of unshelled burned corn that likely were communal granaries.

Ceremonial architecture. Communal architecture was very similar to domestic structures. Early pithouse settlements usually contained a group of a few to dozens of small domestic pithouses and one large ceremonial pithouse or kiva. These large structures were usually built identically to pithouses: round, dug 1 meter into the ground, with a large center pole, a long entry way to the southeast and a hearth midway between the entrance and the center pole; but they were much larger in size, between 35-70 square meters. Similarly to residential pithouses, there was an evolution of the shape of the great kivas, from round or oval to D-shaped, in the middle of the Late Pithouse Period, to rectangular. What differed was their size, the large number of wall posts covered with adobe and the presence of floor grooves (for foot drums) and *sipapus* (white sand filled holes, opening to the underworld). There were no domestic artifacts in most of these large pits, and few burials. The few burials, however, were not directly associated with the use of the kiva (Creel and Anyon 2003).

There were rituals involved in the building and destruction of the large communal structures. Dedicatory objects such as shell bracelets, breads, pendants, quartz crystals, stone bowls, pigment grinding slabs, palettes, vessels, and macaw and owl wings have been found in the floor, roofs and walls of kivas; while additional grinding slabs, stone pipes, stone bowls, vessels and projectile points, but no jewelry, have been found in abandoned kivas. Evidence suggests that people intentionally set fire to the kivas; deliberately made the walls topple and removed the center post as a ritual retirement of the large pit structure. The center post hole was usually filled with rocks. There is evidence of fire intensification towards the end of the Late Pithouse Period, during the Three Circle Phase. In contrast, these large structures were left to fall on their own during the Classic period (Creel and Anyon 2003; Creel and Anyon 2010).

Village-wide Classic ceremonial activities likely took place in the large plaza areas that were adjacent to the room blocks. The shift from large enclosed ceremonial structures, to large open plazas parallels the increase in population. It is likely that large kivas could no longer accommodate the village population. Small kivas, however, remained present in the vicinity of individual room blocks likely for more intimate, family-based ceremonial traditions (Creel and Anyon 2003; LeBlanc 1983; Minnis 1985; Shafer 2003).

Mimbres Crafts and Material Culture

Ceramic

Ceramic evolution. The Mimbres are widely known for their exquisite naturalistic pottery from the Classic Period, but their ceramic tradition began some 800 years prior to the Classic Period. Table 2 illustrates the temporal distribution of all Mimbres ceramic types. The first Mimbres pottery appeared around 200 A.D. The first vessels were jars shaped like gourds, which they had previously been using for food storage, and were made of brown fired clay. These jars were mainly used for cooking and storage. Bowls were also produced, although rarely. Initially the jars and bowls were undecorated brownware but towards the end of the Early Pithouse Period, the Mimbres began to add a red finish to their pottery using red hematite. The bright red color was obtained by firing the vessels in an oxygen-rich kiln (LeBlanc 1983; Scott 1983).

The technique of reddening the pottery was not entirely perfected until the Late Pithouse Period during the Georgetown Phase when a red slip was added onto the unfired vessel, then polished and later fired. This red slip style is called San Francisco Red and lasted for a 100 years alongside the traditional undecorated plain ware (LeBlanc 1983; Scott 1983).

The subsequent San Francisco Phase is characterized by a change in both unpainted and painted pottery. The majority of the vessels made at that time were utility jars that were used for cooking and for storage. Some jars could store up to 20 gallons and were too big to transport. The Mimbres began to make incisions, punches and corrugation on their plain unpainted utility ware. The relief was first added to the neck of the jar, but over time began to be applied to the top half. Similarly painted ware became more elaborated. It retained the exterior San Francisco red slip, but the unfinished interior of the vessels was adorned with simple and linear design painted in red.

TABLE 2. Temporal distribution of all Mimbres ceramic types. All dates are A.D. (based on Shafer and Brewington 1995)

	Type	Dates (A.D.)
Plainware	Plain Brownware	200-1000
Plainware	Alma Neck Banded	650-850
Plainware	Three Circle Neck Corrugated	850-1010
Plainware	Mimbres Partially Corrugated	1020-1130
Plainware	Mimbres Fully Corrugated	1020-1130
Plainware	Three Circle Pitcher	920-1010
Plainware	Mimbres Corrugated Pitcher	975-1020
Plainware	Redware	500-1000
Painted Ware	Mogollon Red/Brown	650-750
Painted Ware	Three Circle Red/White	730-770
Painted Ware	Black/ White Style I	750-900
Painted Ware	Early Style II	880-980
Painted Ware	Late Style II	970-1020
Painted Ware	Style II/III	970-1020
Painted Ware	Early Style III	1010-1080
Painted Ware	Middle Style III	1060-1110
Painted Ware	Late Style III	1110-1130
Painted Ware	Polychrome	1060-1130

This style is known as Mogollon Red-on-Brown. Like San Francisco Red, it lasted approximately 100 years (LeBlanc 1983; Scott 1983).

During the Three Circle Phase that started in 750 A.D., a new process was developed to help make the designs stand out. The Mimbres began to apply a white kaolin slip to the interior of their bowls and kept the red paint for the design. This pottery style is known as the Three Circle Red-on-White (LeBlanc 1983). Sometime before 800 A.D. the potters changed the firing process of their vessels, by reducing the oxygen supply in the kiln, which allowed for the red paint to turn black or different shades of gray (Scott 1983). This new technique gave way to two main styles of pottery: Boldface Black-on-White or Mangas Black-on-White (750-900 A.D) and later Mimbres Classic Black-on-White (1000-1150A.D.). Shafer and Brewington (1995) have demonstrated that Black-on-White ceramic also included a transitional style between Boldface and Classic and they have even deciphered microstylistic variation within each of the three styles. These three Black-on-White styles are often referred to as Style I: Boldface Black-on-White, Style II: Transitional Black-on-White, Style III: Classic Mimbres Black-on-White. During the Classic period, jars remained widely used for cooking and storage and were sometimes painted, put mostly remained undecorated. Bowls, however, became more common though still only representing a small portion of all Mimbres ceramics. While some were used for cooking and serving as gifts or for personal feasting, some had only been made for funerary purposes; most, new or used, were found inverted on top of the deceased's head (LeBlanc 2006; Lyle 1996; Powell-Martí and James 2006).

Plainware pottery. While undecorated brownware was found throughout the entire span of Mimbres occupation, it did not change drastically from one phase to another. Plainware was simply unfinished or red slipped and was textured when the paste was still wet with punctuation, incisions, and corrugations of varying type. Around 650/700 A.D. the Mimbres began to embellish jars at the neck, as what is now known as Alma Neck Banded. By 800 A.D. the corrugation on the jar necks was narrower and is referred to as Three Circle Neck Banded. Later at 900 A.D. neck banding punctuation extended past the shoulder of the jar and by the Classic Period, banding covered one third to half of the vessels, both styles are referred to as Mimbres Partially and Mimbres Fully Corrugated (Shafer 2003; Shafer and Brewington 1995).

Painted pottery. Painted pottery, from its first appearance in 650 A.D to its apotheosis during the Classic Period, developed from simply linear into complex, intricate, naturalistic designs. The first designs on Mogollon Red-on-Brown bowls were simple and linear, consisting of pendants, triangles, chevron, serrated bands and interlocking boxes (Scott 1983). Later, with the Three Circle Red-on-White pottery came more spirals and curvilinear designs, but patterns were still heavily geometric and the design extended to the rim of the bowl, like wall paper with no definite end. Style I pottery design still extended to the rim of the vessel, but lines became wavy and more spirals and hachure were used. Also, rare figurative motifs such as lizards and birds, inspired from Hohokam pottery, began to appear. Subsequently, Black-on-White designs changed drastically from previous forms, in a variety of ways; first, with the introduction of rim bands, then with changes in layout and figures. Style II design mainly constituted of hachure in parallel straight lines that continued to the rim of the vessel, the layout consisted of intricate quadrants with mirror images (LeBlanc 1983; Scott 1983). Framing lines dissipated progressively to make room for more motifs, especially figurative one. Style III was characterized by an increased variety of rim bands, sometimes the motifs were part of the rim bands or hanging from it, while in other occurrences, they were simply framed by them. There is a great diversity of designs that include mammals, birds, fish, insects, hybrids and humans that are often incorporated into geometric designs. Vessels that include human figures show Mimbres domestic and ceremonial activities with great details. The curvature of the vessels also adds depth and mobility to the figurative motifs for great visual effect (Brody et al. 1983).

Painted motifs consisted mainly of birds and non-human mammals. In fact at least 50% of the vessels contained birds and mammals, when 15% contained human figures, 10% fish and the remaining 25% consisted of insect, amphibians, reptiles and mythical figures (Brody et al. 1983). A number of different studies have focused on identifying the different species of animals and birds that were depicted. It was not uncommon for the Mimbres to mix attributes from different species making identification difficult (Brody 1977; Brody 2004). Birds species were identified based on silhouette, bill length and shape, tail shape and size and plumage patterns (Bettison et al. 1996; Jett and Moyle 1986). Bettison et al.(1996) have identified Montezuma quail, turkey, herons, white faced ibis, American kestrel and roadrunner. Similarly, they recognized rabbit, mountain lions, coatimundi, bighorn sheep, weasel, black foot ferret, bat winged armadillo and freetail bats as depicted mammals. Insect depiction was comprised of bees, hummingbirds, moth, flies, caterpillars and butterflies while spade foot toad, snapping turtles and a variety of local snakes were depicted as well.

A great variety of fish have also been depicted, from both freshwater and saltwater origin, although there is limited evidence for fish consumption (Shaffer 1991). The notable presence of marine fish on pottery is surprising because the Mimbres lived at least 500 kilometers away from any saltwater, namely the Sea of Cortez, though long distance travel was not uncommon, especially for shell bead trade (Jett and Moyle 1986). Based on body shape, eye size and placement, mouth size and position, presence or absence of teeth, tail shape, scale size and shape, Jett and Moyle (1986) have identified the following: longnose gar and sucker (which have been inspired from sunfishes or white bass), sea bass, jewfish, parrotfish, jacks, popeye fish, catalufa, snappers, grunts, sea chubs, butterfly fish, angelfish and damselfishes, razor fish, blennies, guitarfish, bonefish, gulf grunion, needlefish, moray eels, flying fish and sword fish.

Based on the high incidence of depicted birds and fish, it has been suggested that different figures where related to different kinship groups as totemic emblems, however, there is currently limited evidence to support the idea (Powell-Martí and James 2006; Shafer 2003).

Stone tools

The overwhelming majority of studies on Mimbres crafts have focused on their ceramic tradition. But the Mimbres were also skilled in working other available resources into a variety of tools and objects.

Chipped stone. The Mimbres Valley was traveled by hunters for a very long time and therefore the presence of projectile points is not uncommon. Few studies have focused on chipped stone technology in the Mimbres valley (Dockall 1991; Nelson 1981; Nelson 1984). Chipped stones were used daily for maintenance and subsistence, such as large choppers, knives, crappers and drills (Cordell 1997; Dockall 1991; Nelson 1984). At NAN Ranch, Dockall (1991) observed that most tools were expedient in nature and they consisted mainly of informal flaked cores and flakes. They do not display much use wear and therefore were only used for a very short period of time and quickly discarded. In addition, two types of hunting implements were common in the Mimbres Valley, the spear thrower (*atlatl*) and spear, and the bow and arrow. Wooden spears had large dart points, with expanding stems and corner notches. When the bow and arrow technology reached the Southwest, around 700 A.D., the Mimbres began to make smaller corner-notched or side-notched points. Dart points remain common in Classic assemblages but it is improbable that they were still manufactured with the same frequency. Likely, they were scavenged remnants of previous occupations. Projectile points were made of local and non-local resources such as rhyolite, chert, chalcedony and obsidian. Stylistically, there is a lack of regional and time differentiation in point typology, which shows that their function and use remained the same throughout the entire Mimbres occupation (Dockall 1991). Nelson (1984) looked at the assemblage of stone tools at Galaz and noted that the type and frequency of each stone tool did not vary greatly between upper and middle valley sites during the Late Pithouse Period. Generally, she found that durable tools used for plant processing were as frequent at sites with long or short growing periods and similarly sharp projectile points were as frequent in areas with abundant or lesser game resources. During the Classic Period, the frequency of projectile points in the Mimbres archaeological assemblage tends to diminish through time, which has been linked to the decreased reliance on hunting that parallels the increased dependence on agriculture, at least in middle valley sites (Diehl and LeBlanc 2001). Similarly, it has been suggested that the shift from fine, unflawed stone tools to less workable but more durable chipped stones reflects a new emphasis on agricultural tools as opposed to hunting tools (Cordell 1997; Gilman 1995; Nelson 1981; Nelson 1984).

Grooved axes. Grooved axes were made of greenstone, found in several outcrops in the Mimbres Valley. They were common at Galaz and Mattocks Ruins where they were likely manufactured. Sites furthest from these outcrops, like NAN Ranch, did not have evidence of grooved axes manufacture; rather axes were brought in as a finished product. They were primarily used for cutting down trees and shaping timber for the construction of pithouses and pueblos. It is not uncommon to find one in the floor assemblage of every residential unit at NAN Ranch Ruin. They were an intrinsic part of room construction and retirement and may have had a ritual significance. At NAN Ranch, most axes have been recovered from the Classic Period, but it has been suggested that they may have been passed down through lineages (Dockall 1991).

Ground stone. Grinding stones (manos and metates) were used in food processing to grind plant seeds and corn kernels; there are often found on the floors of pithouses, pueblos and plazas as well as in middens, fill and burials. Broken and discarded manos and metates have been recovered from cobble adobe masonry, hearth lining and as burial cairns during the Classic Period. They were made of locally acquired rhyolite and andesite/basalt that was medium to fine grained (Shafer 2003). The study of mano and metate evolution has played on important role in trying to establish Mimbres diet evolution, specifically their increased dependence on corn (Diehl 1996; Nelson and Lippmeier 1993). From the Late Archaic to Three Circle Phase, metate morphology did not change drastically. Originally, metates were oval and basin-shaped. By the Three Circle Phase, metates were trough shaped with one open end, and by the Late Three Circle they were opened at both ends. Manos, on the other hand were initially oval and one-handed, and by the Three Circle Phase they were longer to accommodate a two hand grip and rectangular with a convex surface (Diehl 1996; Mauldin 1993). Diehl (1996) estimated that the surface area of manos had increased by 21% by early Three Circle. The change in mano and metate morphology is a result of increased population and increased reliance on corn. Large, more trough shaped metates and longer manos facilitated and expedited food processing.

Perishables

Bone implements. Bone and antlers were often worked into tools or ornaments. Long bones, metapodial bones from artiodactyls, ribs and metatarsals were modified into awls and pins that were likely used for food processing, crafts such as weaving, basket making and pottery making, as well as to secure clothing. Few modified bones and antlers were decorated, but some were carved, incised or painted (Shafer 2003). Shaffer (1990) discovered a large amount of modified jackrabbit pelvis at NAN Ranch, which could have been used as spatulated tools for shelling corn and scrapping. Modified innominates were not widely recognized as tools in the American Southwest prior to Shaffer's analysis (Hayes et al. 1981; Shaffer 1990).

Jewelry. Jewelry has been recovered from Mimbres sites all over the region and it is commonly found on housefloors, plazas, general fill, cached or with burials. Few studies have focused on Mimbres jewelry. Most reports only provide basic descriptions and general categorization, but little information has been published on the material used and site distribution. Mimbres jewelry was primarily made of shell, stone, bone, turquoise and in some cases copper; crafted into effigy, beads for pendants, bracelets, armbands, etc… Stone and mineral pieces were the most common and were made of locally acquired talc, kaolinite, turquoise, galena, quartz, slate, malachite, hematite, limestone, pumice, rhyolite, copper, jadeite and basalt. Shells and turquoise had to be imported into the Mimbres Valley. The majority of shells came from the Pacific, Gulf of California and Gulf of Mexico, and they are a testimony of the large regional trade system. Among the most common shell types were *Glycymeris, Nassarius* and *Pecten* followed by *Haliotis, Spondylus, Olivella, Conus, Coral, Strombus, Turritella, Architectonicidae* and *Columbella*. Jewelry was worn as adornment and used in ritualistic activities and it is often considered a strong indication of social ranking. In a study of NAN jewelry, Parks-Barrett (2001) found that 28.1 % of all burials contained jewelry and that there were no significant differences between room blocks in terms of type or frequency of jewelry inclusions. *Glycyremis* shell bracelets, however, were exclusively found with male burials.

Fiber. Most fiber items have been recovered from rockshelters and dry caves in the northern region of the Southwest. Fiber technology seems to have been continuous from the Late Archaic on (Anyon and LeBlanc 1984; Cordell 1997; Martin et al. 1952). There are few examples of Mimbres fiber technology and most information comes from its depiction in Classic Black-on-White Style III pottery. The only study of Mimbres textiles and basketry was performed by Adovasio and colleagues (2005) on material recovered at NAN Ranch, in the form of fragments and fossil impressions. Fiber technology predates the ceramic era in the Southwest. Techniques did not change much through time and included twinning, coiling and plaiting. Basketry did not require the use of a loom or frame like textile manufacturing. All three techniques were mainly used to make containers of various shapes and sizes, mats, fish traps, cradles, hats, seed beaters, blankets, garments and sandals (Adovasio et al. 2005).

Mortuary Practices

A large number of burials have been excavated throughout the Mimbres Valley but few thorough studies of them have been performed or published. Most studies, especially those from early excavations, did not provide pertinent time and space information that would allow for chronological and stylistic differentiation.

Inhumations

Based on his analysis of NAN burials, Shafer makes some generalizations on Mimbres mortuary practices, that have been reported elsewhere in the valley (Shafer 2003:146-147). In Mimbres burials, the deceased was interred flexed or semi flexed, usually laying on its back (70%), on its left or right side (10-12%) and in few occurrences face down. Most burials were oriented towards one of the four cardinal points. Graves were usually unmarked and were commonly disturbed by subsequent burials or room construction (Shafer 2003). They consisted of a pit, big enough to accommodate a flexed body (Anyon and LeBlanc 1984).

Very few burials have been found at Late Archaic or Early Pithouse sites. This pattern coincides with the idea that these sites were not occupied year round and that people were still largely mobile. At Wood Canyon, two burials have been recovered: they are extramural, and the deceased was interred with few shell beads, flexed, in supine position (Thurnbow 2000). Burials during the Late Pithouse continued to be extramural. Occasionally intramural ones, located below roomfloors, began to appear towards the later part of the Period. More specifically, during the Georgetown Phase, burials were exclusively extramural, but were not organized into bounded cemeteries. Subsequently during the San Francisco Phase, inhumations continued to be predominantly extramural, but few intramural burials appeared. A few infants were buried below room floors, without any grave goods. In some instances, sherds of a smashed bowl were spread across the body in adult burials or whole bowls were placed next to the body. During the Three Circle Phase, there was an increasing number of intramural burials, specifically females, infants and children. The ceramic bowls that once were smashed, and deposited with the body, began to be killed (by punching a hole in its center) and placed over the head of the deceased. Cremations began to appear. During the Classic Period, 90% of burials were intramural beneath occupied rooms or in room fill with a single Classic Black-on-White killed bowl inverted over the head of the deceased. The remaining 10% consisted of extramural burials and cremations. The vast majority of outdoor inhumations did not contain killed bowls and were usually those of males. Shafer and Taylor (1986) have suggested that although nearly half of the Classic burials did not have inverted bowl, inverted baskets could have been placed over the deceased's head.

Grave offerings were not systematically included in burials, but most burial furniture consisted of vessels, or large sherds, jewelry, shells, inlays, projectile points, stone axes, stone palettes and painted stones. Traces of checker-weave mats or shrouds, woven sashes, G-string cordage aprons, coiled baskets and *paho* sticks have also been recovered. During the Classic Period, some intramural burials were marked with stone cairns made of discarded metates and manos, effigy stone mortars, petroglyphs on old metates or large sherds, presumably in an attempt to locate previous burials during the densely populated period or to prevent the room floors from slumping (Shafer 2003).

Cremations

Cremations were rare in the entire Mimbres region for the most part, until the Classic Period (Creel 1989). The occurrence of cremation starting during the Late Three Circle Phase may have been inspired by the Hohokam who lived downstream of the Gila River, and may have come with a population shift to the East that contributed to the increasing population at Mattock and NAN Ranch around that time (Shafer 2003). Based in his review of 26 sites from the Mimbres Valley, Silver City area and Gila River area, Creel (1989:316-321) found that the large majority of cremations were secondary deposits in pottery vessels or organic containers, sometimes covered with one or more inverted bowls. The most typical accompanying mortuary furniture includes projectile points, pottery vessels and jewelry. Compared to contemporaneous inhumations, cremations usually included a large quantity of grave goods: 46% of Late Pithouse cremations and 51% of Classic cremations contained grave goods. Cremations were usually located in association with communal structures such plaza or abandoned pit structures. It has been suggested that they may have been the result of unusual death circumstances, such as accidental, far away or that of people involved in witchcraft though this is speculative (Creel 1989; Creel and Anyon 2003). Similarly, they may be the remains of individuals that had different responsibilities than the rest of the community; responsibilities related to the monitoring of astronomy, farming, or ceremonies. Or they may have belonged to lineages that were foreign to those of the village they were deposited in (Creel 2006).

Other types of burials

Creel (2003) has encountered headless burials in and around retired ceremonial structures at Old Town. Ceremonial pits throughout the Mimbres Valley generally do not contain any burials, especially human ones. Animal burials are common in the Mimbres Valley. Several instances of bird, canid, or bear burials have been reported at Cameron Creek, Swarts, Galaz, Old Town, Wind Mountain and NAN Ranch (Creel and McKusick 1994; Hill 2000; Woosley and McIntyre 1996). They are usually located where one would find human burials beneath room floors, in plazas and middens. They may have had totemic associations with particular kin or corporate groups or could have been ritual offerings (Shafer 2003).

Social Organization

Many studies have focused on the social organization of Mimbres society and the bulk of the data that supports those studies comes from the dozen large pueblo sites that line the Mimbres River (Anyon and LeBlanc 1984; Creel and Anyon 2003; Feinman et al. 2000; Gilman 1990; Ham 1989; Hill 1997; LeBlanc 1983; Minnis 1985; Munson 2000; Nelson 1999; Parks-Barrett 2001; Powell-Martí and Gilman 2006; Shafer 1985; Young Holliday 1996). Even after decades of research, archaeologists have had a hard time defining the social model that tied Mimbres society together. For the most part, they had concluded that it was generally egalitarian with no vertical hierarchy and little to no horizontal hierarchy, though the level of agricultural development seen during the Classic period would call for some type of leadership. It is possible that the leadership that seems necessary for the management of the irrigation systems was in the form of a council of village members, or a rotating tenure, or was administered by clerics (Shafer 2003). It has also been suggested that some leaders may not have worked the fields, but only managed them (Creel and Anyon 2003).

Recently new ways of assessing social power and inequalities have made their way in Southwestern archaeology (Mills 2000). These new ways have allowed researchers to look past the egalitarian/ranked society dichotomy and to focus more on the contrast between social and political inequalities through ritual and identity (McGuire 2011). Among those new ways is the introduction of the concept of heterarchy, which looks at the different ways certain social elements can be ranked, rather than assuming a hierarchical ranking, thus embracing the diversity and flexibility of social categories (Crumley 1995). Another model, the dual process theory has been applied to Pueblo societies and favors different modes of political organization that are at both end of a continuum: the network mode, which focuses on individuals within their own network and the corporate mode, where political power is not that of one but instead is shared by a group. We will see that the corporate mode seems to be the best fit to Mimbres society (Feinman 2000a; Feinman 2000b; Feinman et al. 2000).

Prior to the establishment of pithouse villages, Mimbres society likely consisted of small egalitarian tribal bands. Hunting and gathering subsistence requires a certain amount of flexibility on a daily basis and therefore at the social level (Nelson 1999). There is no evidence of hierarchy or status difference and no extensively organized trade system at that time (Minnis 1985). With the appearance of cultigens like corn, we began to see more permanent settlements which require and show some degree of cooperation at the village level. During the Early Pithouse Period, Mimbres society was likely made up of small groups of people living seasonally in pithouses of similar size and built. Likewise, during the Late Pithouse Phase, Mimbres villages consisted of pithouses of similar built and size and there was no specialized structures other than one large ceremonial pithouse per village. Whether those early pit structures were seasonal (Gilman 1987; Gilman 2010a; Lekson 1988) or permanent (Anyon and LeBlanc 1984; LeBlanc 1980) is still a debated issue which affect our interpretation of Mimbres society during that time. Nevertheless, the presence of similar pithouses with one large communal kiva in early Mimbres settlements shows that nuclear families likely interacted at the village level for ceremonial purposes whether seasonally or permanently. At the end of this period, during the Three Circle Phase, changes accelerated for the Mimbres, including in terms of their social organization at the local and regional level. The pithouse to pueblo transition marks a shift towards more agricultural dependence and food surplus that sustained an increasing population throughout the valley. The establishment of irrigation systems around that time likely required more labor and cooperation within each village and between villages through communal rituals (Nelson 1999; Shafer 2003). Corporate labor groups must have become necessary and were likely held together by rules of kinship through land ownership, food storage and distribution, and a common belief system (Feinman 2000a; Feinman et al. 2000; Shafer 2003; Shafer 2006).

Architectural evidence

Such social reorganization is largely visible at the village level in terms of architecture evolution (Hegmon et al. 2006; Hill 1997; Shafer 1995; Shafer 2006). During the Three Circle Phase we see an increasing amount of remodeling and a shift from semi subterranean houses to above ground pueblos that facilitate the modification and addition of rooms as a village population grew. The emergence of specialized storage rooms, integrated within room blocks or stand alone in the form of communal granaries as seen at NAN, points toward the emergence of a cooperative system from extended families to corporate groups with lineage cemeteries tied to land ownership, and secret shrines (Goldstein 1980; Goldstein 1981; Saxe 1970; Shafer 2003; Shafer 2006). These extended households were aggregated at the room block level and several room blocks linked by large plazas constituted a village wide community (Creel and

Anyon 2003; Shafer 2003). But the great variety in room configuration and sizes across the entire Mimbres valley reveals that there was no pressure to conform and does not point toward a strong leadership that would have controlled every aspects of Mimbres life (Hegmon et al. 2006; Hegmon et al. 1998). Thus based on architectural analysis of Classic Mimbres villages, we can decipher three organizational tiers of Mimbres society: the household (roomsuites), the corporate group (room blocks) and the village as a whole; but there is hardly any architectural evidence for social ranking (Clayton 2006; LeBlanc 1983; Minnis 1985).

There is some evidence of acquired or achieved wealth, through land ownership as it has been seen in nearby Chaco Canyon in northern western New Mexico (Earle 2001). As certain families or corporate groups had access to better farmland their agricultural production would have been more successful, possibly yielding food surplus that could have been traded. At NAN Ranch, Shafer (2003) saw a difference in the construction of the two main room blocks where the southern one is more strongly built and remodeled, suggesting that the corporate group that occupied that room block had acquire more wealth overtime and had a longer lasting history in the community relative to those that lived in smaller or minimally altered room blocks. In a comparative study of Classic ceremonial spaces (great kivas and large rooms) at Galaz, Mattocks and NAN, Clayton (2006) found that not all room blocks were associated with communal spaces and that groups living in larger more established blocks likely controlled those formal ceremonial spaces and the ritual associated with them, hence likely having some social standing related to their control and knowledge of communal rituals. In contrast, in her analysis of room block layout at Mattocks, Hegmon et al. (2006) found that special purpose rooms (storage, ritual) were rare and that each room block was likely that of a family rather than extended families and found little difference in room layout at Mattocks that would have shown that a family was wealthier than another.

Mortuary evidence

Another large source of information in trying to determine social differences among the Mimbres is through ceramic studies, especially the Classic Black-on-White mortuary bowls as well as other funerary customs and overall health and nutrition as observed on skeletal remains. Most have failed to identify evidence for vertical hierarchy. There is no significant difference in the quality and quantity or uniqueness of grave goods, in the treatment of the dead, or in access to different foods based on nutritional studies that would constitute evidence for an elaborate vertical social ranking (Anyon and LeBlanc 1984; Gilman 1990; Gilman 2006; Ham 1989; Hill 1997; Lippmeier 1991; Parks-Barrett 2001; Provinzano 1968; Spreen 1983; Young Holliday 1996).

Interment patterns and grave goods. Several studies on mortuary customs in the Mimbres Valley have looked at similarities and differences in the treatment and disposal of the dead. These studies have found that there were little differences in funerary traditions, which suggested that the Mimbres social structure was mainly homogeneous. In her comparative study of burial rituals at NAN and Galaz, Spreen (1983) found little differences between the two sites and that within each sites there were little evidence for differential treatment of the dead that would signal horizontal or vertical social hierarchy. She found that the Mimbres were likely a tribal society that had shifted to a chiefdom with some acquired status, but that there were no signs of a centralized redistribution system. Likewise, Hill (1997) looked for archaeologically identifiable mortuary patterns (sequential intramural ancestral interments, periodic refurbishing, remodeling and expansion of room blocks) at both Swarts and NAN and concluded that the Mimbres were socially organized in matrilineal corporate groups based on ancestral ties to the land. Some differential treatment of the dead, such as cremations and midden burials as opposed to the common subfloor burials consolidate the idea of corporate groups, as some individuals were excluded from corporate cemeteries and did not receive the same mortuary treatment as others. At Mattocks, Gilman (1990; 2006) studied the incidence and quality of grave goods (pottery and exotic goods such as copper bells, turquoise, shells, axes, knives and hoes) in Classic burials. She found that each room block had at least one rich grave, which does not support the idea that one family was wealthier than others. She also tried to determine if rich graves were a result of specialization but since there were no difference between adults and children, this confirms that wealth was likely acquired at the family or corporate level rather than at the individual level. In a similar study of NAN jewelry, Parks-Barrett (2001) found that 28.1 % of all burials contained jewelry and that there were no significant differences between room blocks or corporate groups in terms of type or frequency of jewelry inclusions. *Glycyremis* shell bracelets, however, were exclusively found with male burials. In addition, Neitzel (2000) detected a hierarchical distribution of grave goods among males at Galaz Ruin.

The relative homogeneity of mortuary practices across the Mimbres valley confirms that there is little evidence for vertical and horizontal differentiation. However there are some instances of burials with substantially more grave goods than average, such as three Mattocks burials with more grave goods than the rest of the population, a child's burial at Galaz with 20 vessels and an adult at Saige McFarland with 21 vessels (Gilman 1990), suggesting a more subtle social ranking. The overall absence of graves with large quantity and better quality offering does not necessarily preclude social inequalities.

Health and nutrition. A few studies have focused on skeletal remains to address Mimbres social organization (Lippmeier 1991; Marek 1990; Olive 1989; Patrick 1988; Provinzano 1968; Young Holliday 1996). Provinzano (1968) examined a little over 100 skeletal remains at Galaz, only about 11% of the total number of recorded burials. He discussed certain pathologies, diet and social structure, and found that most people show signs of calcium deficiency through "bone demineralization" and "tooth decay", but that a small group was relatively healthy. Thus he argued for a class system at Galaz. However, his study was mainly descriptive and based on a small sample. Also there is some problem with assuming calcium deficiency when noting tooth decay alone. Tooth decay can be a result of diet but also hygiene. Lippmeier (1991) compared pathological conditions on skeletal data from seven Classic Mimbres sites and four Post Classic sites to determine if the stress level on the population was different between the two periods but she found no significant differences. Several studies at NAN have been performed on skeletal remains and they are discussed in Chapter IV, but Young Holliday (1996) is the only one to have tried to find evidence for social difference based on those remains. She looked at trace elements, stable isotopes, pathologies and trauma. Generally she found little to no significant differences between room blocks and midden burials that would point towards prescribed social ranking. Based on her study of carbon isotopes, she did find that midden burials likely had a more diverse diet and relied less on maize than the rest of the NAN population which would confirm Hill's (1997) suggestions that those buried in the middens likely did not belong to long established kinship groups and did not have access to the best farmland. Therefore osteological analysis of Mimbres people yielded similar results in terms of possible social rankings. There is evidence for some difference between kin groups that are likely tied to landownership and acquired wealth through agricultural production.

Thus architectural, and mortuary evidence show little difference between people and across ages, though there could have been some level of craft specialization that would have yielded some social differences, possibly in terms of gender differences.

Gender studies

Multiple studies tried to identify gender roles among the Mimbres. Many are centered around the types of activities that were depicted on bowls, to try to determine if a specific gender was more likely involved in activities that bore more prestige (Espenshade 1997; Hegmon and Trevathan 1996; Munson 2000; Munson 2006; Shaffer et al. 1996; Shaffer et al. 1997). The majority of the scenes that are depicted on Classic Black-on-White bowls includes but is not limited to hunting, trapping, fishing, gathering, warfare, ceremonies, child care, birthing, weaving and pottery making. "No other prehistoric southwestern culture produced art that has managed to survive into modern times and that chronicles so many activities in such details" (Shaffer et al. 1996:114). Different studies have focused on identifying gender based on the presence or absence of genitalia, beards, breasts, pregnancy and on the presence or absence of certain adornments, such as hair knots, plaits, feathers on heads and eye masks for men; and string apron, headband and leggings for identifying women (Munson 2000; Munson 2006; Munson and Hays-Gilpin 2010; Shaffer et al. 1996). It has been determined based on the pottery that men were mainly involved in hunting large animals and trapping, fishing, warfare, farming and weaving; while women likely took care of child care and births, water procurement and assisted hunting parties. Hunting small animals, gathering foods and ceremonies were likely carried out by both genders. These role depictions are in agreement with Pueblo historical data. However, several facts remain subjects of contention. Men are usually pictured as active while women are depicted in a static manner, which have led some to conclude that there were status differences between men and women among the Mimbres (Munson 2000). This is based on the general assumption that men had social power because the type of activities they apparently engaged in were driving forces for evolutionary changes, while activities thought to be typical of women remained unchanged through time (Spielmann 1995). However, these social inequalities are usually not visible at the nutritional or funerary level among the Mimbres (Gilman 1990; Young Holliday 1996). Because many depicted fish were of saltwater origin, it has been suggested that men must have painted the exquisite pottery, since they seemed to have been involved in long distance trade (Jett and Moyle 1986), but women were most often shown carrying burden baskets used to transport traded goods. However, based on other evidence, it has been demonstrated that women were actually the potters and likely the painters, which fits with historical Pueblo ceramic tradition (Moulard 1984; Shafer 1985; Shaffer et al. 1997). There is evidence of subpart painting from novice potters and possibly even of painting made by children, though it is commonly excluded from most pictorial publications (Brody 1977; Brody 2004; Crown 2001; Crown 2007; Moulard 1984). These modest paintings could have been those of daughters being taught this specialized craft by their mothers (Crown 2001). More work is needed in terms of gender studies to consolidate the different interpretation of Mimbres gender roles and to try to decipher a gender based distinction in prestige and social ranking, if there was one.

Craft specialization

Aside from pictorial indication of Mimbres activities there is little evidence for craft specialization in the Mimbres archaeological record and few studies have focused on the issue. Most of these studies concentrate on ceramic production, especially the Classic Black-on-White bowls. Who made them and where?

At NAN, Shafer (1985) discovered a burial that he interprets as that of a female potter, based on the accompanying potter's tools (smashed vessel, whole vessels, worked sherds, pot polishing stones, unfired Style I jars, inlays, adorned jewelry, lumps of kaolin clay and red pigment) but he found no strong evidence for full blown craft specialization. The idea that women made and painted pottery is in agreement with ceramic production among the neighboring Zuni.

LeBlanc (1983; 2006; 2010) suggested that most people knew how to make and paint pottery but that only a few individuals at a given time were highly skilled in this trade. In a study of painted bowls, he looked for similarities in design that would allow to group bowls by artists and help estimate the number of potters, as well as to attempt to estimate the number of bowls made by each potter. While many assumptions were necessary to perform this study and while LeBlanc conceded that his method was not the only one or the best to try to decipher that kind of information, he found that his conclusions help support those assumptions. He found that there were not many skilled painters at any given time, that only one or two per large to medium site would have been sufficient to produce the amount of ceramics we have collected. It is likely that only about 20 to 40 potters practiced their trade contemporaneously through the entire region at one given time. This shows a certain degree of craft specialization among the Mimbres though there is limited evidence to suggest that there was strong craft specialization. Making and painting ceramic bowls was likely a prestigious activity that few women could acquire and pass down (Brewington et al. 1996; Crown 2001; LeBlanc 1983; LeBlanc 2006; Shafer 2003).

Regional organization

While ceramic production was important at the village level, it was also important at the regional level. Whereas LeBlanc (2006) was not able to positively determine bowl provenience in his study of artists clustering, other studies using INAA (Instrumental Neutron Activation Analysis) have successfully identified production centers and helped determine distribution and exchange patterns of Mimbres ceramic

(Brewington et al. 1996; Dahlin 2003; Gilman et al. 1994; Powell-Martí and James 2006; Powell 2000). Powell-Martí and James (2006) set out to find social asymmetry in the Mimbres region during the Classic period using a compositional and iconographic analysis of Mimbres bowls from Galaz, NAN, Old Town, Cameron Creek and Saige McFarland. Using INAA, they were able to establish five clusters that correspond to the five sites and iconographic analysis confirm those clusters. They were able to determine trade patterns between each site and throughout time during the Classic period. Trade was most extensive and integrated during the middle of the Classic period and group membership changed slightly overtime. Saige-Farland was only importing ceramics while all four other sites were involved in ceramic exchange throughout the Classic period. Several sites seemed to have a more prominent part in exporting ceramics, namely Galaz and Old Town. Galaz exported the most, which, coupled with additional data such as size and elaborateness of communal structures, incidence of exotic goods, presence of headless burials and parrot and macaw burials, demonstrate that Galaz had a special place within the Mimbres region, especially during the middle of the Classic Period. Old Town featured more ritual structures but demonstrated less involvement in ceramic trade than Galaz. These sites are located next to larger tracks of good arable land than other Mimbres villages, further demonstrating a link between heightened agricultural production and ritual influence by those two villages (Creel and Anyon 2003; LeBlanc 1983; Shafer 2003).

Identifying social organization at the archaeological level is not always straight forward. Among the Mimbres we see little differences at the architectural level and in mortuary practices, but there is considerable conformity in ceramic production and exchange which shows that social conformity was more symbolic than behavioral (Hegmon 2010; Hegmon et al. 1998). As among contemporary Pueblo people, leadership and social inequalities were not likely based on material things but rather more on knowledge and access to knowledge (Brandt 1994). Some social control may have occurred based on knowledge of ritual power that only a few possessed within each village and that only a few villages exerted over others. Such control may not be visible through all aspects of Mimbres material culture but the importance of ceramic trade within the region and the presence of the elaborate figurative motifs on Black-on-White pottery suggests a "cult of the dead" that is strongly tied to land ownership and successful agricultural output and that might have been controlled by a few (Brody 1977; Brody 2004; Hegmon et al. 1998; Shafer 2003).

Mimbres ritual and leadership

Rituals and the control of rituals were likely important parts of Mimbres society and it has been recognized as a basis for social organization and a power resource (Brandt 1994; Potter and Perry 2000). The control of ritual knowledge helps mediate inclusion and exclusion of certain members of society and can be seen in the evolution of architecture and settlement patterns in the Mimbres valley. As discussed previously, we see a general evolution from pithouses to roomblocks, where domestic and ritual activities shifted location over time. That is, during the pithouse period, most activities took place within individual kivas, but overtime, more activities took place outside the home, on roof tops and in communal plazas. This switch facilitated social interaction and inclusion. In contrast, restricted kivas and corporate cemeteries favored exclusions by those with ritual powers and reinforced lineage affiliation (Potter and Perry 2000). Duality, such as that seen in the inclusion and exclusion of people in rituals, is a common traits in Southwest and Mesoamerican ideology (Thompson 2006). Such similarities are found in architecture, ceramics and mortuary practices across the American Southwest and Mesoamerica, however it is important to be cautious when interpreting ancient ideology because while some motifs stand the trial of time, their meaning and interpretation changes overtime. Therefore similarities are likely more circumstantial that they were real (Shafer 2003:210-211). That said, we can make some inference on Mimbres worldview and rituals.

Architectural evidence. Native Americans share the idea that the world is bounded by the four cardinal points and that within our world there are multiple layers (usually under, middle and outer worlds) that are linked by *sipapus* (access to the underworld) and the *axis mundi* (linking the layers together) (Ortiz 1972). While hunters and gatherers found their ritual places in their landscapes, more sedentary people started to recreate their worldview in their material cultural, including architecture. Shafer (1995; Shafer 2003:210-216; Shafer 2010) suggests that Classic architecture is a reflection of those worldviews. Mimbres constructed rectangular pueblo rooms that were aligned with the four cardinal points. Rectangular hearth and floor vaults found inside those rooms were also aligned with cardinal points. The rooms represented the middle world of the living, while intramural below ground burials represented the underworld of ancestors and the roof of the pueblo was the upper world of spirits. All three layers were linked by the ladder or *axis mundi* coming out of the ceiling hatchways. Passage from one world to the next was through holes, the hearths (in home rooms), floor vault (in corporate cemeteries) or *sipapu*s (in kivas) allowed communication with the underworld, while the hatchway linked the middle to the outer world.

Mortuary evidence. Such representation of worldview has also been identified in Mimbres mortuary practices where the inverted bowl over the head of the deceased may have been the representation of the sky dome, a boundary between two layer and the kill hole a necessity to communicate between the two worlds (Moulard 1984). An alternative interpretation for placing the bowl over the deceased's head might have also been to prevent access to the ancestors, similarly to the masking tradition seen in the later Katchina cult, where a bowl served as a mask and the kill hole as the orifice for ritual feeding (Schaafsma 1994). Ancestors likely held and retain ritual powers as oracles providing advice on scheduling and orchestrating agriculture related events. This view is similar to what has been observed in Mesoamerica, where ancestors were bundled, placed into caves and frequently consulted for advise (Headrick 1998). There is one instance of such burial at NAN Ranch, where San Francisco phase burial 127 was found in a crypt with unusual goods and it has been suggested that it was that of a shaman (Shafer 2003:216).

Other examples suggesting that certain individuals may have held a special place through their ritual knowledge is seen at Galaz and Old Town, where headless burials where found in proximity of kivas. At Old Town, Creel (1997) found a burial that was not associated with the use of the kivas, but that was touching the floor of two of them.

In addition cremations were commonly associated with communal pit structures, suggesting that certain people remained in touch with sacred spaces even after their death (Creel 2006).

Iconographic evidence. Iconographic studies of rock art and ceramic also can help us make additional inference about Mimbres world view and ritual. The puebloan cult of the dead and lineage belonging has been recognized on Mimbres ceramics for a long time (Brody 1977; Brody 2004; Crown 1994). But it is now recognized that Mimbres iconography represents more generally the continuity between man and cosmos, between the living and the dead, life and death (Brody and Swentzell 1996). Motifs found in the Mimbres region have been tied to populations ancestral and succeeding to the Mimbres, such as the multilayered universe, veneration of ancestors, Hero Twins, the Flower World, the feathered or horned serpent linked to the rain cycle and Tlaloc as well as the Katchina cult (Hays-Gilpin 2000; Hays-Gilpin 2006; Schaafsma 1994; Shafer 1995; Thompson 1994; Thompson 2006; also see VanPool et al. 2006). These similarities are a testament that, even if the meaning of such icons may have changed overtime, people and their ideas remain connected in the region over long periods of time.

Mimbres Connectivity and Movement

The Mimbres were connected in a variety of ways and such connections could not have been possible without the movement of people and ideas. Many studies focused on the initial aggregation of people into the Mimbres Valley; what drove them to congregate and how quickly did they settle into the sedentary lifestyle that culminated during the Classic Period are some of the main questions.

Aggregation

Mobility is a necessary mechanism in arid landscapes such as the American Southwest (Nelson 1999). The scarcity of resources during the Paleoindian and Archaic eras forced people to remain in small groups and to move about frequently. It has been assumed that settling even for short periods of time was unlikely until the Post Archaic periods, though there is some evidence for early semi-sedentism in the Tucson Basin or in Northern Chihuahua during the Late Archaic (Mabry et al. 1997; Roney and Hard 2002). The emergence of sedentism is often strongly linked to the development of agriculture and the introduction of maize in the Southwest, but both the degree of sedentism of early southwestern populations and the introduction and reliance on corn in those areas are highly debated topics and vary from region to region.

Originally, it was assumed that the presence of pithouses, in the Mimbres Valley and elsewhere in the American Southwest, meant that people settled there as they started the cultivation of corn and that they stayed there, thus inferring limited mobility; though we now know that agriculture in the Southwest does not necessarily equate to full blown sedentism (Carmichael 1990; Fish et al. 1990; Hard 1990). That is, once thought to be strictly contemporaneous, it is unlikely that pithouses were all used at the same time and therefore represent a semi sedentary lifestyle rather than a strictly sedentary one (Gilman 2010b; Gregory and Dielh 2002).

There are several driving forces for population aggregation but they are not all centered on the emergence of agriculture. The transition that occurred around 1000 A.D was more of an organizational change rather that a shift in settlements and subsistence (Hegmon 2002). "In an aggregated village context, cooperative labor investments are possible; social networks can be established within and between villages to address economic, social and political needs: to hedge against risk of shortfall in production, for protection against others, for finding mates, and for meeting ritual obligations" (Nelson 1999:10). In the North American Southwest we know that the transition to agriculture was not as sudden as in Europe or the Levant and that its influence varied across the region (Kohler et al. 2008). The transition to agriculture and its impact on the landscape is a result of the slow introduction of corn from the southern regions, but not through the massive migration of agricultural migrants (Malhi et al. 2003). Though some assume that the increased need for landownership put pressure on the remaining hunter and gatherers forcing them to aggregate (Mabry 2008), it is unlikely that the slow introduction of crop would have had such a drastic impact on a population (Kohler et al. 2008).

We see the slow evolution of Mimbres society following those driving forces in the archaeological level with the building and remodeling of pithouses and subsequent roomblocks, the evolution of ceramic, social and spiritual interaction throughout the Pithouse and Classic periods. The overlaying of pithouses and pueblo houses shows a continuity in occupation and but not necessarily a continuity in mobility or immobility (Shafer 2006). Even during time of aggregation such as those seen in the Late Pithouse phase and during the Classic period, mobility remained an essential part of Mimbres way of life as they continued to hunt and gather food, farmed distant fields, and interacted at the village and regional level to avoid social conflict and maintain ritual connectivity (Nelson 1999). Even though during the Classic Period we see a primarily inward village focus, safe some interaction with southern area as seen through the presence of macaws, it does not mean that the Mimbres had abandonment any movements or connection with surrounding communities. The regional cooperation, we see through the exchange of pottery within the Mimbres Valley, exotic goods trading with southern and western region, the emergence of certain villages as ritual strong hold like Galaz and Old Town as well as the recurrent use of distant fieldhouses shows that people remained widely mobile aside from their apparent sedentism.

The concept of mobility in late prehistory is widely recognized among the Ancestral Pueblo and the Hohokam, but is rarely discussed in Mimbres archaeology (Lekson 2006). This is due in part to the different scale and time-space systematics used in the analysis of Mimbres archaeology especially in terms of movement (Hegmon et al. 1999; Lekson 2006). Since the Mimbres were widely assumed to be sedentary, and migration studies had largely focused on Post Classic dispersal, movement of people, food and ideas was often rejected or overlooked (Gilman and Whalen 2011; Lekson 2006). Though the driving forces for population aggregation are well understood, those related to population dispersal are often less obvious. Because some researchers had a tendency to assume sedentism as an end and to not recognize other continuing patterns of mobility, the decline of a population can be seen as a dramatic, abrupt ending. This was the case in Mimbres archaeology, where the depopulation of the Mimbres Valley around 1150 A.D. was interpreted as the collapse of its social structure and the disappearance of its people.

Dispersal

The Mimbres grew from small pithouse villages to elaborate pueblo villages in a span of 800 years. The evolution of their social organization and belief system was paralleled by a growing population, changes in architecture, technology, subsistence, storage behavior, water procurement, mortuary customs and ceramics; all of which culminated during the Classic Period and dissipated in the middle of the twelfth century. Abandonment of the Mimbres Valley is a much discussed topic that is likely the result of many factors including a growing population, climate fluctuations and a reorganization of the social and belief system.

Dispersal models suggest that the Mimbres Valley and other parts of the Southwest had reached their carrying capacity during a wet period that spanned from the mid-1000s to the mid-1100s. Subsequently, extended periods of drought in early twelve century contributed to crop failure in a region that was already exploiting farmland and animal resources to its maximum (Benson and Berry 2009; Minnis 1981; Minnis 1985; Minnis and Sandor 2010; Sandor and Homburg 2011; Schollmeyer 2005). Another climate related model suggests that El Niño like heavy rain that followed years of drought may have disturbed the irrigation systems and negatively affected crop production (Shafer 2003; Waters and Ravesloot 2001). In turn, Minnis (1981; 1985) suggested that it might have caused a widespread famine and forced people out of the valley. However, there are limited bioarchaeological data to support a sudden change in food intake and famine, which confirms the idea of dispersal rather than a dramatic collapse. In addition, there is no evidence of violence among the Mimbres like it is the case among certain Ancestral Pueblo and Hohokam settlements who also suffered from the prolonged drought and were forced to migrate (Kuckelman et al. 2000; Kuckelman et al. 2002; LeBlanc 1999).

Initially it was thought that the abandonment of the Mimbres Valley was also linked to the fall of Chaco Canyon to the north and the rise of Paquime (Casas Grandes) in Mesoamerican, since most Mimbres settlements lied in route between the two locations, that were strong regional trade centers (LeBlanc 1983; Nelson 2010a). This view was misled by the idea that almost no one inhabited the Mimbres Valley between the Classic Period and the seemingly unrelated Black Mountain Phase some 100 years later. This was due to the fact that early on archaeologists only focused on large Mimbres sites and overlooked the significance of nearby smaller hamlets. This was an issue of scale and time-space systematics (Hegmon et al. 1999; Lekson 2006). But in the last decade, researchers' view shifted to expend our time-space systematics, which has helped us rethink population movement in the twelfth century.

To better understand Mimbres dispersal it is important to recognize the Terminal Classic Period in the Mimbres valley and Post Classic occupation in the eastern part of the valley, then we can see that people did not simply vanished but instead extended their social or kinship ties to surrounding areas as drought and resource depletion likely forced them to do. This concept of extra regional dispersal in times of hardship is not a unique phenomenon, in fact it is a common response to lasting stress that has been observed elsewhere in prehistoric America such as among the Hurons, Plains Indians, Arctic Hunters and other Southwestern groups (Cordell and Plog 1979; Halstead and O'Shea 1989 ; O'Shea 1989; Upham 1984), though dispersal and migration may not be obvious at the archaeological level.

Carr (1995) suggested that certain aspects of the material culture of a population may have a low visibility at the archaeological level in terms of social identity and evidence of migration; specifically traits associated with the domestic sphere, such as technology associated with food procurement, preparation and disposal. In the Tonto Basin, Clark (2001:9-12) found that items that had high visibility in terms of social identity were more likely to be kept by migrants, while low visibility attributes were quickly assimilated by the migrating group. However, the degree to which a society adopts new technology is highly dependent on the context of migration (Ortman and Cameron 2011; Stone and Lipe 2011). Tammy Stone (Stone 2003) showed that in western Arizona certain groups assimilated quickly, weakly expressing social identity after they moved to Silver Creek or Grasshopper, while the Kayenta people that formed a migrant enclave at Point of Pines showed highly visible traits. Therefore it is important to consider that material evidence of migration is highly context dependent and that a low visibility of material difference does not necessarily indicate a social breakdown of the migrating group and *vice versa*.

The most obvious sign for the apparent “collapse” of Mimbres society was seen in the scarcity of Black-on-White pottery in the Mimbres Valley after the Classic Period.

However, scarcity does not mean disappearance. Though Classic sites were largely depopulated or abandoned there is still evidence of population movement in south and middle valley sites as well as among small hamlets in the eastern portion of the valley during the Terminal Classic Period. At NAN (room 74), Old Town and Galaz, archaeologists have found a ceramic assemblage that still primarily included the Classic Black-on-White bowls as well as other ceramic styles such as El Paso Polychrome, Playas Red Incised, Chupadero Black-on-White, Tularosa Patterned Corrugated and Chihuahuan Corrugated (Anyon and LeBlanc 1984; Creel 1999; Hegmon et al. 1998; Nelson 1999; Shafer 1999). In the middle valley at Swarts and Mattocks there is evidence that people returned occasionally to those sites to visit, gather resources or bury their dead (Anyon and LeBlanc 1984:143). During the Post Classic period, there is no more evidence for Mimbres occupation in the central and southern Mimbres valley, but small hamlets in the eastern part of the valley were already established during the Classic period and were modified during the Post Classic period, namely Buckaroo, Lee Pueblo, Ronnie Pueblo and Phelps sites (Nelson 1993; Nelson 1999:72-141). Those sites show evidence of seasonal occupation during the Classic period and more intense use during the Post Classic. They still contained Mimbres Black-on-White ceramics mixed with a variety of other styles. The presence of Classic Mimbres pottery in relative abundance in the eastern Mimbres Valley during the Post Classic shows that Mimbres people did not initially move South towards Casas Grandes but instead likely migrated to eastern settlements. In addition the increased ceramic diversification is a witness to the growing need for regional and interregional ties in times of lasting hardship.

While symbolic conformity is useful to keep social ties, social flexibility is necessary to cope with changing environment and population movement. Such social flexibility is visible at the ceramic level and at the architectural level (Nelson 1999; Nelson 2010b). Eastern settlement architecture is more variable than Classic architecture, where fieldhouses were turned into roomblocks over time forming small hamlets (Hegmon et al. 1998). Habitations in each roomblocks were not as interconnected, but rather isolated compared to Classic Mimbres villages (Hegmon et al. 1999). Though ceramic styles and architecture became more diverse the Mimbres did not give up on their way of life as they moved to other areas, they still maintained the same subsistence, relying on maize agriculture, gathering plants and hunting small games, though at a much smaller scale (Hegmon et al. 1998; Nelson 1999; Nelson 2010b; Nelson and Diehl 1999).

The central Mimbres Valley was later repopulated during the Black Mountain Phase by people that brought with them a diverse assemblage of ceramics from Paquime. These people did not seem to have any social ties with the Mimbres, because they did not have any Classic Black-on-White ceramics, but they showed similarities with them in other aspects of their material culture and of their use of the landscape (Hegmon et al. 1999).

It is important to widen our time-space systematics, especially in analyzing population movement. Early models focused narrowly on the central Mimbres valley assumed a complete collapse of Mimbres society while a wider approach at a broader regional level favors the dispersion of Mimbres people rather than disappearance. The dispersion and reaggregation of people is a common theme in other areas on the North

American Southwest in Arizona and Colorado where population dispersal coincide with the emergence of groups such the Hopi and Zuni.

Population studies in the Southwest are essential in refining our understanding of population aggregation and dispersal (Lekson 2006). Specifically, they play a role in understanding the transition to agriculture and the reorganization of the Mimbres valley during the twelfth century drought and after.

Mimbres and Southwest Paleodemography

There are two main aspects to reconstructing the demography of ancient people. Paleodemography focus on one of two things: how many people lived in a village or region at a given time, or what were the population characteristics, such as mortality and fertility rates, life expectancy. The vast majority of the literature on Mimbres demography refers to estimating maximum population. Poor preservation, lack of secure chronology and limited skeletal collections have rendered paleodemographic analysis, based directly on Mimbres skeletons, difficult and therefore it is performed infrequently.

Maximum population

Estimating the maximum population of a site, village or region can be achieved by looking at the number of dwellings, their size, construction sequence and remodeling as well as the number of human burials (Hassan 1981). Estimating population based on these factors can be difficult since most sites are not always entirely excavated and surveys may not capture all sites in their entirety. However, it has been demonstrated that excavation data can help consolidate population estimates that were based on surveys only. This is the case in the Mimbres Valley.

Valley wide maximum population. Based on the vast survey of the Mimbres Valley by the Mimbres Foundation in the 1970's and subsequent excavations, Blake et al. (1986) have estimated the population growth rate and the maximum population during each period of occupation. They estimated site size by simply counting pit depressions for the Pithouse Periods and by estimating the number of pueblo rooms for Classic Period on, and by dividing the total dwelling area for the site by the average room size based on excavated examples. To estimate maximum population, they assumed that the amount of floor area per person remained constant through time and that it followed Casselbury's (1974) ethnographic estimates of six square meter per person or 2.27 people per pithouse. Blake et al.(1986) also estimated the use-life of each pithouse and pueblo room to be about 75 years, though some have found these estimates to be too much. Therefore based on site size, number of dwellings and their use-life as well as the amount of floor area per person, they were able to estimate that through Mimbres occupation, the valley had an average growth rate of 0.3%, which is well within the 0.1% and 1% estimated growth rates for prehistoric agricultural societies as per Hassan (1981).

Based on their reconstructions, they found that 150 to 200 people initially settled in the Mimbres Valley, forming six to eight communities, at the beginning of the Early Pithouse Period. The population subsequently more than doubled, having established a dozen midsize communities and marginal ones. During the Late Pithouse Period, hilltop sites were abandoned, new ones were formed on the river terrace, and the valley population continued to grow as the Mimbres became increasingly sedentary and as agriculture developed.

During the Early Pithouse Period, the valley population grew from a few hundreds to about 830 people. Subsequently, during the Late Pithouse Period, it increased slowly to about 2133-3200 people. During the Classic Period, the population then more than doubled, with more people living in large communities and in more marginal areas. They estimated the maximum population to have peaked between 3334-5135 people with a growth rate of 0.58% between the beginning and the end of the period. After the Classic Period, people deserted the area with only a little over 100 people left by 1420 A.D. (Blake et al. 1986). Table 3 show those population estimates. There are two estimates A or B, to reflect the different structure use-life and floor area per person. While Casselburry (1974) suggested a floor area of 6 square meters, Catherine LeBlanc (1981) later modified her estimates to 3.4 square meters per person or 4.89 people per pithouse, which she believes to be more realistic. Similarly, while Blake and colleagues suggested a 75 year use-life for most pithouses or pueblo room, Cameron (1990) and others found that a shorter use-life estimates, closer to 15 years, would be more accurate (Crown 1991; Schlanger 1988).

Lekson (1992) has argued that Blake at al.'s (1986) population sizes were overestimated and offered a new model of population estimates with shorter dwelling use-life that suggest a much smaller valley population through time. Like Cameron (1990), he recommended using a use-life of 15 years, which yielded a valley population of just a few hundreds that was much more mobile than previously thought.

TABLE 3. Population estimates based on 0.3% annual growth rate (Blake et al. 1986)

Period	Estimate	Area of Floor Space per Person	Structure Use-Life	Initial Population	Mid-Period Population	Final Population
Early Pithouse	A	4	75	290	491	830
	B	6	75	194	327	553
Late Pithouse	A	4	75	830	1630	3200
	B	6	75	553	1086	2133
Classic Period	A	6	75	3275	4099	5133
	B	6	40	2126	2662	3334

However, it has been suggested that his results were much too low (LeBlanc 2001). Blake et al.'s (1986) estimates for the entire Mimbres Valley, had been widely corroborated by additional data, such as site specific population estimates as well as Minnis (1985) estimates of the valley carrying capacity. Unfortunately, no other population estimates have been calculated for other parts of the Mimbres region.

Site specific maximum population. At Galaz and Mattocks, Anyon and LeBlanc (1984) have found comparable estimates with a growth rate of 0.6% and 0.4% respectively, between the beginning of the Late Pithouse Period and the Classic Period. At Harris Site, Blake et al. (1986) reported a 0.4% growth rate and at the McAnally and Thompson sites a growth rate between 0.3% and 0.5% has also been suggested (LeBlanc 2001). At Grasshopper, a Late Mogollon pueblo in Eastern Arizona, it has been suggested that the annual growth rate was likely around 1%, though it is higher that most contemporaneous Mogollon societies and it is likely that the remaining population increase was a result from local immigration (Longacre 1976). Given the technological and stylistic continuity as well as evidence for a lineage based organization of the

Mimbres society, immigration was not a significant contributor to population growth so a 0.3% annual growth rate is a reasonable estimate for the Mimbres Valley.

Currently the lack of consensus in terms of structure use-life, and the lack of population estimates in other parts of the Mimbres region limit our understanding of population movement and growth. More studies are needed.

Population dynamics

Most paleodemographic studies tend to concentrate on presenting trends at the regional level, but very few studies actually focus on the dynamics of single populations. While maximum population studies at the region or site level in the American Southwest are rendered difficult due to lack of secure chronology, because part of the data come from surveys rather than excavations, population studies have benefited from a strong interest in the Black-on-White bowl that favored careful excavation of human remains. Demographic studies also profited from a relatively good preservation of those skeletal remains, as well as secure dates and strong archaeological data through excavation that allowed inferences about population growth and decline independently of the skeletal remains; however few site specific demographic studies have been published to this day.

Of those that have been published, general trends are represented in the form of life tables and mortality curves. Generally, data from life tables can be matched to model life tables, but mortality data have been difficult to fit to model life tables in several instances, including Arroyo Hondo (Palkovich 1985), Grasshopper (Paine 1989) and Point of Pines (Bennett 1973).

In his study of Point of Pines, a western pueblo occupied from 400-1450 A.D., Bennett (1973) found a life expectancy at birth and a life expectancy for those less than 5 years old to be around 21.74 and 27.42 respectively. Those numbers are in the higher range as compared to the life expectancy for the first five years of life at other sites: 14.17 at Grasshopper, 20.86 at Arroyo Hondo, 27.15 at Black Mesa, 19.87 at Mesa Verde, 25.65 at Chaco Canyon and 21.55 at Casas Grandes (Berry 1985; Nelson et al. 1994; Palkovich 1980; Palkovich 1985). Grasshopper life expectancy estimates are lower than other sites, but it is likely due to the high number of infants recover during the Abandonment Period, which is likely due to a bias in mortuary practices and research design. Similarly, Point of Pines life expectancy is high for a Mogollon site, which is likely due to an underenumeration of infants (only 23%) (Berry 1985).

When comparing a series of Ancestral Pueblo and Mogollon sites, it has been suggested that Ancestral Pueblo populations from Black Mesa, Mesa Verde, Chaco Canyon, Houck, Turkey Creek and Salmon Ruin could expect to live longer than Mogollon population at Point of Pines, Grasshopper, Arroyo Hondo, NAN Ruin (Berry 1985; Nelson et al. 1994; Patrick 1988). This is due in part to differences in water supply and availability of good arable land (Nelson et al. 1994; Palkovich 1980). These general trends in mortality and life expectancy are based on skeletal samples at the site level only. The small size of individual skeletal series from the American Southwest do not allow for more precise analysis of demographic patterns based on gender or to compare different periods of occupation within most sites.

Overall, it has been demonstrated that demographic patterns in the American Southwest are different from those in the American Midwest (Nelson et al. 1994). Generally, there is a high infant mortality rate and low life expectancy at birth, low subadult mortality and higher mortality among women of childbearing age (Palkovich 1980). However, most of these studies were performed in the early years of paleodemography before statistical advancements help correct some of the problems encountered at the osteological and statistical level. Those problems are discussed in Chapter III.

In all, Mimbres archaeology has come a long way since the early work of Bandelier, Webster, Hough and Nelson, Bradfield, the Cosgroves, Haury, Nesbitt and Bryan. The extensive amount of excavation and surveying during the 1970s-1980s has provided us with a plethora of information laying the ground for our first understanding of the Mimbres, their architectural, ceramic and mortuary traditions. In recent years additional work within the valley and surrounding drainage system has helped archaeologists better understands the different patterns of human behavior within different time-space systematics, such as leadership, exchange, mobility and connectivity. In the present study, which focuses on the population dynamics of the people of NAN Ranch Ruin during the Classic Period, I hope to contribute to our understanding of mortality and fertility patterns in the Southwest and how they compare with other horticulturalist populations. Using more recent paleodemographic methods, relying on Bayesian statistics on the entire NAN skeletal sample, I hope to draw a more accurate and pertinent picture of Mimbres population dynamics, especially in terms of adult mortality, which has been misconstrued due to the limitations of previous methods.

CHAPTER III

PALEODEMOGRAPHY

Definition

Demography is the study of populations. It encompasses the size, structure and dynamics of populations (Chamberlain 2001: 298). It provides information on sex and age distribution, mortality and fertility, survivorship and life expectancies as well as the growth and decline of a population, and it focuses on a living population at a specific moment in time. Similarly, paleodemography is the study of ancient populations. Demography differs from paleodemography in that it relies on census data and vital statistics; data which are usually unavailable for past populations. Paleodemographers look at a deceased population and treat it as a single cohort even though the skeletal sample contains an unknown number of generations (Angel 1969; Bennett 1973).

Paleodemography is particularly useful to the study of ancient populations in that it determines general population trends but it also helps further our understanding of the overall health of a population. Without proper sex and age assessment of each individual skeleton, we cannot make inferences about past pathologies and nutrition at the population level (Milner et al. 2008). Paleodemographic studies help identify how certain diseases and pathologies affected people based on their sex or age and help understand how diseases evolved and spread. Thus paleodemography is not only useful to population studies, but it is also an intrinsic part of paleopathology and paleonutrition, which both look at skeletal changes to assess the health and diet of ancient populations.

There are, however, several challenges in the field of paleodemography. Much of the information that is available to demographers is not available to paleodemographers, which makes the study of ancient demography challenging. It is common to make certain assumptions before beginning the paleodemographic analysis of a skeletal sample. We may assume that the sample is that of a single population, that it is stable and potentially stationary, that the forces that govern population dynamics and aging processes have remained uniform over time and that the sample is representative of the living population we are studying (Angel 1969; Howell 1976). However, before making such assumptions, archaeologists need to justify them for the particular skeletal population that is under study.

Assumptions in Paleodemography

A single population

The most basic assumption is that the skeletal sample is that of one single population that experienced the same way of life over multiple generations and maintained similar fertility and mortality rates over the period during which the skeletons accumulated (Angel 1969). People of diverse origins can be interred at the same place but their shared burial location does not necessarily mean that they had anything in common whether culturally, socially and demographically. Take, for example, people who would have come to a medieval monastery to be treated for the plague and died there (Milner et al. 2008). While they likely all died of the same disease, they most likely came from different communities surrounding the monastery, with slightly different fertility and mortality rates. This is, however, an example of an extraordinary event that has occurred at certain times and certain places in history. Fortunately, additional archaeological data may help us determine whether or not a skeletal sample does represent a population that maintained the same way of life over extended periods of time and whose demographic profile remained relatively constant over time (Buikstra and Konigsberg 1985; Milner et al. 2008).

In the present study, the general homogeneity in mortuary practices, architecture, land use and ceramics across the entire Mimbres region suggests a single homogeneous population. There is strong evidence to show that people interred together belonged to long established lineages (Shafer 1982; Shafer 2003). There is some evidence that some individuals were buried amidst a certain village population, though they may not have belonged to a particular lineage. For example, it has been suggested that those individuals that were cremated and interred in plaza areas, may have had special status or may have come from different populations (Creel 1989; Creel and Anyon 2003). However, because cremated remains are so fragmentary, it is not possible to successfully estimate their age and sex therefore I excluded them from this study.

Stability and stationarity

Another important assumption in Paleodemography is the fact that the population in question is stable. A stable population has constant birth and death rates, meaning that regardless if the population is increasing or decreasing, the change occurs at a constant rate. The same rate applies to different age groups and the population as a whole (Chamberlain 2001). While certain dramatic events such as famine, epidemic or war can rapidly change a population’s fertility and mortality rate, the population usually returns quickly to its original rates after a disaster. It is especially true in small populations, like those found in the Mimbres region (Buikstra and Konigsberg 1985; Howell 1976; Paine 2000; Sattenspiel and Harpending 1983; Weiss 1973; Weiss and Smoose 1976).

Also, due to the common lack of information on population growth in the osteological record it is usually assumed that a population is not only stable but stationary. Stationary means that a population is stable and that the growth rate “r” is equal to zero, meaning that birth and mortality rates are equal and that if immigration and emigration occurred they remained in balance. In other words, the population size is not changing. There are ways to determine whether a population was stationary by studying the accompanying archaeological record including settlement size, number of dwellings and land use, but that information is not always available to osteologists (Hassan 1981). Based on these criteria, Blake et al. (1986) estimated an average growth rate of 0.3% throughout the Mimbres valley during the entire Mimbres occupation.

The assumption that a population is stable and stationary is important for the construction of life tables, but while significant, the assumption of stationarity is not without problems. It has been shown that one may mistake a change in mortality for a change in fertility when analyzing a population under the assumption of stationarity (Johannson and Horowitz 1986; Milner et al. 2000; Sattenspiel and Harpending 1983). However, the cumulative nature of the skeletal samples in the Mimbres valley, their small size and the short periods of occupations, are indicators of relatively stable and stationary populations. If small demographic variations occurred they evened out overtime, making this assumption reasonable for the present study (Weiss and Smoose 1976).

Uniformitarianism

A third assumption is the uniformitarian principle, which, for paleodemography is the assumption that "variation in fertility and mortality rates throughout the human lifespan is constrained in predictable ways" (Howell 1976; Milner et al. 2008: 564); meaning that patterns of population dynamics tend to remain similar all through time, as we have learned from modern analogies. Such uniform patterns help give a range of normal variation to better identify the unusual (Milner et al. 2008).

Uniformity is not only assumed in the statistical representation of birth and death rates, but in the osteological approach to aging processes. It is assumed that skeletal markers change in a unidirectional way, across time and populations. It does not imply that the rate of change remained uniform, despite various constraints, but rather that the processes themselves remained the same. The rate of change is influenced by environment, health and nutrition, which affects populations in different ways (Buikstra and Konigsberg 1985; Jackes 2000; Kimmerle et al. 2008; Storey 2007). Therefore, it is important to appreciate the amount of variation among populations to ensure the use of appropriate reference samples and statistical models with comparable environmental and nutritional elements that best fit a target sample. Although this assumption can be problematic due to those environmental and health factors, the method used for this study addresses this problem with the selection of an appropriate archaeological prior as discussed in Chapters V and VII.

Representativeness

Finally, paleodemographers assume that the skeletal sample was randomly collected and that it is representative of the living population of the time. Archaeological sites are rarely entirely excavated for many reasons, including the fact that archaeological work is destructive and that ideally parts of a site should remain intact until further scientific knowledge and methods can be applied to it, if needed. It is the same with cemeteries and burial grounds. Sites can potentially be excavated in their entirety in the case of salvage archaeology, but even then it is difficult to assert with certainty that the sample of deceased people is representative of the living population. In addition, areas of excavations may be constraint by modern lot limits. I discuss the assumption of representativeness of the NAN Ranch sample in Chapter VI.

These assumptions are made to better capture demographic dynamics and to counteract some of the challenges in paleodemography. Those challenges occur both at the osteological and statistical and they have been widely discussed in the past thirty years. A series of improvements have been formulated over time, though some issues remain unresolved. Both challenges and advances are discussed in the following sections.

Challenges of Paleodemography

Osteological problems

Bone preservation and recovery. In the early years of archaeology, skeletal remains were of little interest to antiquarians and looters and were often disturbed, destroyed or discarded. At the beginning of the 20th century, skeletal remains drew more interest, but there were no systematic collection of remains; instead individual bones of unusual shape or with unusual features were collected separately. Crania were often collected, while the rest of the skeletons, if present, were ignored (Kemkes-Grottenthaler 2002). Also, skeletons are not always excavated by trained bioarchaeologists. Excavators with little training in osteology might not always notice a burial, especially it is that of an infant or if only a few bone or teeth fragments were all that remained. Sites with better potential for yielding numerous quality artifacts have been more attractive to excavators and more coveted (Milner et al. 2008). The fact that the collection of skeletal remains has not always been part of a research design or that the research design targeted places producing large quantity of nice artifacts introduces bias in the skeletal collection since only certain parts of a population tend to be excavated. For example, people of higher social ranking may be buried with more goods and in different areas than the remainder of the population. Thus, if one only excavates the tombs of those high ranking individuals, the resulting skeletal collection is only representative of that particular portion of the population, not of the entire group.

In the Mimbres region, there were no significant difference in the amount of grave goods interred with a body (Gilman 1990; Gilman 2006; Ham 1989; Hill 1997; Spreen 1983), therefore burials were usually equally excavated. Their careful excavation, luckily, benefited from the fact that most Classic burials contained an exquisite Mimbres Black-on-White bowl inverted over the head of the deceased. If the bowls were not so coveted, Mimbres burials may not have been systematically so well excavated (Lekson 2006).

In addition to excavation bias, cultural practices can influence the representativeness of the sample; certain individuals who died at the same time as others may not be found or excavated (Weiss 1972). Infant skeletons, for example, do not preserve well and they are often subject to different burial rites which make their recovery less likely and introduce a bias in the sample (Chamberlain 2001; Milner et al. 2000; Walker et al. 1988). A simple look at modern cemeteries in the United States will show that infants are often buried in a special part of the cemetery with other infants rather than with other family members. Social stratification also often translates into different burial practices, including treatment of the body and disposition. Such differential treatments among different parts of the population can influence the likelihood of preservation and the randomness of the sample.

In the Mimbres valley, there is no evidence that infants and children received different burial treatment, they were found among adults under room floors or middens. There are some instances of differential burials in the form of secondary interment of cremated remains, buried under plaza areas, such as it is the case at Old Town or NAN Ranch. Though their remains are so fragmentary, which makes estimating their sex and age difficult, they are believed to be that of males that may have died elsewhere or that may not have belonged to the local lineages (Creel 1989; Creel 1997; Creel 2006).

Differential bone preservation is an issue in the recovery of skeletal remains. The preservation of bones is affected by intrinsic factors such has the nature of the bone structure, diet and health, and by extrinsic factors like soil pH, cultural practices and scavenging (Bello et al. 2006; Gordon and Buikstra 1981). The level of preservation of a skeletal sample can be determined by comparing the sample to historical records when obtainable. However, such records are not always available or reliable since they may have their own bias. Therefore, one must rely on other ways to recognize and account for the differential preservation of bones. Poorly calcified bones disappear more rapidly, therefore individuals with low bone density such as young children, elderly adults (especially females) will be underrepresented in skeletal collections (Bello et al. 2006; Walker et al. 1988). In many parts of the world, today, demographic profiles of many populations under various economic and cultural traditions show that women tend to live longer than males; yet in the archaeological record there usually are more elderly males than females. This underrepresentation of females in some samples is due in part to differential bone calcification of postmenopausal women, which negatively affect preservation, and to the tendency for women's skeletons to appear more masculine with age. Unfortunately, sexing methods that we have been using for the better part of the 20th century do not always account for this masculinization, which can introduce further bias in the sample (Weiss 1972).

Methods for sex estimation. Sex is estimated in a variety of ways and with minimal error, around 10 %. Because sexual dimorphism in the skeleton is influenced by hormonal changes that begin at puberty, it is difficult to sex juveniles based on their skeletons and it is seldom done with accuracy. Sex determination of adults can be done by looking at the pelvis and the cranium as well as other bones. The pelvis is more reliable for sexing, since it contains specific functional characteristics to accommodate childbearing in women (Meindl et al. 1985b; Phenice 1969; Sutherland and Suchey 1991; Walker 2005).

The sexing of the cranium is different from that of the pelvis because it focuses on differences in size and robusticity, since there is no functional difference between the sexes. For this reason, there is a large amount of overlap in the range of each of the cranial traits between males and females. These traits also vary greatly between populations. It is important to account for the environmental, genetic and cultural variations when analyzing skeletons so sexing can be done with a fair amount of accuracy (Bass 1971; Buikstra and Ubelaker 1994; Steele and Bramblett 1988; Ubelaker 1978).

In sex estimation, the most common misclassification results in classifying young gracile males as females and classifying robust elderly women as males (Buikstra and Konigsberg 1985). Such misclassifications can greatly affect our understanding of population dynamics and our findings on nutrition and health. Ideally, osteologists use different sexing methods on different parts of the skeletons to overcome some of these problems when the skeleton is relatively complete (Acsàdi and Nemeskéri 1970; Lovejoy et al. 1985a; Meindl et al. 1985b; Weiss 1972). Fortunately, there are additional reliable methods to be used on incomplete skeletons. Other than common qualitative methods of sex determination, scholars have also promoted the use of discriminant function analysis, which is particularly helpful when skeletal remains are fragmentary (Giles and Elliot 1963).

Finally, the use of DNA in sex determination is very promising. It is particularly useful in ambiguous cases such as incomplete skeletons and those with low sexual dimorphism, as well as among infants and juveniles. Unfortunately, ancient DNA is not always available or intact for study, there is a high chance of contamination and it is very costly to analyze (Sutton et al. 1996; Wright and Yoder 2003).

In the present study, sexing of the skeletons was performed using general robusticity, pubis symphysis, sciatic notch (Phenice 1969; Ubelaker 1978) and discriminant function analysis for the talus, calcaneus, femur and tibia (Black 1978; İşcan and Miller-Shaivitz 1984; Steele 1976). Though Patrick (1988) was able to estimate the sex of most adult skeletons, the NAN sample is too small to make a pertinent demographic analysis differentiating between sexes. Some information can be extrapolated using those sex estimates, but the shortcomings of sexing methods and the tendency to classify young males as females and old females as males must be kept in mind when drawing any conclusions based on sexual differences.

Methods for age at death estimations. While sex estimation can be fairly accurate, estimating the age of an individual, especially that of an adult, is a lot more challenging and has limitations. The human skeleton is composed of two types of bone, endochondral and intramembranous. Intramembranous bones ossify early in the fetus while the rest of the human bones mineralize at a much slower pace throughout fetal development, childhood and adolescence. The different stages of ossification provide clues in estimating age at death. There are 450 ossification centers (primary and secondary ones) or elements at birth and by adulthood those centers have grown and fused to form 206 bones. While primary ossification centers appear during fetal development, secondary ossification centers mature by late adolescence. It is the different stages of mineralization at primary ossification centers and epiphyseal unions that make aging children and adolescent fairly accurate, because mineralization occurs consistently around the same time for every individual, through time and in different environments (Baker et al. 2005; Buikstra and Ubelaker 1994; Steele and Bramblett 1988). Thus aging immature skeletons (those of children and adolescent) usually relies on analysis of dental development which is more accurate.

Teeth are very useful and important in aging immature skeletons, especially because they preserve better than bone and sometimes they can be all that is left for the osteologists to analyze. Unlike bone, a tooth develops accretionally and does not remodel overtime, so its structure contains valuable information regarding the formation process and any incidents that might have occurred during development. Dental formation begins at 6 weeks of intrauterine development and continues during infancy and early childhood. Deciduous teeth and permanent teeth calcify and erupt at different times, but the time at which a each particular tooth calcifies and erupts is consistent among humans, which, coupled with the fact that teeth preserve well, makes dental analysis of immature skeletons a very accurate aging method (Gustafson 1950; Liversidge and Molleson 2004; Ubelaker 1978).

Estimating the age at death of mature skeletons is more challenging because it does not rely on developmental changes, but rather, on degenerative changes which vary greatly depending on many environmental factors, occupation, diet, health, endocrine status and cultural practices. All bones and teeth can start to show signs of wear and deterioration as early as young adulthood, but the amount and pattern of wear is dependent on many factors. As for sex estimation, the skull and pelvis provide the most reliable information regarding age estimates. Endocranial and ectocranial sutures on the skull fuse at different times. The degree of closure and the timing is correlated with advancement in age. This correlation has been recognized since the sixteenth century by Vesalius (Masset 1989). But by the turn of the twentieth century, Pommerol (1869), Ribbe (1885) and Frédéric (1906) had been the main contributors to estimating age at death based on cranial sutures (Stewart 1979). Their work was based on several samples of different sizes, but age at death was not consistently well-documented or was erroneous. In addition, their work focused on complete crania, gathering data primarily on ectocranial sutures and minimal information on endocranial sutures. Subsequently, two large studies widely influenced cranial analysis (Martin 1928; Todd and Lyon 1924; Todd and Lyon 1925a; Todd and Lyon 1925b; Todd and Lyon 1925c). Todd and Lyon's method has been widely used in English speaking countries while Martin's was favored by researchers who could read German. Martin (1928)'s work was largely inspired from Frédéric (1906)'s previous work. Todd and Lyon studied a large sample of male crania from European and African ancestry and concluded that there were no difference between sex and races and that endocranial sutures yielded more reliable age estimates than ectocranial sutures. Both studies produced a variety of results when applied by different scientists, an indication that the methods were not as accurate or as easily duplicable as originally thought. Prior to Todd and Lyon and to Martin's work, it had been suggested that the use of cranial sutures was questionable (Dwight 1890; Frédéric 1906; Hrdlička 1920). But the strongest criticism occurred in the 1950s, Singer (1953), Brooks (1955), McKern and Stewart (1957) recognized that the use of cranial sutures as a means to accurately estimate age at death was too unreliable, especially for females (Brooks 1955). "[W]ith techniques available at present, an assessment regarding the precise age at death of individual, gauged only on the degree of closure of the vault sutures of the skull, is a hazardous and unreliable procedure" (Singer 1953:59).

While thorough, Todd and Lyon's analysis excluded anomalous crania, which contributed to erroneous age estimates when later compared with other age skeletal age indicators (McKern and Stewart 1957). While some scientists continued to try to refine those methods with new skeletal samples (Genovés and Messmacher 1959; McKern and Stewart 1957; Necrasov et al. 1966; Nemeskéri et al. 1960), others have directed their attention towards other aging methods that were already known to be more reliable. The main problem with the use of cranial sutures as an age indicator is that we do not understand the forces that govern the variability in the timing and degree of suture closure that is commonly reported (Key et al. 1994).

Renewed interest in cranial sutures emerged in the 1980s. These studies focused on establishing the best correlation coefficients and smallest deviation between specific cranial sutures, or part of cranial sutures and age (Masset 1982; Masset 1989; Meindl and Lovejoy 1985). While those coefficients are still less than ideal, the use of certain sutures to estimate age at death can be used with some degree of accuracy. However, it is best and a common practice to use cranial suture aging methods in combination with other aging methods to corroborate results, like it is the case in the Transition Analysis method used in the present study (Boldsen et al. 2002; Brooks 1955; Krogman 1962; Lovejoy et al. 1985a). Transition Analysis (Boldsen et al. 2002), uses a combination of skeletal features from the cranium, pubic symphysis and auricular surface of the ilium. Despite, best efforts to refine cranial studies over the years, cranial sutures consistently underperform as age indicators as it is the case in my analysis of the NAN sample (see Chapter V).

Of those other aging methods, many focus on the pelvis, which provides the most reliable clues in age estimation. Its analysis, when possible, is most widely used in forensic and bioarchaeological studies (Acsàdi and Nemeskéri 1970; Hrdlička 1952; Krogman 1962). There are two main areas that sustain consistent, measurable changes with age. They are the pubic symphysis and the auricular surface of the ilium.

Like with cranial sutures, the first systematic aging method based on the pubic symphysis was developed by T.W. Todd on the Western Reserve University sample, the early stage of the now renowned Hamman-Todd Collection (Todd 1920; Todd 1921a; Todd 1921b). The sample consisted of 306 White males and 47 females, plus an additional 90 individuals of mixed ancestry. Focusing on five features: the ventral and dorsal rampart, superior and inferior extremities and subsidiary features such as billowing, ridges and nodules, Todd created a ten-phase system to age individual between 18 and 50 + years old. He found no notable differences based on sex and race. In the 1930s, he also developed a four-phase system based on changes noticeable on x-rays (Todd 1930). While his aging system remained widely used and is the basis for most subsequent aging techniques, there are some shortcomings. Cobbs (1952) noted that mortality graphs based on Todd's aging methods peaked at regular five-year intervals, which he attributed to the tendency for relatives of the deceased and certain records to round off an individual's age. In addition, Brooks (1955) demonstrated that while fairly accurate to estimate ages for individuals in their 20s, Todd's method has a tendency to overage those in their 30s and 40s. She also noted a greater range of error for females. She suggested some modifications to Todd's phases to counter this susceptibility to overage.

Another important contribution to aging methods using pubic symphysis is that of McKern and Stewart (1957). They found that Todd's method did not capture the amount of variability of the different components of the pubic symphysis. This is due in part to the fact that Todd excluded anomalous specimens from his sample. McKern and Stewart found in their analysis of Korean War Dead that different parts of the pubic symphysis changed at various times. Therefore, they established a scoring system based on three components, the dorsal plateau, the ventral rampart and symphyseal rim, and a series of five stages per component, hence "translating a large number of morphological combinations into chronological terms" (McKern and Stewart 1957: 72). Their method presents some problems too because it is based on an all-male population, primarily White and primarily in its late teens and early twenties.

In the light of Brooks (1955) and McKern and Stewart (1957)'s work, there was an obvious need to establish different standards to age females, for their pubic symphysis evolves differently due to the stress of parturition. Without separate standards, females tended to be greatly overaged because they undergo certain changes sooner than males, such as the flattening of the dorsal surface (Gilbert 1973). Therefore Gilbert and McKern (1973) developed aging standards for females based on the three components and five stages each. But Suchey (1979) later found their system inaccurate and unreliable.

While there are definite differences between male and female pubic symphysis, some studies found that there were few racial differences in the different morphological stages of the pubic symphysis. In their studies of Japanese individuals, Hanahira and Suzuki (1978) found little differences using Todd's system, save a difference of minus two to three years. However, Katz and Suchey (1989) found that there were some racial differences. Individuals with African or Mexican ancestry showed lower average age than Whites even though they had advanced patterns. However, it is unclear if such differences are strictly racial of if they are based on environmental or nutritional factors.

During the 1980s, new efforts were made to test existing methods on new samples that were larger, more diverse and encompassed a wider range of ages, more representative of a population. Meindl et al. (1985b) compared all existing pubic symphysis methods on the Hamman-Todd Collection and found that Todd's phase-based system was most reliable and modified it in accordance with the test results, to correct existing shortcomings. They found that Todd's descriptive phase-based approach, while requiring more expertise, was more desirable than a simpler numerical scoring system (Meindl et al. 1985b: 30,44). Katz and Suchey (1986) performed the first regression analysis on male pubic bones using a large sample (n=739) that included a wide age range and had excellent age documentation. They simplified Todd's method into a six phase regression model. They later performed the same study on female bones (Suchey et al. 1982). Later Brooks and Suchey (1990) also compared existing American techniques to that in Europe and found that Acsàdi and Nemeskéri (1970) five stage method only allowed to place individuals in large age categories, focusing on early and late changes only, and did not capture the most variable changes that occur in mid-adulthood.

The Transition Analysis method (Boldsen et al. 2002:79) used in the present study follows the logic of McKern and Stewart (1957) as well as that of Gilbert and McKern (1973), which emphasizes the scoring of five different components on the pubic symphysis, rather than classifying the entire symphyseal surface of the pubis at once like in the methods by Todd and Suchey and Brooks described above . Morphological changes of the pubic symphysis while unidirectional, do not all occur at the same time in "lockstep", but rather each component of the pubic symphysis morph at different times at their own pace.

Unfortunately, the pubic symphysis is delicate and highly susceptible to damage (Buikstra and Ubelaker 1994; Katz and Suchey 1989; Kimmerle et al. 2008; McKern and Stewart 1957; Todd 1921a). The auricular surface of the ilium, on the other hand, offers similar precision as pubic symphysis analysis but it is less likely to be damaged (Waldron 1987). Unlike for cranial sutures or the pubis symphysis, aging methods based on the auricular surface of the ilium are much more recent. Sashin (1930) was the first to document the changes of the sacro-iliac joint and their relation to age but it is not until

1985, that Lovejoy and colleagues (1985b) published the first method to use the auricular surface as a means to estimate age at death. They devised eight modal age phases based on the texture and degenerative changes of the auricular surface, each of the phases corresponding to a 5-year interval, based on modern and archaeological skeletal samples: the Libben Collection, the Todd collection and some forensic cases. They then tested the new method on two other samples from the Todd collection. The different modes they established generally correspond well with those established by Sashin 55 years earlier. Subsequently, several studies have tested the reliability of Lovejoy et al. (1985b) method and have found that it had a tendency to overage young individuals and underaging older ones. Using this method on a sample from the Terry collection, Murray and Murray (1991) found that it, indeed, had a tendency to overestimate the age of young adults and to underestimate that of old adults. While they determined that the method was not biased by sex and age, they found it to be too unreliable to be used as a single age indicator in forensics. Similar conclusions were drawn by others (Bedford et al. 1993; Buckberry and Chamberlain 2002; Saunders et al. 1992; Schmitt 2001; Schmitt 2005; Schmitt and Broqua 2000). In addition to an age bias, it has been suggested the Lovejoy et al.'s method did not take into account the amount of variability of each features and that they might have oversimplified the developmental changes of the auricular surface. The method has also been found to be difficult to apply based on a lack of pictorial evidence (Buckberry and Chamberlain 2002; Garst 2003; Saunders et al. 1992). In effect "[…] the method of Lovejoy et al. (1985b) oversimplifies the changes seen, and that the 5-year intervals in their scheme of age estimation may be optimistically narrow. This problem contributes to the difficulty found with applying the method, as it leads to uncertainty, and in some cases confusion, in assigning individual auricular surfaces to a particular age stage" (Buckberry and Chamberlain 2002: 232).

Buckberry and Chamberlain (2002) proposed a revised method for the auricular surface of the ilium, using a sample from the Blackgate Anglo-Norman site from New Castle-upon-Tyne and the Spitalfield Collection in Great Britain. They found that a combination of transverse organization, surface texture, microporosity, macroporosity and apical changes had the highest correlation with age. They applied a uniformed prior to the method to compensate for the tendency for the reference sample to affect the target sample. They found that their revised method was easier to use, had low interobserver error and that there was no bias based by sex, race or sides of the os coxa. Others, however, have found that there can be a difference between the right and left auricular surface and they suggest combining the age estimate from each side (Debono et al. 2004; Schmitt 2005; Schmitt and Broqua 2000). In an extensive study, Schmitt set out to simplify Lovejoy et al.'s method and to better account for the variability of each feature as well as to avoid common bias. She studied four morphological features on 933 skeletons from seven historical and modern collections from a variety of genetic and environmental backgrounds and applied a Bayesian approach to avoid bias from the reference collection. She found that the method was fairly accurate and easily applicable, though not totally devoid of interobserver difference. Similarly to pubic symphysis analysis, the Transition Analysis method (Boldsen et al. 2002) used in my study focuses on different components of the auricular surface of the ilium, rather than the surface in its entirety, hence capturing the different combinations of morphological changes that occur overtime.

Assigning an age interval. Because the different factors that affect the human skeleton are not always easily recognizable and measurable (Jackes 2000; Masset 1993), and because recovered skeletons are not always complete and well preserved, is it best to use a variety of aging methods to try to narrow down the likely age at death of an individual (Baccino et al. 1999; Bedford et al. 1993; Lovejoy et al. 1985a; Saunders et al. 1992; Schmitt 2001). Without historical records of any form or vital statistics to confirm the age at death of individuals, it is not possible to precisely age a skeleton even when many methods are used. Therefore, it is common for biological anthropologists to assign an age interval to a skeleton as opposed to one chronological age, in recognition of the shortcomings of our current aging techniques and to lower the chance of misclassification. Usually, paleodemographers will use broad age categories (i.e. Infant, Children, Subadult, Adult, Old Adult) or will assign ten-year or five-year intervals when possible, except for young children and older adults. To better capture infant mortality and because aging methods allow more precision in aging infants and children, the first five years of life are commonly broken down into 1-year intervals. On the other hand, because aging adult skeletons is less accurate, and senescent changes are harder to measure, “old” skeletons are grouped in an open ended interval of 50 years old and older. While this is the safest way to represent the aging population, it does not entirely provide a precise snapshot of an ancient population and leads to the common assumption that people of the past did not live to be very old. However, we know from historical accounts that people lived well into their sixtieth years and beyond, but paleodemographic studies usually fail to capture that, due to the limitations of the aging methods we used (Baccino et al. 1999; Jackes 2000; Schmitt 2001). It is not until the 1990s that new methods combining osteological observations and statistics were developed, allowing better age estimates among the elderly population. Yet very few demographic studies have since included more information on the senescent portion of ancient populations.

Statistical challenges

The use of statistics in demographic studies began during the early part of the 20^{th} century although it was not widely applied to paleodemography until decades later. Like osteological methods, the statistical methods used in ancient demography studies are not without challenges.

During the first half of the century, age and sex data were simply tabulated and few studies comparing populations were carried out. Beginning in the 1950s through the 1970s, when computers became more readily available, allowing advances in statistics, paleodemographers started to borrow analytic tools from demography, such as life tables and model life tables (Acsàdi and Nemeskéri 1970; Angel 1969). The standard use of life tables in paleodemography allowed for more systematic analyses and for comparisons between ancient populations and with historical or ethnographic data, hence forging our understanding of ancient population dynamics. During the late 1970s and early 1980s, however, scientists outside and within the field of paleodemography began to criticize the reliability of the data and methods used, as well as to doubt the future of the discipline.

Erroneous methods and results. In 1975, demographer William Peterson questioned the validity of the data and procedures used in paleodemography. He recognized that archaeologists face challenges in accurately estimating population sizes and other demographic indices when sites are only partially excavated and when bone preservation affects the recovery of human remains, but he deplored the lack of statistical knowledge among paleodemographers at the time and the lack of cooperation with demographers. He also questioned the use of ethnographical populations as a tool for comparison with ancient populations (Peterson 1975). He suggested that instead of developing mathematical techniques based on the assumption that the sample is representative of the living population, one should develop mathematical models that accounted for the bias in the sample.

In *Farewell to Paleodemography*, French paleodemographers Jean-Pierre Bocquet-Appel and Claude Masset further questioned the downfalls of the data and methods used in the field and pointed out an apparent mimicry between the age distribution of the reference and target samples (Bocquet-Appel and Masset 1982). Age estimate methods rely on the correlation of specific biological features and age. According to the authors, to accurately draw a population structure from skeletal remains, the correlation coefficient must be at least 0.9, but none of the osteological methods of the time could produce such a coefficient. In addition, Bocquet-Appel and Masset pointed out that sexual dimorphism was often overlooked and that old individuals were often left out of population analysis producing inaccurate population structure. Furthermore they questioned the assumption that aging processes affect the skeleton at the same rate through time. This assumption of uniformitarianism is the basis of paleodemography's osteological method and statistical work, which they also criticize.

Age at death distribution mimicry. Bocquet-Appel and Masset (1982) demonstrated that the age structure from the target population had the tendency to closely mimic that of the reference population from which the aging method has been developed. Many of the aging methods used on the early years of bioarchaeology and forensics relied on skeletal samples that were not entirely representative of their contemporary living population, let alone of an ancient population. The Hamman Todd and Terry collections, widely used to shape many aging techniques, contain thousands of well documented skeletons from a variety of ethnic and socioeconomic backgrounds which have made them excellent sources of information. The Korean War Dead collection also used to develop a widely used aging method by McKern (1957) was a large sample but only provides information on young adult male traits. Aging methods rely on the fact that a specific trait is most likely to occur at a specific age. If, for example, the reference sample used to established a particular aging method contains more 30 year olds than 70 year olds, but a particular trait is more typical of 70 years old, the calculated probability of the trait will be greater for the 30 years old than for the 70 years old because of the nature of the sample, not because it is true (Milner et al. 2000). Thus using methods derived from modern, somewhat biased samples to apply to prehistoric samples will have a tendency to produce age estimates and mortality curves that are biased in the same direction of the reference sample (Konigsberg and Frankenberg 1992; Milner et al. 2000; Milner et al. 2008).

The defeatist article (Bocquet-Appel and Masset 1982) predicted the end of paleodemography as we knew it and provided no real solutions, but the bioarchaeology community responded vividly to challenge some of the questions the authors had raised because while true, their accusations were exaggerated. The responses were numerous and fruitful. Van Gerven and Armelagos (1983) defended their study of the Nubian skeletal samples, the accuracy of the mortality curve and conclusions they drew, all of which were under scrutiny in Bocquet-Appel and Masset's (1982) article. They also compared chronological and skeletal age at death from the Todd collection and concluded that there were no significant differences in all age groups except among individuals in the 40s. They dismissed Bocquet-Appel and Masset's claim that 50 year olds were that numerous and therefore that significant, and rejected the conclusion that paleodemography was doomed and useless. In their response to Van Gerven and Armelagos, Bocquet-Appel and Masset (1985) maintained the significance of the problem of current age estimation which underestimated the number of older people (over 50 years old). Subsequently, Paine and Harpending (1998) have observed that underestimating the elderly tends to inflate birth rates by 10-20 % while the underrepresentation of infants in the archaeological record decreases fertility and birth rates by 20-25 %. Buikstra and Konigsberg (1985) recognized that early paleodemography studies must be used with caution because they did not rely on the latest ethnographic data and sophisticated models that had emerged in the late 1970's. Buikstra and Konigsberg demonstrated the use of life tables as a means to compare human demographic profiles across time and space, using principal component analysis. With proper statistical work much can be learn from skeletal populations. Bocquet-Appel and Masset's criticism of the uniformitarian model and their alarming statement in regards to our inability to properly age older individual was overstated and their farewell unwarranted.

Problems with stationarity. While widely accepted for the use of life tables, in the light of newer methods, the assumption of stationary has been challenged in the last 30 years. Several authors noted that if one assumes stationarity, two populations with the same mortality rates but with different fertility rates would actually produce different age at death distributions, where one could confuse a difference in fertility and population growth for one in mortality (Johannson and Horowitz 1986; Milner et al. 2000; Sattenspiel and Harpending 1983). Fortunately, competing hazard models have been used successfully to counteract the problem associated with stationarity. Hazard models help fit survivorship curves to determine if the noted mortality pattern is biologically sound (Gage 1988; Jackes 2000; Konigsberg and Frankenberg 1992; Muller et al. 2002).

By the late 1980s, it was clear that the field of paleodemography was not dead, but that it needed much improvement in terms of osteological and statistical methods. Much of the paleodemographic work of the following decades has focused on the development of statistical models to better account for the bias introduced by certain reference collections and to correct some of our common assumptions.

Recent Advances in Paleodemography

Improvements in osteological methods

While in recent years much of paleodemographers' work has focused on statistical methods to overcome the bias introduced in our sex and age estimates, osteological methods have been refined to better estimate sex and age at death, especially in terms of population specificity. Some of these osteological methods have been discussed in earlier parts of this chapter. Mainly, osteologists have worked to improve existing methods to make them less arbitrary and more reliable, by increasing the number of reference collections from different regions of the world and from different periods; to better capture the variety in the osteological record and to offer better references for different environments. They examined the reliability and applicability of existing methods that had been created and used on modern cadavers and archaeological collections. Refined methods coupled with computer assisted statistical estimates have improved aging accuracy from 80 % to close to 90 % among well trained osteologists (Hoyme and Isçan 1989; Meindl et al. 1985a). We still face problems of inter- and intra-observer differences, but this can be overcome in the long run with additional training. Also, whereas most osteological methods rely on the observation of macroscopic features of the skeleton, advanced imaging has allowed us to performed microscopic analyzes of bones and teeth and to create aging methods such as tooth cementum annulation, which are validated and less subjective (Stout 1992; Wittwer-

Backofen and Buba 2002). But these techniques are destructive and costly and therefore not widely used. The transition analysis (Boldsen et al. 2002) method that I used in the present study is one of those more recent, improved methods, that combines refined osteological analysis and computer assisted Bayesian statistics.

Improvements in statistical methods

Paleodemographic studies have greatly improved since basic tabulations and life tables and have increasingly turned to a model based approach to interpret age and sex data. The bulk of statistical advances come from the increased application of biostatistics which rely heavily on Thomas Bayes statistical theorem (Bayes 1763).

Recent publications. At the close of the 20th century, increased collaboration between osteologists and statisticians has produced an extraordinary amount of improvements to the field as we can see from the numerous edited volumes that have been published in recent years following the various workshops held to coordinate ideas and find consensus. The purpose of these workshops was to provide participants with an opportunity to share their new techniques and findings, and to come to a consensus in terms of better osteological methods, reference samples and statistical methods, including the need to use Bayesian statistics, and to better recognize and interpret patterns in the target populations. From the 1999 summit in Rostock, Germany emerged the *Rostock Manifesto.* This collegiate plea underscores the need to be more meticulous with our reference samples and to produce more research on specific stages-to-age correlations. It calls for increased collaboration between anthropologists and demographers to estimate the probability that a given trait occurs at a given age, and to better decipher it from its opposite, the probability of a given age having a given trait, following the principles of Bayesian statistics, outlined later in this chapter. The work of paleodemographers present in Rostock was compiled by Hoppa and Vaupel in Paleodemography: age distributions from skeletal samples (2002). In this edited volume, Usher (2002) gives an overview of what constitutes a good reference collection for testing aging techniques, while Kemkes-Grottenthaler (2002) describes the history, challenges and advances in age-indicator methods. The following chapters offer different osteological methods and statistical models that have proven to be successful, and that help in identifying and interpreting population dynamics patterns including various multivariate approaches, transition analysis, Markov chain Monte Carlo estimates, hazard models and mortality models.

Like Hoppa and Vaupel's (2002) edited volume, Bocquet-Appel reported the latest paleodemographic research as discussed at the World Population Congress in 2005. In this volume, Bocquet-Appel (2008) gathered recent work in understanding the evolution of human populations, by providing information in three areas: data, techniques and pattern detection. While most data in paleodemography come from skeletal remains, other aspects of human lives can be used to determine population size such as DNA studies and land surveys. The second part of the book offers different techniques to better estimate age distribution of skeletons and its confidence intervals, using several statistical theorems, including Bayesian statistics and provides model life tables for pre-industrial populations. The final part of the book focuses on different models that can be used to detect and interpret demographic patterns that have been detected in skeletal samples from Europe and North America, including a pattern for the Neolithic transition. Other edited volumes provide an insight into the recent advances of Paleodemography by the main contributors to the field (Katzenberg and Saunders 2000; Katzenberg and Saunders 2008; Paine 1997; Saunders and Katzenberg 1992).

Bayesian statistics. Thomas Bayes was an 18th century British mathematician and clergymen, whose theorem allows one to determine the probability that an event occurred given certain conditions. There are three components to a Bayesian statistical model, the *likelihood*, the *prior* and the *posterior probability*. The *likelihood* is a statistical function which depends on a specified statistical model. "[It] is the probability of observing particular data values given some specific values of the unknown parameters"(Buck 2001:696). On the other hand, the *prior* is "the probability we attach to observing specified values of the unknown parameters before we *a priori* observe the data"(Buck 2001:696). The prior is what we know before we look at the new data we are testing. Finally, the *posterior* is "the probability we attach to specified values of the unknown parameters after observing the data" (Buck 2001:696). As Buck sums it up: "given an explicit statement of our *a priori* information, a clearly defined statistical model and a desire to obtain *a posteriori* understanding, Bayes' theorem provides us with a probabilistic framework within which to make interpretations" (Buck 2001:697). This approach is being used in both forensics and paleodemography to calculate the probability that someone is a certain age, given that the body possesses a particular skeletal characteristic or a combination of skeletal features.

The majority of the newer methods begin with estimating the probability of witnessing a particular developmental stage of certain bone features, given that an individual is a specific age. Then scientists must perform a Bayesian inversion to estimate the probability that an individual is a certain age given that we witness a particular stage of an age marker.

Parametric models. Much of the statistical work since the 1990's onward relies on a Bayesian statistical approach because it addresses the problematic influence of the age structure of the reference population on the age at death estimation of skeletal samples (Milner et al. 2008). Scientists began to look outside the field of paleodemography to borrow methods used in other biological population studies. Konigsberg and Frankenberg (1992) drew from fisheries biostatistical literature and adopted the iterated-age-length key method to better estimate age distribution of the target sample without mimicking the age distribution of the reference collection. This study uses a model by Gage (1988), inspired from Siler's five-parameter competing hazard model to capture a wide range of human mortality patterns. Gage's model assumes that one's risk of death at a given age is determined by juvenile causes, senescent causes and independent causes, such as accidents. How much these three elements interact with each other and affect the skeleton changes with age (Gage 1988; Jackes 2000; Konigsberg and Frankenberg 1994; Leslie and Gage 1989; Milner et al. 2000; Milner et al. 2008). Muller et al. (2002) also uses a semi-parametric model to better fit the age estimation to the age distribution of a sample. It has been demonstrated that such parametric mortality models successfully solve the problems with non-stationarity and sexing and aging error. It also provides an insightful look at the later ages of life, which was not possible, using early aging methods.

Parametric models can be fitted to age at death distributions through the use of maximum likelihood estimation (MLE). Using different parametric models, we can calculate the likelihood of getting a combination of age markers on a skeleton. From this likelihood, we can calculate the most likely age at which one would find a particular suite of skeletal traits. MLE's have very small standards errors which makes them appealing (Milner et al. 2008). However it has been demonstrated that if the MLE is not constrained by a mortality model, it tends to turn the age distributions of the target population into an unrealistic age distribution (Chamberlain 2006). "The unconstrained MLE method generates a highly irregular, multimodal mortality profile which is *a priori* unlikely to represent the true age structure of [a] prehistoric sample" (Chamberlain 2006: 119). Therefore it has been suggested that MLE should be constrained with a fitted Gompertz hazard model to obtain a smooth mortality profile (Boldsen et al. 2002; Chamberlain 2006; Herrmann and Konigsberg 2002; Konigsberg and Hermann 2002).

Transition analysis (Boldsen et al. 2002), which I use in my analysis of the NAN skeletal sample represents a combination of the many improvements in osteological and statistical methods that have been posited in the last decade. From an osteological standpoint, the method uses several anatomical units in conjunction with each other. Those anatomical units are the cranium, the pubic symphysis and the auricular surface of the ilium. The method breaks down each anatomical unit into specific components or segments to better capture the timing of transitions between particular, adjacent skeletal states. Previously, older methods had a tendency to look at the morphological changes that occurred over an entire anatomical unit, assuming that the whole cranium, the entire pubic symphysis or the auricular surface of the ilium, aged at the same rate. However, it is not the case. Different parts within each of those three anatomical units change at different rates, therefore Boldsen et al. (2002) broke down these units into nineteen scorable components to better capture the considerable morphological variations that occur progressively with age. The scoring system of those components is described in Chapter V.

In addition, transition analysis relies heavily on Bayesian statistics. Specifically, it looks at the statistical likelihood that an individual died at a particular age, given that a certain combination of anatomical traits is observed. “It is the age-specific probability of having completed the transition between one state and the following state that forms the basis of the likelihood” (Boldsen et al. 2002; Chamberlain 2006: 119; Konigsberg and Herrmann 2002). This statistical likelihood is estimated based on observations made *a priori* on skeletal collections with known age at death and is constraint by the use of fitted Gompertz hazard models to help smooth out any discrepancy in the mortality profile of the population that is being studied. The forensic prior for the Transition Analysis software is based on the Terry collection and the archaeological prior is based on a 17th century rural Danish parish (Boldsen et al. 2002).

Although the previous demographic analysis performed on the NAN skeletal sample uses a variety of aging methods in conjunction with each other, those methods were implemented before the many changes that have been suggested in recent years.

Some of the methods used by Patrick (1988) have been proven to mimic the age distribution of the reference sample that were used to create them and do not utilize Bayesian statistics to counteract some of those problems. I feel that the Transition Analysis method addresses most of the concerns that were raised in the 1980s and 1990s and that it is a pertinent method for my analysis of the entire NAN skeletal sample. In future years, the method is expected to be refined with additional skeletal information from known age at death collections to better estimate the archaeological or forensic priors and including more skeletal traits to better capture the timing of transition from one osteological stage to another (Milner 2011 personal communication, April 20, 2011)

Conclusion

Today, scientists continue to work towards a consensus. They continue to refine aging and sexing methods, by testing their methods on an increasing number of well-documented reference collections and they continue to test and adapt statistical models to be employed to interpret the demographic patterns of ancient populations. Though paleodemography was once thought to be doomed, it has taken a new road towards more accurate and reliable demographic estimates that can be used successfully to provide a more meaningful insight into the lives of ancient people. In the current study, I expect the Transition Analysis Method to yield some pertinent information on the entire NAN population, including on the senescent part of the population that is often overlooked due to the shortcomings of older methods.

CHAPTER IV

THE SAMPLE

NAN Ranch Ruin

Site description and history of excavation

The NAN Ranch Ruin site is located on private property in Grant County, the Y-Bar NAN Ranch, New Mexico. Figure 2 illustrates the location of the NAN Ruin site in relations to other Mimbres sites referred to in this manuscript. It is nestled in the northern confines of the Chihuahuan Desert, on a low alluvial terrace remnant

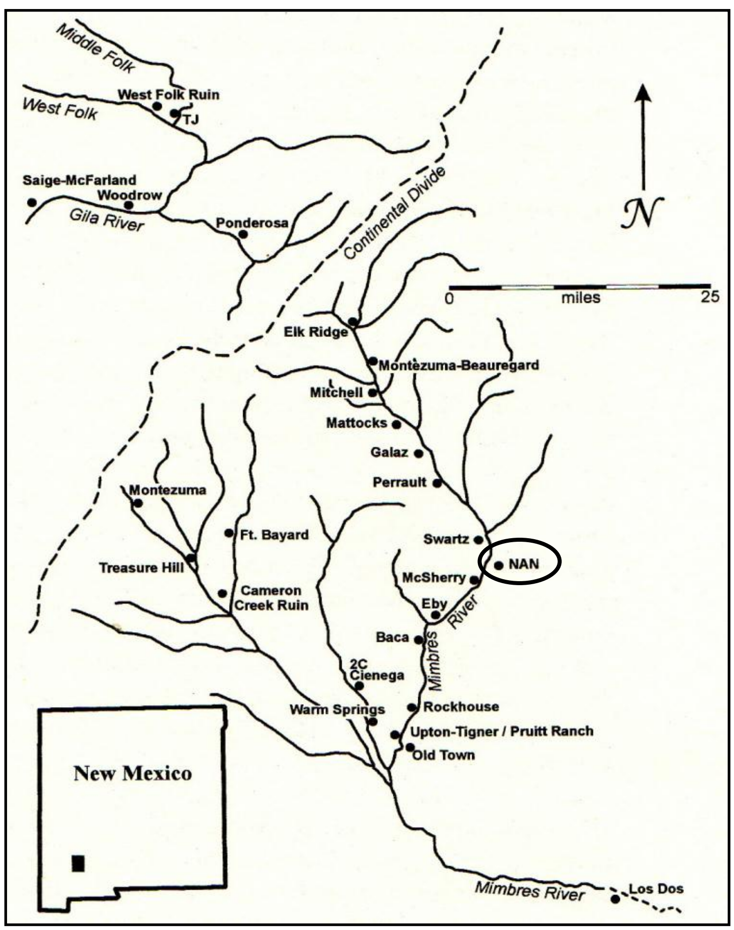

Fig. 2. Major Mimbres Sites (after Shafer, 2003: Figure 1.7).

overlooking the Mimbres river, about 60 meters east of the river and 5 meters above the floodplain (Shafer 2003; Shafer and Murry 1978; Shafer et al. 1979).

Site description. The NAN Ranch site can be found in the literature as LA 21165, NAN, NAN Ranch, Hinton Ruin or LA 15049. Before excavations it was a rubble mound of about 6500 square meters (100 meter long and 65 meter wide). It is a large Classic Pueblo, under which also lies a large pithouse village. An estimated 75-100 pithouses lay below the ancient pueblo (Shafer 2003). The Classic Pueblo emerged from an arrangement of early core rooms. It consists of at least five room clusters, which contain a varying number of rooms, from two to over 50. Figure 3 features a map of the NAN Ranch site and shows the distribution of rooms and features.

It is located on the remnant of a low alluvial terrace, which is made up of a thick deposit of stream gravel, topped by calcareous clay. Above the clay layer sits a thin layer of alluvial and colluvial wash from the higher terraces. The Mimbres collected the calcareous clay for their ceramic and adobe production. They dug their early pithouses into the slim terrace deposits. Following abandonment of the pithouses, the pits were filled with natural sediments deposited by wind and water, midden debris and architectural rubble (Shafer and Taylor 1986).

History of excavation. Explorer-archaeologist Adolph Bandelier was the first to mention the ruins at the NAN Ranch during his winter exploration of the American Southwest in 1882-1883. He investigated three or four roomblocks and storage rooms, drew maps and made observations (Lange and Riley 1970). Later, Webster mentioned a rubble mound and Fewkes took notes of the site, but neither excavated the site.

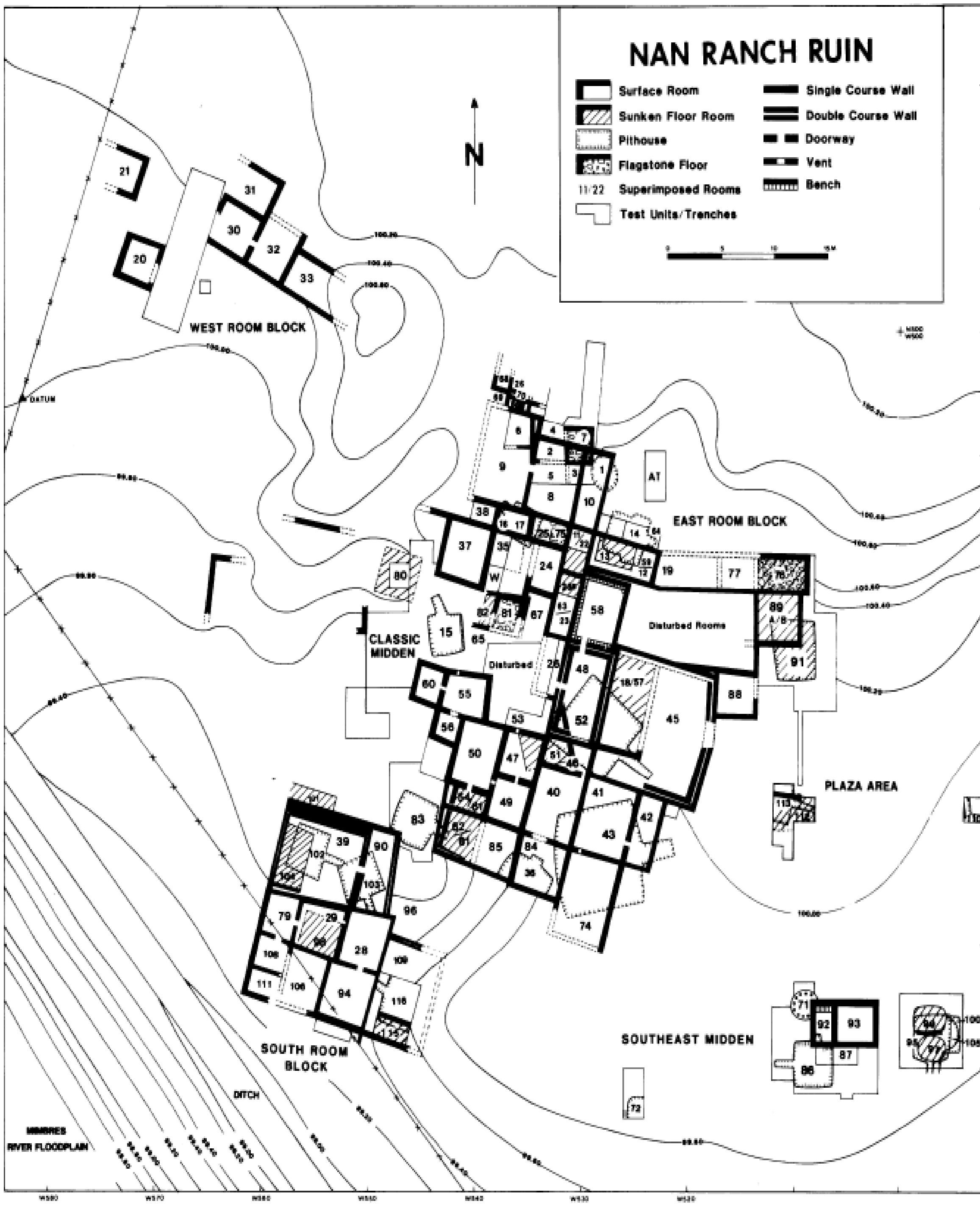

Fig. 3. Map of the NAN Ranch Ruin Site (after Shafer 2003: P.2).

In 1926, Harriet and Cornelius Cosgrove performed the first organized excavation of nine rooms on the western portion of the site concurrently with their excavation at the nearby Swarts Ruins.

The Cosgroves named the site after the cattlebrand "NAN" from the Y-Bar NAN Ranch. During their investigation, they excavated 53 burials and found 47 vessels as well as jewelry, but they never published a report. Only a few pictures of vessels and jewelry were ever printed in their 1932 publication on the Swarts Ruin (Cosgrove and Cosgrove 1932). The Cosgrove's excavation consisted of trenches along walls to maximize burial discovery and the excavation of entire rooms, but they did not systematically record features, doorways or floor surfacing (Shafer and Taylor 1986). This first excavation was followed by fifty years of relic hunting which resulted in theft of artifacts from about fifty eight rooms. It is not until the 1970s that a systematic excavation took place. In 1976, Margaret Hinton, owner of the Y-Bar NAN Ranch, contacted Harry Shafer to excavate the site, which resulted in a decade long project (1978 to 1989) involving archaeological staff, students and *Earthwatch* volunteers in summer fieldschools (Shafer 2003). After a hiatus of a few years, archaeologists returned in 1991, 1992 and 1996 for brief investigations. The goal of the excavation was to learn about building sequence, room uses, subsistence patterns, extramural areas, social patterning, mortuary customs and ceramic and technological developments; but it did more than that (Shafer 2003).

History of occupation

Initial occupation of the site began during the Late Pithouse Period, during the Georgetown Phase around 600 A.D. and lasted until the region was abandoned around 1140 A.D. at the close of the Classic Period.

NAN Ranch Ruin Late Pithouse period. The Late Pithouse patterns at NAN Ranch are similar to those in other Mimbres sites, such as Old Town, Swarts, Galaz, Mattocks, Cameron Creek and Saige McFarland. There is a general continuity, with slow changes during the Georgetown and San Francisco phases, but much more rapid changes during the later parts of the period, during the Three Circle and Late Three Circle Phases (Shafer 2003). There are between 75 and 100 pithouses that lie below the ancient pueblo town. These pithouses were in use at different times throughout the 400 year span until the Classic Period. These pithouses served primarily as storage and night and winter shelter for small nuclear families; most activities took place outside these pithouses.

Georgetown phase. The first NAN pithouse (room 105) was round or elliptical and it is the only excavated room that dates to the Georgetown Phase. It had an extended entryway facing south, a lobed entrance and a circular hearth with a deflector stone between the entrance and fire pit. The ceramic assemblage recovered consisted of plain brownware and red-slipped ware in the form of hemispherical bowls, narrow mouth jars and necked jars. No burials that could be dated to this phase have been recovered.

San Francisco phase. There are four excavated pithouses at NAN that have been assigned to the San Francisco Phase (rooms 72, 86, 95 and 100). They were subrectangular domestic structures around 10-12 square meters. The roof was supported by a combination of three central posts, four corner posts and two entrance posts. The floor and entrance ramp were plastered. There were remnants of grass or yucca mats for bedding, sandals, grass baskets as well as Neck Corrugated and Neck Banded Jars and San Francisco Red, Three Circle Red-on-White and Mogollon Red-on-Brown bowls. Only one intramural burial (burial 127) was recovered. It is that of an adult male in a sitting position inside a crypt in a pit structure (room 86). Accompanying mortuary furniture such as a tubular stone pipe, quartz crystals, a turtle plastron, *Olivella* shell beads and a biface, lead the excavator to speculate that this was the grave of someone regularly involved with rituals, maybe a shaman (Shafer 2003).

Three Circle phase. There are 15 structures, partially and fully excavated, that can be assigned to the Three Circle Phase. Some of the excavated structures were domestic in nature. They were subrectangular or square, between 9-13 square meters, the walls and floors were plastered and the fire pits were lined with adobe or clay sometimes accompanied by a deflector stone or a wall vent. The floor assemblage consisted of Three Circle Neck Corrugated jars, plain and Style I sherds, manos and metates. In addition, there were two large pithouses (around 40 square meters) that served as large civic or ceremonial rooms. Like domestic structures, they had plastered walls, an adobe-lined pit with a deflector stone, and a pattern of three small postholes was identified as a possible altar (Burden 2001). There were no subfloor features such as human burials or storage pits associated with these great rooms. One other Three Circle structure was excavated at NAN. It is the only one of its kind, round in a shallow pit (as opposed to part of the pit). It contained no artifacts or features. Shafer (2003) speculated that it could have been a menstrual hut, labor and delivery room or sweat lodge.

Nine burials were assigned to the Three Circle Phase. There were a small number of intramural burials of adult females and children, with increasing occurrence of grave goods. These female burials represent the first adult intramural burials at NAN. Room 14 contained the most Three Circle burials, including burial 86 which has been identified as that of a female potter, based on the accompanying potter's tools, smashed vessel, whole vessels, worked sherds, pot polishing stones, unfired Style I jars, inlays, adorned jewelry, lumps of kaolin clay and red pigment (Shafer 1985). The first instance of cremation and the only primary cremation at NAN (burial 174), was also excavated and belonged to the Three Circle Phase. It was the cremation of a 30-39 year old male; the long cremation rack was still present in the pit, along with projectile points and two ears of corn (Creel 1989).

NAN Ranch Ruin Transitional phase or Late Three Circle. Shafer and his team excavated 24 transitional rooms including one pithouse, three modified pithouses, and 16 early Pueblo rooms. The floor of the modified pithouses had been resurfaced with plaster, existing entry way walled off, deflector stone removed, wall vent added and ceiling hatchways created. Early pueblos were free standing cobble adobe structures that were arranged much like pithouses with wood posts and fire pits. The Late Three Circle Phase is also characterized by the appearance of outdoor storage or granaries. Two transitional granaries were excavated at NAN (rooms 51 and 76). Compared to other structures, they had unusually thick adobe floors, reinforced with slabs or cobbles. The wall base was made of large cobble and vertical slabs were set both inside and outside the wall base, presumably in the attempt to keep moisture and burrowing rodents away. Mortuary patterns also stand out compared to previous phases. Some 47 Late Three Circle burials have been recovered at NAN, of which 56% were intramural, including all sexes and ages, 36% were extramural inhumations, including secondary cremations. Two main mortuary patterns consequently emerged, one is the affirmation of subfloor burials as corporate or lineage intramural cemeteries (room 104 held 13 burials) and the other is the creation of a cremation cemetery in the east plaza. Most cremations were those of subadults or adult males with more mortuary furniture than intramural burials. This is the largest concentration of cremations in the Mimbres Valley but low numbers at other sites could be a consequence of the different research designs.

Overall this transitional phase at NAN shows a shift towards a more corporate social organization, a change in symbolism that mirror the increased dependence on agriculture and land claims, and confirms at least two long rooted lineages in the south room block and in the northern part of the east roomblock (Shafer 1995; Shafer 2003).

NAN Ranch Ruin Classic period. Like at other Mimbres sites, the Classic period corresponds to an explosion in population, building remodeling and construction and in ceramic production and elaborateness. Over 55 Classic structures have been excavated at NAN, 29 of which were habitations and five were corporate kivas. Corporate rooms differ from habitation rooms in that they have an additional slab lined floor vault next to the formal hearth (Burden 2001). Those rooms with floor vaults have the largest concentration of burials. Storage rooms were either private (accessible through a small crawlway only, from a habitation room) or public with a ceiling entrance. Most activities took place outside the pueblo rooms, in rooftops, courtyards and plazas. Courtyards are small areas enclosed in between habitation rooms and serve for domestic activities. Several courtyards have been excavated at NAN; they consisted of adobe-paved floors, with pits, middens and some burials. Two main plazas have been partially excavated at NAN; they contained burials, cremations, roasting pits and adobe mixing pits. The east plaza appeared to have been most widely used with repeated remodeling and resurfacing, its large number of inhumations and cremation pits, adobe lined pits, artifact caches and its raised border.

In comparison with Creel's work (1989; 1997) at Old Town, it has been suggested that the east plaza was a main roadway through the Classic village, possibly linking it to other major Mimbres roadways, hence linking several settlements together (Creel 1989; Creel 1997; Lucas 1996; Shafer 2003). Mortuary customs by the Classic Period had almost exclusively shifted to intramural inhumations. Ninety three percent of Classic NAN burials were below roomfloors, while only 8% were in exterior areas, 2% of which were cremations (Shafer 2003).

The Skeletal Sample

While burials are plentiful in the Mimbres valley, preservation is not the best and very few studies assessing the health and nutrition of the Mimbres have been conducted (Lippmeier 1991; Marek 1990; Olive 1989; Patrick 1988; Provinzano 1968; Young Holliday 1993; Young Holliday 1996). The majority of the projects in the region have focused on collecting and salvaging architecture and ceramics, but few included or focused on the recovery and analysis of skeletal remains. From their excavation at NAN, the Cosgroves (1932) did not publish any osteological data on the 53 burials they uncovered nor did they for the 1009 skeletons from Swarts Ruins. Howells (1932) did not provide any basic demographic information on the Swarts sample. He provided osteometric data for only eight skeletons. At Mattocks, Nesbitt (1931) only provided cranial measurements from three individuals and post cranial measurements from ten, out of over 200 skeletons recovered. Similarly, of 130 skeletons from Warm Springs and Cameron Creek, Bentzen (1929) was only able to perform a dental analysis on a few dozen individuals. Finally, at Galaz, Provinzano (1968) presented basic osteometric and pathological information on 108 skeletons out of the 934 burials recovered by Jenks.

Mimbres bioarchaeology faces many challenges. Early excavation projects and looting focused mainly on the recovery of ceramic bowls, sometimes in total disregard for the human skeletons they were found with. Little was done to record pertinent information about a burial and a skeleton or to preserve it. Consequently, early reports generally do not contain the data necessary for intra-site comparison. In addition, these reports usually reflect inadequate or unclear field methods. The NAN Ranch skeletal sample is one of the few to have been recovered carefully and in a systematic manner. Nonetheless, like other Mimbres sites, the main challenge remains poor preservation. Mimbres burials consist mainly of unlined pits dug in the alluvial terrace and calcareous clay, where water seeped in and collected at the bottom contributing to the disintegration of the bones.

Excavation and conservation

Close to 250 human burials have been recovered from NAN Ranch, consisting of intramural and extramural inhumations as well as primary and secondary cremation deposits. In addition, disarticulated bones were encountered frequently throughout the site, as early inhumations were often disturbed during later burials or during the construction of additional rooms. When discovered, a burial was assigned a number immediately. The skeleton was carefully uncovered with soft bristle brushes, infant ear syringes and wooden tools. Samples of tissue and white precipitates (possible remnants of textiles) as well as pollen samples from the stomach area and control samples were collected. A coat of poly-vinyl acetate (PVA) thinned with acetone or 95% alcohol was applied to the skeletal remains. During the first three excavation seasons, all bones were covered with PVA, but later only the skulls and pelvis were coated with PVA (Patrick 1988). I noted that skulls and pelvis from later excavation seasons had large amount of soil still glued to the bones with PVA, which rendered the scoring of the skeletal features for this study difficult in some cases.

Preservation was fair, but varied greatly throughout the site. All five preservation categories from Gordon and Buikstra's (1981) classification are represented, with a higher incidence of Stage 2 preservation. When Stage 2 has been reached "outermost concentric thin layers of bone show flaking, usually associated with cracks, in that the bone edges along the cracks tend to separate and flake first. Long thin flakes, with one or more sides still attached to the bone, are common in the initial part of Stage 2. Deeper and more extensive flaking follows, until most of the outermost bone is gone" (Buikstra and Ubelaker 1994: 98). Some of the skulls exhibit puffy layers of bones and apparent spalling, which is a result of repeated wetting and drying overtime (Patrick 1988).

Bioarchaeological findings

Aging and sexing. Preliminary age and sex analysis was performed in the field by Suzanne Patrick, under the supervision of Gentry Steele. Patrick (1988) determined that these age and sex assessments were fairly accurate, when compared to the later laboratory analysis.

Patrick (1988) aged juvenile skeletons using tooth calcification and tooth eruption (Ubelaker 1978), degree of epiphyseal union of long bones (Bass 1971; Krogman 1962; McKern 1970) and length of long bones (Fazekas and Kósa 1978; Ubelaker 1978). Adults (above 15 years of age) were aged based on status of eruption of third molar, functional tooth wear (Brothwell 1972; Lovejoy 1985), completion of epiphyseal union, degenerative changes (Bass 1971; Krogman 1962; McKern 1970; Stewart 1958; Stewart 1968) and pubic symphyseal plates (Gilbert 1973; Gilbert and McKern 1973; McKern 1970). Sexing of adult skeletons was based on general robusticity, pubis symphysis, sciatic notch (Phenice 1969; Ubelaker 1978) and discriminant function analysis for the talus, calcaneus, femur and tibia (Black 1978; İşcan and Miller-Shaivitz 1984; Steele 1976).

Physical characteristics. Based on the analysis of the skeletons from the first few seasons, males were 162 cm tall and females 154.9 cm tall on average (Patrick 1988). Neither sex was robust but females tended to have more robust upper limbs than did men, likely as a result of grinding corn and carrying baskets. Facial features (nose, orbit and jaw) were average to broad. Crania exhibited occipital flattening which made the face look wider. This is due to cradle boarding, a common practice in the North American Southwest (Dennis and Dennis 1940; Kohn et al. 1995).

Health and nutrition. Three studies focus on the overall health and nutrition of the NAN skeletal sample. Marek (1990) focused on the growth rate of subadults. She compared chronological age determined with tooth eruption, to the length of long bones in order to determine the average growth rate of NAN subadult long bones. Results show that at NAN the growth rate was similar to that of other Southwestern skeletal samples such as Grasshopper, Arizona and New Mexico Pueblos, but that it was generally lower than that of Indian Knoll, the Arikara and Eskimos. This was likely due to a lack of a balanced diet and a deficiency in animal proteins.

Olive (1989) and Young Holliday (1996) looked at the dental health of the NAN sample. Olive analyzed teeth from the first six years of excavation and Young Holliday expanded the study to the whole NAN skeletal sample. Both ended with similar results. The frequency of enamel hypoplasias, caries, periodontal disease and antemortem tooth loss is comparable to other Mimbres and Southwest populations as well as other agricultural societies. There were some differences between sexes and between roomblocks but most were not statistically significant. Young Holliday did notice, however, that females from the south roomblock had a statistically higher incidence of antemortem tooth loss than any other group.

In addition to her dental study, Young Holliday (1993; 1996) performed a variety of analyses to assess the health of the sample to determine whether there were differences between the south and east roomblocks and the midden burials and whether there were differences between sex and age categories. Trace elements and stable isotope analyses were disappointing because it could only be applied to a handful of individuals, due to postmortem changes and due to the application of a chemical preservative on the bones at the time of collection. These analyses confirmed that the NAN people relied heavily on maize, which they likely treated with alkali or lime (as demonstrated by the barium level in the bones analyzed) and that they supplemented their diet with other C-4 tropical plants and CAM plants (cacti and succulents) and with meat from animals that fed on C-4 plants. There was no significant difference in $\delta^{13}C$ levels between the two roomblocks, but a slight difference with burials from the middens, suggesting that individuals from the midden burials may have consumed less cultigens but had a more varied diet than other groups. This could have been the result of different access to farmland and different lineage affiliation. Perhaps those buried in the middens did not have access to the best agricultural land, forcing them to have a different diet than other groups.

In addition, 36% percent of skeletons had signs of cribra orbitalia and 18% had porotic hyperostosis, both signs of childhood anemia. Young Holliday also noted a high incidence of infection (40%), especially infectious lesions of the occipital bone, which could have been a consequence of cradle boarding. She found that infection equally affected people from different roomblocks. The south roomblocks did present more infectious lesions on the occipital bone, but the difference is not statistically significant. She suggested that the people of the south roomblock may have been more susceptible to infections, that there may have been more sources of infections in the roomblock or that they used cradleboard for a longer period of time than other roomblocks (Young Holliday 1993; Young Holliday 1996). She found no evidence of tuberculosis, or treponemal infection and only one possible case of coccidioidomycosis.

When looking at subadult growth rate and stature, again Young Holliday noted no significant differences, though southblock females had a tendency to have more robust arms. Twenty two percent of NAN skeletons had at least one fracture, usually of the ribs or vertebrae. Females had more moderate to severe arthritis than males, especially of the elbow and cervical vertebrae as opposed to lumbar vertebrae in males, where they exhibited a higher incidence of Smorl’s nodes. These patterns of robusticity and arthritis are consistent with corn grinding, which was primarily performed by women. Overall, Young Holliday (1996) did not find many statistical differences in the health of the NAN people, between roomblocks and the middens or between sexes, except in the case of southblock females who show higher rates of antemortem tooth loss and more robust humeri and narrow tibias. The overall health and nutrition of the NAN population was similar to that of other Mimbres and Southwest sites, but show a slightly more deficient diet, lacking animal protein compared to groups outside the Southwest region (Young Holliday 1996).

NAN Paleodemography

Patrick (1988) performed a paleodemographic study based on the 95 burials that were recovered up until the 1982 excavation season. She focused mainly on 81 burials that had been assigned to the Classic period and intended to provide general demographic trends. Table 4 shows the age and sex distribution of those 81 Classic Mimbres burials at NAN.

She set out to calculate age at death in five-year intervals, life expectancy, survivorship expectations, probability of death and crude mortality rate. She made the following assumptions prior to building composite, abridged life tables: 1) the sample is random, 2) age and sex estimates are correct and 3) the population was stable both from a biological and social stand point. Her life tables are shown in Tables 5 to 8. Some individuals were too fragmentary to be aged accurately so, following Palkovich (1978), she distributed the number of individuals of unknown age throughout each age interval, proportionally to the numbers of individuals of known age in each age category.

TABLE 4. Age and sex distribution of 81 Classic Mimbres burials from Patrick (1988)

Age interval	No. males	%	No. females	%	Unknown sex	%	Totals
1 (0.-.9)	-	-	-	-	26	32	26
2 (1-4.9)	-	-	-	-	12	15	12
3 (5-9.9)	-	-	-	-	8	10	8
4 (10-14.9)	-	-	-	-	-	-	0
5 (15-19.9)	-	-	2	2.5	-	-	2
6 (20-24.9)	2	2.5	1	1.2	-	-	3
7 (25-29.9)	2	2.5	3	3.7	1	1.2	6
8 (30-34.9)	1	1.2	-	-	-	-	1
9 (35-39.9)	2	2.5	-	-	-	-	2
10 (40-44.9)	5	6	1	1.2	-	-	6
11 (45-49.9)	1	1.2	4	5	-	-	5
12 (50+)	1	1.2	2	2.5	1	1.2	4
20+	1	1.2	1	1.2	2	2.5	4
25+	1	1.2	-	-	-	-	1
30+	1	1.2	-	-	-	-	1
Totals	17	20.7	14	17.3	50	61.9	81

TABLE 5. NAN Ruin abridged, composite life table, unsmoothed (Patrick 1988)

	D_x	d_x	l_x	q_x	L_x	T_x	e_x
0-1	26	32.11	100.00	.3210669	83.95	1760.81	17.61
1-4.9	12	14.82	67.89	.2182612	241.94	1676.86	24.70
5-9.9	8	9.88	53.07	.1861331	240.68	1434.92	27.04
10-14.9	0	0.00	43.20	0	215.98	1194.25	27.65
15-19.9	2	2.47	43.20	.0571755	209.80	978.27	22.65
20-24.9	3.44	4.25	40.73	.1043056	193.01	768.46	18.87
25-29.9	7.13	8.80	36.48	.2413676	160.38	575.45	15.78
30-34.9	1.25	1.54	27.67	.0557787	134.51	415.07	15.00
35-39.9	2.49	3.07	26.13	.1176749	122.96	280.56	10.74
40-44.9	7.46	9.21	23.06	.3995715	92.24	157.60	6.84
45-49.9	6.23	7.69	13.84	.5557538	49.98	65.36	4.72
50+	4.98	6.15	6.15	1	15.37	15.37	2.50

TABLE 6. NAN Ruin abridged, composite life table, smoothed (Patrick 1988)

	D_x	D_x smoothed	d_x	l_x	q_x	L_x	T_x	e_x
0-1	26	26.00	30.51	100.00	.3050569	84.75	1676.71	16.70
1-4.9	12	15.33	17.99	69.49	.2588778	242.00	1591.96	22.90
5-9.9	8	6.67	7.82	51.50	.1518718	237.96	1349.96	26.20
10-14.9	0	3.33	3.91	43.68	.0895335	208.63	1112.00	25.40
15-19.9	2	1.81	2.13	39.77	.0534959	193.54	903.37	22.70
20-24.9	3.44	4.19	4.92	37.64	.1305974	175.93	709.83	18.80
25-29.9	7.13	3.94	4.62	32.73	.1412524	152.08	533.91	16.30
30-34.9	1.25	3.62	4.25	28.10	.1512664	129.89	381.83	13.50
35-39.9	2.49	3.73	4.38	23.85	.1836367	108.31	251.94	10.50
40-44.9	7.46	5.39	6.33	19.47	.3249649	81.54	143.62	7.30
45-49.9	6.23	6.22	7.30	13.14	.5554894	47.47	62.08	4.70
50+	4.98	4.98	5.84	5.84	1	14.61	14.61	2.50

TABLE 7. NAN Ruin abridged, composite life table, unsmoothed without neonates (Patrick 1988)

	D_x	d_x	l_x	q_x	L_x	T_x	e_x
0-1	16	22.54	100.00	.2253521	88.73	2002.75	20.03
1-4.9	12	16.90	77.46	.2181818	276.06	1914.01	24.71
5-9.9	8	11.27	60.56	.1860465	274.65	1637.96	27.05
10-14.9	0	0.00	49.30	0	246.48	1363.31	27.66
15-19.9	2	2.82	49.30	.0571429	239.44	1116.83	22.66
20-24.9	3.44	4.85	46.48	.1042424	220.28	877.39	18.88
25-29.9	7.13	10.04	41.63	.2412043	183.06	657.11	15.78
30-34.9	1.26	1.77	31.59	.0561748	153.52	474.05	15.01
35-39.9	2.47	3.48	29.82	.1166745	140.39	320.53	10.75
40-44.9	7.46	10.51	26.34	.3989305	105.42	180.14	6.84
45-49.9	6.25	8.80	15.83	.5560498	57.15	74.72	4.72
50+	4.99	7.03	7.03	1	17.57	17.57	2.50

TABLE 8. NAN Ruin abridged, composite life table, smoothed without neonates (Patrick 1988)

	D_x	D_x smoothed	d_x	l_x	q_x	L_x	T_x	e_x
0-1	16	16.00	22.25	100.00	.22249	88.88	1967.53	19.60
1-4.9	12	12.00	16.69	77.75	.2146179	277.63	1878.65	24.10
5-9.9	8	6.67	9.27	61.06	.1518142	282.15	1601.02	26.20
10-14.9	0	3.33	4.64	51.79	.0894935	247.38	1318.88	25.40
15-19.9	2	1.81	2.52	47.16	.0534696	229.49	1071.50	22.70
20-24.9	3.44	4.19	5.83	44.64	.1305296	208.62	842.01	18.80
25-29.9	7.13	3.94	5.48	38.81	.1412875	180.34	633.39	16.30
30-34.9	1.26	3.62	5.03	33.33	.1510431	154.05	453.05	13.50
35-39.9	2.47	3.73	5.19	28.29	.1833224	128.50	298.99	10.50
40-44.9	7.46	5.39	7.50	23.11	.3245737	96.78	170.49	7.30
45-49.9	6.25	6.23	8.67	15.61	.5553906	56.36	73.71	4.70
50+	4.99	4.99	6.94	6.94	1	17.35	17.35	2.50

Patrick recognized that there could be some cultural or statistical anomalies with the data, which she hoped to smooth by using five-year age intervals and by proportionally distributing unclassified adults. In addition, she smoothed Dx, the column representing the number of individual that died at a particular age interval, using a formulation from Palkovich (1980). "In the smoothed lifetable (Table 6), Dx is recalculated by combining an interval with the intervals immediately before and after and dividing by 3. The two exceptions to this are the first and last intervals which remain discrete. In assigning individuals to age categories, especially after seriation, where one individual might have been assigned an age of 44 relative to another at 45 years, smoothing reduces stochastic fluctuations and other inherent errors in the data without hiding major irregularities in the age distributions" (Patrick 1988: 79). This method breaks down the number of people dying per age interval in decimal forms, which seems unrealistic but it helps alleviate possible aging errors.

Based on her analysis, she noted high infant mortality, low life expectancy and a slight increase in mortality for women of child bearing age. She compared her results to Arroyo Hondo, Grasshopper and Cochiti as well as Weiss model life tables 22.1-40.0. Specifically, 57% of all burials were those of juveniles, 32% were less than a year old and 47% less than five. She found that there was a higher infant mortality rate for individuals that had been assigned to the middle of the Classic period. The mortality rate for those less than five (47%) is similar to Arroyo Hondo (42%), Grasshopper Ruins (54.5%) and Cochiti (48.8%). Subsequently, the mortality rate decreased for individuals between five and ten years old and the probability of death was the smallest for those between ten and 14 years old. After 15, the mortality rate steadily increased.

Life expectancy at birth was only 16.77 years, it increased to 23.92 years if an individual made it past their first year, and to 30 years if one made it past five years old. These results are similar to what one would expect of an agricultural society and compare well to other Southwest sites such as Grasshopper (14.17 years), Point of Pines (21.74 years), Arroyo Hondo (16.23 years) and Cochiti (16.86 years).

Among adults of child bearing years (15-40 years old), seven males and six females died, but all females died prior to age 30. Adult males died at a constant rate throughout the age intervals but for females the rate varied from 7.5% before age 30, 0% between 30-40 years old, 1.23% between 40-44.9 years old and 7.5% again for those of old age. If they survived their childbearing years, women could expect to live well into their 40s. The data show a high mortality rate for females of child bearing years, which is to be expected in an agricultural society but this could also be a result of the emigration of young women to other villages.

The crude mortality rate for NAN is 56.76, which is higher than other Mogollon sites like Point of Pines (43.69), Grasshopper (50.86) and Turkey Creek (51), but it is smaller than that of Salmon Ruin (78.43).

Overall, based on Patrick's (1988) results, NAN paleodemography is similar to other agricultural sites with high infant mortality, increased mortality for females of childbearing age and low life expectancy at birth. The NAN paleodemography most closely resembles that of the Grasshopper and Salmon sites. But she recognizes that a paleodemographic analysis of the skeletal remains including those excavated after 1982 may confirm or refute those trends.

Sex and age at death estimates performed by Patrick (1988) in the field and those subsequently carried out in the laboratory are relatively accurate in that they are the results of the multiple methods that were available at the time and in that they yield similar results to other Southwestern skeletal samples. However, one may wonder whether these demographic trends are true representations of the lives of the Mimbres or if they are a reflection of existing paleodemographic methods and their shortcomings. Were there really so few elderly? By reanalyzing the NAN adult skeletal sample in its entirety, using Boldsen et al. (2002), I hope to establish a shaper demographic profile of the skeletal sample and to shed light on the senescent portion of the population.

CHAPTER V

TRANSITION ANALYSIS AND AGE ESTIMATES

Methods

An age and sex analysis for the NAN Ruin skeletal sample was completed following the excavation of the remains nearly 30 years ago (see Chapter IV). In this study, I have reanalyzed the age of all adult skeletons using the Transition Analysis method (Boldsen et al. 2002). The method is twofold. It consists of scoring skeletal components of the cranium, pubic symphysis and the auricular surface of the ilium, and of calculating ages using the Transition Analysis software, provided by the authors. The software calculates a maximum likelihood estimated age-at-death.

Skeletal Observations and Scoring

To score the skeletal characteristics of the NAN Ruin adult skeletons, I followed the procedures outlined in Boldsen et al. (2002), which focuses on the progressive bone changes that develop with age. The specific location of each of the nineteen scorable components as well as the description of each component's characteristics and associated scores are taken from Boldsen et al. (2002:97-104). They are listed in Appendix A and B. When present, I scored the left and right sides for each component. I observed each component with the naked eye and occasionally with a 10 x lens, using both pictures and descriptions provided by the authors as reference. Then I recorded the scores on the Transition Analysis Form (Appendix C). Finally each score was entered in the Transition Analysis computer program. Figure 4 shows a typical screen shot from the program using burial 62 as an example. The software provides estimated ages, following

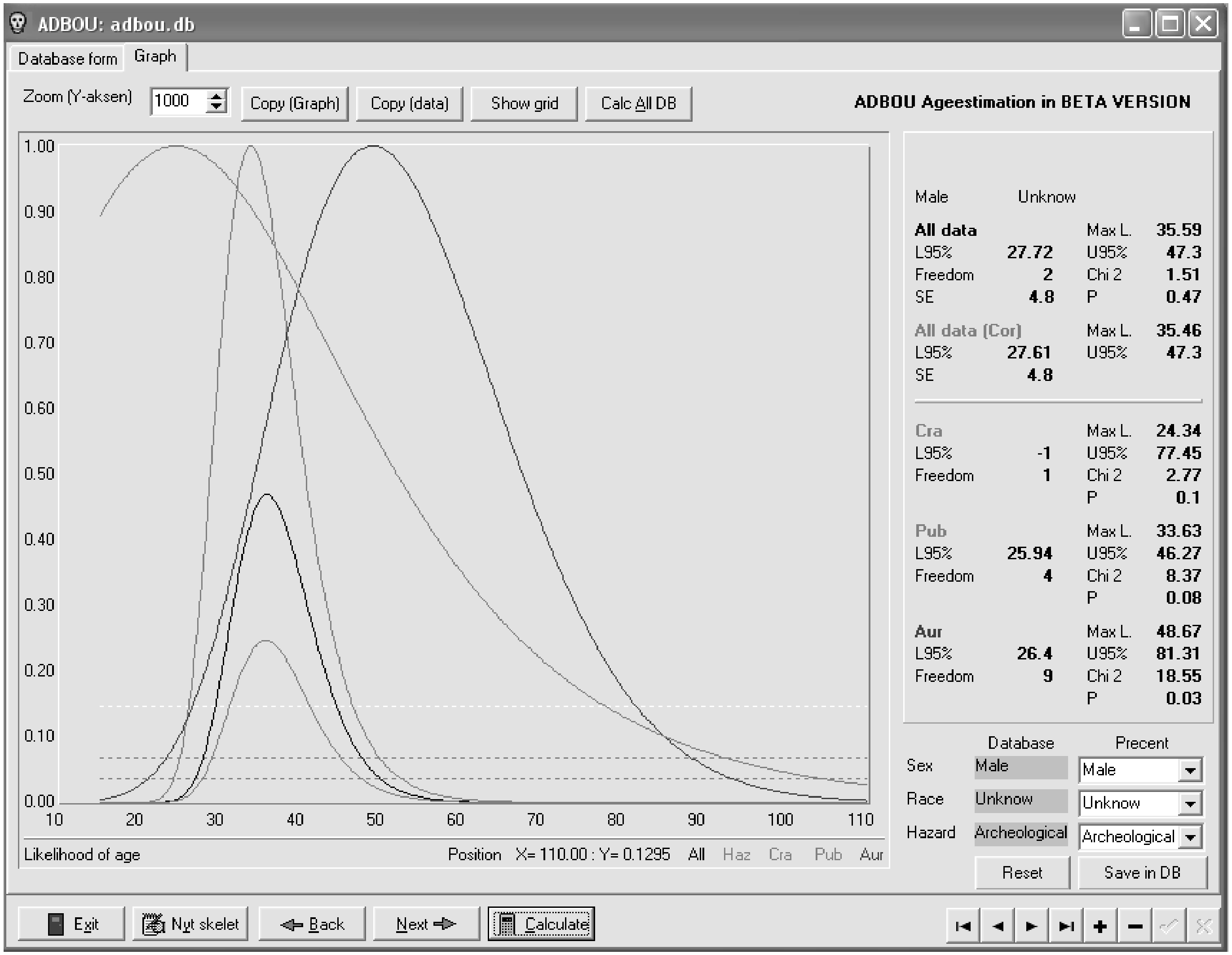

Fig. 4. Screen shot showing how the estimated age data are displayed with the Transition Analysis software, using Burial 62 as an example.

the maximum likelihood that the individual is a certain age, given the observed stage of each of the scorable components. Those estimated ages are presented in the program as follows "All data" is a uniform prior age distribution, "All data (Cor.)" is the informative archaeological distribution based on 17th century rural Danish parish record, "Cra", "Pub" and "Aur" are the estimated ages based solely on each anatomical unit, the cranium, pubic symphysis and the auricular surface of the ilium. The uniform prior distribution assumes that based on any combination of skeletal traits it is equally likely to yield any age. For instance, it assumes that it is as likely that we have a 30 year old or an 80 year old individual, which is unrealistic because the likelihood of dying is based on a combination of the risk of dying as well as the number of individuals that are at risk of dying. The archaeological distribution is based on a real age distribution therefore it is more appropriate to use than a uniform prior which would tend to overage. Using the software, the uniform prior distribution "All data" and the archaeological distribution "All data corrected" yielded age estimates that differ somewhat. I use the archaeological prior in the following analysis, as its outcomes are more realistic. I discarded the "All data" age estimates and used the "All data corrected" ones for the purpose of this study.

Results

This study focuses mainly on the Classic Period since other periods yielded such a small number of individuals. However all adults, regardless of their chronological placement, were analyzed following the guidelines outlined above (Boldsen et al. 2002) Appendix D contains the raw scores obtained for each features by skeleton that were entered in the software. Table 9 shows estimated ages combining all three elements (using the archaeological prior), by skeletal unit and those excluding cranial suture data and/or symphyseal texture as discussed below.

TABLE 9. Estimated ages by skeletal elements of all adult scorable adult skeletons

Burial #	Sex	Combined (Corrected)	Cranial Sutures	Pubis	Auricular Surface	Without Cranial Sutures	Without Symphyseal Texture	Without *both* Cranial Sutures and Symphyseal Texture
1	M	72.12	72.6		64.32	72.08		
4	F	71.83	42.71					
12	M	22.85	15	21.96	48.87	24.38	22.52	23.93
13	M	29.55	15	40.67	23.23	33.72	29.01	32.8
15	F	21.22	18.38		22.53	21.16		
20	M	38.4	15	38.18	76.96	41.63	37.2	40.28
25	M	75.1	47.59					
27	M	15	15					
36	M	44.27	32.43	98.91	34.06	52.14	42.27	47.54
41	M	22.41	19.04		27.29	17.72		
42	M	38.8		38.92				
43	F	43.25	18.87	82.43	36.18	71.76	36.96	68.49
46	F	76.21	35.61	102.59	81.34	81.15	74.7	80.11
52	M	19.2	20					
56	F	73.02		57.49				
57	F	35.46		32	52.64			
58	F	69.04	24.27	81.66	76.35	65.38	76.94	75.22
62	M	35.46	24.34	33.63	48.67	36.04	34.08	34.57
64	M	32.34	15	47.2	25.27	36.28	31.39	34.86
68	M	23.99	19.42	22.46	64.8	24.19	23.86	24.06
73	F	26.88			27.57			
76	F	42.93		38.65	52.99		39.04	
77	M	48.8	17.27	110	73.53	82.17	45.79	81.34
82	M	63.27	66.24	41.7	71.08	62.89	59.54	58.44
83	F	16.37	16.37					
87	F	70.01	44.56		68.83	73.24		
88	M	26.05	15	27.11	32.64	27.88	25.68	27.46
92	M	35.62	110	32.78	40.19	45.59	23	33.5
95	M	76.31	82.84					
100	M	66.18	110	34.04	104.48	55.72	66.11	54.62
103	M	36.96		35.72	55.68		40.24	

TABLE 9. Continued

Burial #	Sex	Combined (Corrected)	Cranial Sutures	Pubis	Auricular Surface	Without Cranial Sutures	Without Symphyseal Texture	Without *both* Cranial Sutures and Symphyseal Texture
109	M	43.48		55.42	37.23		42.54	
111	F	28.72		33.13	23.56		27.75	
115	M	69.42	110	37.99	94.6	68.95	69.18	69.18
119	F	79.87		87.53	84.45		80.02	
123	F	31.25		49.93	25.05		30.22	
130	F	41.69		42.19	40.52		40.61	
131	M	36.28	110	33.08	65.83	35.47	35.66	
132	F	78.63		65.26	110		78.79	
138	M	59.35	31.77		74.45	75.5		
139		77.33	34.99		108.34	78.72		
140	F	47.62	15	34.49	83.93	61.31	60.63	72.8
144	F	49.75	15	44.55	52.56	49.75	49.38	49.38
146	M	72.59	41.59					
147	M	31.81	29.85	34.23	23.91	31.91	31.11	31.17
150	M	32.76	21.74	40.18	23.26	35.67	32.11	34.86
151	F	56.54	31.23	82.36	51.36	75.01	56.54	75.29
153	F	36.39	35.25		46.18	74.09		
154	M	46.68	19.74		66.62	73.35		
155	M	38.29	75.18	38.26	35.14	37.21	37.83	37.33
156	F	26.01	38.42		22.84	22.27		
157	M	36.47	28.29		44.39	46.09		
160	?	43.53	15	81.97	51.69	73.01	40.88	70.97
161	F	75.84	34.33	110	53.34	79.3	73.12	77.57
165	F	30.67	23.38	37.84	23.36	30.07	31.79	31.07
169	F	57.18	32.61	53.53	58.56	59.38	55.22	56.41
170	F	20.81	35.52	19.34	32.08	20.26	20.92	20.36
173	F	53.99	41.11	85.52	37.16	53.85		
175	M	78.04		85.41				
178	M	37.31	110	32.92	88.96	36.3	36.8	35.77
179	F	27.94	23.09	27.83	29.22	28.02	26.96	27.01
184	M	41.57	76.63	35.94	62.07	39.99	40.9	39.98
185	F	50.22	27.23	63.11		73.56	46.73	73.88
188	M	37.63	22.95	37.99	71.41	49.71	37.19	47.36
189	M	32.87	25.41		82.34	77.65		
198	F	56.18	15	81.25	46.83	71.04	53.09	69.22
203	F	25.2		67.51				
204	F	73.2	40.4	110	37.69	76.95	70.73	75.19
205	M	20.13	29.75	18.78	36.18	19.91	20.21	21.34

TABLE 9. Continued

Burial #	Sex	Combined (Corrected)	Cranial Sutures	Pubis	Auricular Surface	Without Cranial Sutures	Without Symphyseal Texture	Without *both* Cranial Sutures and Symphyseal Texture
207	F	39.64	53.36	38.14	34.35	36.06	38.79	34.93
210	F	45.45	31.04	69.95	39.37	54.52	41.73	42.62
211	F	73.51			62.21			
219		75.09	62.96					
222		72.93	34.99	68.12				
223		25.95	23.09	26.07		25.97	25.52	

Exclusions

Although I scored all 19 features available on both sides of the body for all skeletons, I excluded symphyseal texture scores and cranial scores from the final age estimates that I used to construct life tables because these features yielded questionable results.

Symphyseal texture

Despite including it in their method, the Transition Analysis authors suggested scoring the symphyseal texture, but excluding the scores for analytical purposes because "it is [their] impression that prehistoric Native American skeletons have microporosity more often and at an earlier age than medieval northern Europeans, on whom the archaeological prior is based. More importantly, they differ from the modern people of the Terry (United States) and Coimbra (Portugal) collections used to generate the transition curves" as mentioned in the Transition Analysis manual (Milner and Boldsen 2007:8-9). As recommended, I scored the symphyseal texture for each scorable pubic symphysis but I excluded the score from the final age estimates. A paired t-test comparing ages estimated including and excluding symphyseal texture scores demonstrates that there is a significant difference between both age estimates, with ages calculated when including symphyseal both age estimates, with ages calculated when including symphyseal texture scores being older ($t = 2.35$, $p = 0.024$). Figure 5 illustrates the difference between age estimates when including and excluding symphyseal texture scores. In the majority of cases, excluding symphyseal texture scores yielded younger age estimates, on average by -1.8 years, with a median of -0.9 years, but in some cases by entire age intervals (burials 43 and 92). By contrast burials 103, 119, 132, 140, 165, 170 and 205 returned older aged estimates (+2.2 years on average). As symphyseal

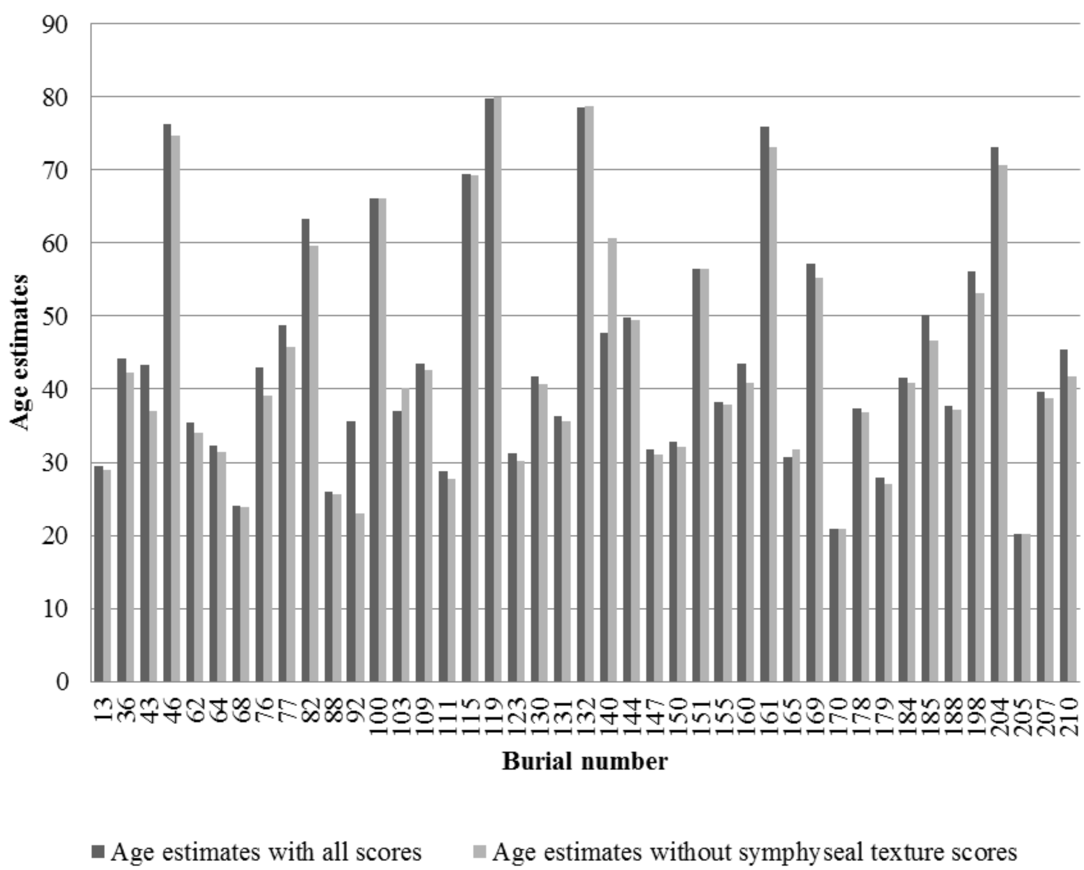

Fig. 5. Age estimates including and excluding symphyseal texture scores.

texture scores were excluded only three individuals would be classified in different age categories by more than one age interval. Burial 92 would be 12.62 years older, and burial 43 would be 6.26 years older as well, while burial 140 would be 13 years younger. Though the difference would not greatly affect the demographic characteristics of the population because most age differences are less than one age interval, I followed the authors' suggestion to exclude symphyseal texture scores.

Cranial data

Similarly, I excluded cranial data from my final age estimates. Boldsen et al.'s (2002) method is multifactorial and takes into account the tendency for cranial sutures to close in a less predictable and reliable way as other age indicators. Despite their best efforts, the Transition Analysis method also confirms that cranial sutures are not very informative about age, especially for adults in middle and upper adulthood (George Milner, personal communication, April 20, 2011). In order to determine the quality of each of the three anatomical unit as age indicators, the authors determined correlation coefficients between estimated age and known age and found that both the pubic symphysis and the iliac part of the sacroiliac joint had coefficients well above 0.80, while cranial sutures only yielded 0.66 (Boldsen et al. 2002: 90)

At NAN Ruin, I found that many of the crania showed signs of cradle boarding and it is possible that it may have significantly affected suture closure. Many studies have focused on the incidence of wormian bones associated with cranial deformation (Bennett 1965; Berry and Berry 1967; Dorsey 1897; El-Najjar and Dawson 1977; Gottlieb 1978; O'Loughlin 2004; Ossenberg 1970; Sanchez-Lara et al. 2007; White

1996; Wilczak and Ousley 2009) and on the effect of wormian bones on suture closure (Gerszten 1993; Hinton et al. 1984). The formation of wormian bones (bone ossicles at fontanelles and along cranial sutures) is highly genetically controlled but is often exacerbated by external factors such as cranial deformation. At NAN, Patrick (1988:121) noted that "all observable skulls exhibited [occipital] flattening to some degree" and I have observed wormian bones, especially along the lambdoidal suture, on most observable crania. It has been suggested that sutures near lambda are more prone to the formation of wormian bones when affected by external stress (Gottlieb 1978; O'Loughlin 2004; White 1996), whereas others have found no significant relationship between cranial deformation and increased occurrence of wormian bones (El-Najjar and Dawson 1977; Konigsberg et al. 1993). Many of these studies focused primarily on the phenomenon of craniosynostosis (premature suture closure) and on its correlation with artificial or accidental cranial deformation, concluding that cranial suture closure began years earlier in deformed crania than in undeformed crania. Gerszten (1993:96) found that while closure began seven years earlier on many deformed crania, a significant proportion of his sample of Chilean skulls had unclosed sutures up to age 42 years. In addition, in a study of an autopsy population, Hinton et al. (1984) found that the lambdoidal suture had begun to close prematurely but was not completely fused (or obliterated); a distinction that is not always clearly noted in the rest of the literature.

It is unclear to what degree cradle boarding may have affected suture closure at NAN and if it may have caused unobliterated sutures to crack open postmortem, a phenomenon commonly observed on the sample. But I found that including cranial scores yields age estimates that are notably different. A paired t-test comparing age estimates including and excluding cranial scores shows a significant difference between the age estimates, with a strong tendency for younger ages to be estimated when including cranial scores ($t = 4.16$, $p = 0.00012$). Figure 6 illustrates the difference between age estimates when including and excluding cranial scores. I found that including cranial scores yielded age estimates that were on average 11.2 years younger, with a median of 6.4 years, causing a difference of at least one age interval. Sixteen burials (burials 1, 15, 41, 82, 100,115, 131, 155, 156, 165, 170, 178, 184, 205, 207, 222)

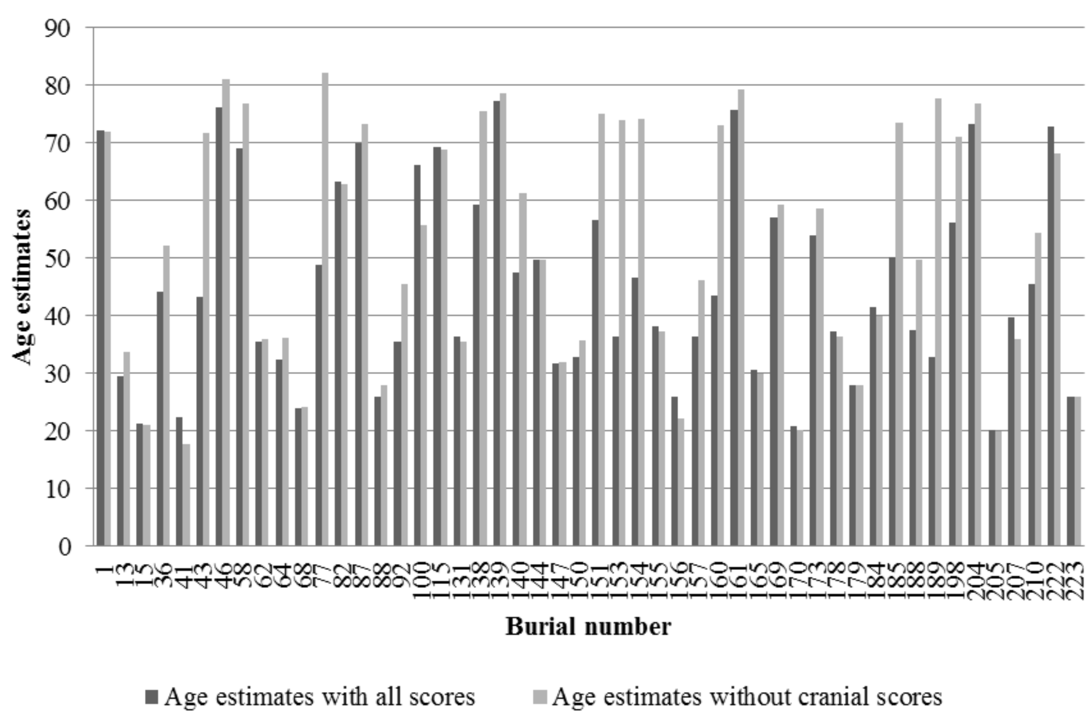

Fig. 6. Age estimates including and excluding cranial scores.

produced older age estimates when including cranial scores but the average difference is only +2 years. In addition, nine adult individuals only had partial crania available for scoring (burials 4, 25, 27, 52, 83, 95, 146, 175, 219). For the reasons mentioned above, I have considered the age estimates for them to be unreliable. However, I cannot exclude them entirely from the sample without taking the risk of underrepresenting adult mortality. Therefore I retained them in my sample as adults of undetermined age.

Eastern Plaza exclusions

Finally, I excluded all burials from the Eastern Plaza (n=15). Those burials contained mainly cremated individuals. Their remains were so fragmentary that it is not possible to establish their sex or age. Most of these burials belong to the Transitional Period (n=44). Due to the small sample of Transitional burials I would not be able to build a life table that would provide realistic information for this Period. Their exclusion will only affect other life tables minimally.

To sum up, once exclusions are considered, the final age estimates used to build life tables rely on the scoring of all available features following the guidelines of Transition Analysis, excluding cranial scores and symphyseal texture scores. In addition out of 243 skeletal remains from all periods, 15 skeletons from the eastern plaza were excluded from the sample, which represents only 4 skeletons out of the Classic sample of 185 that I use in my analysis. Nine individuals only had partial crania available for aging and since crania are problematic to age with any method, their estimated ages from the Transition Analysis software were excluded but they were counted as adults of undetermined age, and distributed throughout the adult sample proportionally to the number of other individuals in each adult age group.

CHAPTER VI

NAN RANCH DEMOGRAPHY

After over a decade of excavations at NAN Ranch, a total of 243 individuals have been collected. The majority of them belonged to the Transitional and Classic Periods and few from previous phases of occupation. The total number of individuals here is different from previously published data (Patrick 1988; Shafer 2003; Young Holliday 1996) because nearly a dozen newborn and juveniles had been omitted from those reports. I found them in boxes with adult skeletal remains and assigned them numbers according to the adult burial they were associated with (i.e. newborn 157A was found in the box for burial 157). Table 10 represents the number of individuals per period.

*TABLE 10. Number of individuals per period or phase (*no specific phase assigned)*

	Infants & Neonates	Juveniles (5-15)	Adults (>15)	Undetermined	Total
Late Pithouse *			2		2
San Francisco				1	1
3 Circle	6		1	1	8
Transitional	9	12	8	15	44
Classic	55	47	62	21	185
Undetermined	3				3
Total	73	59	73	38	243

Expectations

Generally, in a prehistoric population we can expect to see a high infant mortality rate, and a higher mortality rate for females of childbearing age as compared to that of males and a relatively low life expectancy at birth (Bennett 1975; Hassan 1981; Weiss 1973). Weiss (1973) and Howells (1960) report an infant mortality between 30%-50% among prehistoric populations, while Angel (1969) reports it to be as high as 50%-80% in some cases. In addition, in the prehistoric agricultural Southwest, Martin (1990) found that there was chronic, though not necessarily severe, endemic nutritional stress which resulted in high infant and childhood mortality and low life expectancy at birth.

Building Life Tables

To facilitate comparison for other demographic studies from skeletal series, I have tabulated the age estimates for the sample into composite, abridged life tables. Life tables have been widely used to compare demographic characteristics of ancient populations (Acsàdi and Nemeskéri 1970:29; Berry 1985). A life table "is a mathematical device for representing the mortality experience of a population and for exploring the effects of survivorship of age-specific probabilities of death" (Chamberlain 2006: 27). There are different types of life tables. In a composite life table, the population is one that has an unknown number of generations and that is considered as one single cohort that experienced a relatively stable growth rate (Palkovich 1980). An abridged life table contains age intervals as opposed to single-year classes. Due to the nature of age estimation based on skeletal remains, single-year classes are not possible; therefore I grouped the age estimations from the NAN Ruin into five-year intervals for individuals older than 1 year old. For those under 1 year old, I either used a single age interval (0-0.9 years) or two smaller intervals: interval 0-0.17 years, which reflects premature births and deaths as well as neonatal deaths (those occurring within the first two months of life). The interval 0.18-0.9 years reflects infant mortality excluding those neonatal deaths.

Life tables used in demography are usually calculated for a cohort of 1000, representing population characteristics per one thousand. In paleodemography, it is preferable to express population characteristics per 100, especially since skeletal samples are usually small. Table 11 provides the definitions and formulas of the different components of life tables.

Assumptions

Before building life tables, one has to make and justify several assumptions (Chamberlain 2006: 87). First, I assume that the sample is random and that it is representative of the population (Acsàdi and Nemeskéri 1970). The representativeness of this sample can be questioned on several grounds. Based on the first five years of excavations, Patrick (1988) found *a priori* that only juveniles were buried in storerooms, which could have introduced excavation strategy bias to the sample. However, subsequent excavations have shown that these rooms were excavated equally as often as any of other rooms at the site and that adults were also buried under the floors of storerooms (Shafer 1990a; Shafer 1991a; Shafer 1991b; Shafer 1991c; Shafer 1992).

Similarly, it had been previously noted that midden burials were mainly those of adult males (Patrick 1988) and that their exclusion would possibly underrepresent Classic male burials, since not all middens were entirely excavated. But based on additional information from the subsequent years of excavation not included in Patrick (1988)'s analysis, we can no longer say that midden burials were solely those of adult males. Many midden inhumations are actually those of juvenile individuals (n=9) and several adult burials remain unsexed (8 were sexed and 10 were not).

TABLE 11. Components of a life tables (Acsàdi and Nemeskéri 1970; Bennett 1973; Hassan 1981; Palkovich 1980)

Column	Name	Formula	Definition
1	x: age interval	x to x+n	age at which an individual died, usually given in 1-year, 5-year or 10-year intervals
2	D_x: number of death		number of individuals that died in a given age interval
3	d_x : mortality rate	$D_x / \sum D_x$	number or proportion who die between two adjacent age intervals - those alive at the beginning of the age interval that will die before reaching the next age interval
4	l_x: survival rate	$l_{x-n} - d_{x-n}$	number or percentage of survivors out of the original cohort
5	q_x: probability of death	d_x/l_x	probability of dying in a given age interval
6	L_x	$l_x-(d_x/2)$	total number of person-years lived *in* a given age interval
7	T_x	$\sum L_x-L_x$	total number of person-years lived by those that survived *after* a given age interval
8	e_x: life expectancy	T_x/l_x	the number of years one may expect to live if he/she reaches a given age interval

In addition to middens located outside room blocks, many rooms were built over previously used middens, and individuals were buried under these rooms intruding into those abandoned middens, therefore a midden burial does not seem to constitute a differential burial treatment of adult males, as some have argued. Also of the midden burials (n=18) only nine are from the Classic Period, therefore I included burials from middens in my analysis to better capture the whole Classic demographic profile.

Finally, some burials were destroyed by the Mimbres themselves and by looters, but the amount of damage was limited (Shafer 2003). The thorough research design at the NAN Ruin site, allows us to assume that the sample was random and representative of the living population.

Secondly, I assume that the population was stable biologically and socially, where in- and out-migration, as it occurred, remained in balance (Acsàdi and Nemeskéri 1970; Angel 1969; Chamberlain 2006; Hassan 1981). The NAN population was likely not entirely stable, for small villages of various sizes were established along the Mimbres and within its drainage system. Also, it has been suggested that individuals who were cremated and buried under the plazas might constitute a different part of the population (Creel 1989; Creel and Anyon 2003). It is unclear if they were an intrinsic part of the NAN population of if they belonged to outside lineages. But the length of sampling of the NAN skeletal series is sufficient to smooth any stochastic variations out of its age distribution (Weiss and Smoose 1976).

Along with the assumption of stability, it is important to assume stationarity when building life tables, where the population growth rate is zero. While the assumption of stationarity can be problematic when a population is actually growing (Ammerman et al. 1976), previous studies have shown that small human populations tend to return to stable and stationary conditions quickly, especially within short periods of time, following disturbances (Howell 1976; Paine 2000; Sattenspiel and Harpending 1983; Weiss 1973; Weiss and Smoose 1976). The NAN sample represents a small population, spanning several generations, and the Classic period was only about 130 years, therefore it is reasonable to assume that small demographic deviations are balanced by the cumulative nature of the sample and that the population was stable and stationary (Sattenspiel and Harpending 1983; Weiss and Smoose 1976).

Third, I assume that the age estimates for the sample are accurate (Acsàdi and Nemeskéri 1970; Chamberlain 2006). Patrick (1988: 69) claimed that her age estimates were 80% accurate for adults and a little more accurate for juveniles; while adult estimates, using Boldsen's at al. (2002) method, are believed to be closer to 90% accuracy (Milner et al. 2008). Since Boldsen's method requires age-specific prior probabilities, I also assume that the chosen archaeological prior probability from the Transition Analysis software is appropriate for our sample (Chamberlain 2006; Milner 2011 personal communication, April 20, 2011).

Smoothing

Despite my best efforts, the data may contain some anomalies. Several methods are used in this study sequentially to "iron out" some of these anomalies, while building composite abridged life tables.

Composite abridged life tables. As discussed above, the choice of five year intervals in an abridge life table, instead of single year intervals, helps smooth possible aging errors of adult skeletons; hence assuming that adult age estimates are accurate, within a reasonable range. By using wider age intervals, one can lower the chance of misclassification, but on the other hand using age intervals that are too broad (i.e. ten-year intervals) can conceal pertinent information (Angel 1969).

Undetermined adults. Some individuals could not be aged because their remains were too fragmentary and did not contain any of the 19 features used in this study. Excluding these individuals from my analysis could result in the underrepresentation of adults; therefore I distributed those individuals throughout the different adult age categories proportionally to the number of individuals in each age group, assuming that the apparent percentage of the age intervals is truly representative of the population (Palkovich 1980). For example, there were five individuals aged between 20 and 24.9 years old. They represent 8.77% of the 57 adults aged with Transition Analysis. I then multiplied this percentage by 17 (total number of undetermined adults) and .149 was added to the total number of 20-24.9 year old. I then repeated those steps for the rest of the adult age intervals. Table 12 shows the distribution of unaged adults throughout the entire adult sample.

D_x smoothing. Another way to smooth out possible errors related to estimating the age of each individual, is by calculating a "smoothed" D_x, the number of people dying in each age interval (Palkovich 1980: 31). One may smooth the number of individuals that died in each age interval (except the first and last intervals) by combining three consecutive intervals and then dividing the resulting number by three. This allows the redistribution of those individuals aged close to one age interval to another without significantly altering the overall age distribution.

TABLE 12. Apportioning of adults not aged with Transition Analysis to the different adult age categories to determine NAN D_x in the life table

Age Interval	# of Classic adults aged with Transition Analysis	% adult over 20	Apportioned unaged adults	D_x including newly apportioned undetermined adults
0-0.9				55
1-4.9				29
5-9.9				15
10-14.9				3
15-19.5				5
20-24.9	5	8.77%	1.49	6.49
25-29.9	4	7.02%	1.19	5.19
30-34.9	9	15.79%	2.68	11.68
35-39.9	8	14.04%	2.39	10.39
40-44.9	4	7.02%	1.19	5.19
45-49.5	3	5.26%	0.89	3.89
50-54.9	1	1.75%	0.30	1.30
55-59.9	2	3.51%	0.60	2.60
60-64.9	0	0.00%	0.00	0.00
65-69.9	4	7.02%	1.19	5.19
70-74.9	9	15.79%	2.68	11.68
75-79.9	6	10.53%	1.79	7.79
80+	2	3.51%	0.60	2.60
Total	57		17.00	180.99

For example, I estimated that the individual in burial 20 was about 40.28 years old, which puts him in age interval 40-44.9 years old but, he is also really close to age interval 35 to 39.9 years old. Smoothing D_x helps evening out possible errors in estimating age.

Competing hazard model. Many researchers have favored additional smoothing of demographic indicators such as survivorship and age-at-death distribution following a method inspired from Siler's work (1979) on a variety of animals (mammals, fish and birds) (Eshed et al. 2004; Gage 1988; Gage 1989; Gage 1990; Gage 1991; Gage and Dyke 1986; Hoppa and Vaupel 2002; Jackes 2000; Konigsberg and Frankenberg 2002; Manton et al. 1986; Mode and Busby 1982; Nagaoko et al. 2006; Siler 1983). In this model, the mortality rate or individual risk of death at each age is determined by juvenile mortality, senescent mortality and mortality independent of age. The model spans a wide range of mortality patterns and it is particularly useful because when used with maximum likelihood estimates, it has lower standard errors as caused by problems of age estimation and non-stationarity (Milner et al. 2008). Specifically, here, I used a modified Siler four parameter competing hazard model to fit survivorship (Herrmann and Konigsberg 2002), defined as follows:

$$h(a) = \alpha_1 \exp(-\beta_1 a) + \alpha_2 + \alpha_3 \exp(\beta_3 a)$$

where *h(a)* is the "force of mortality resulting from all three competing hazards at exact age [a]" (Gage 1988:430). The parameter α represents specific forces of mortality and β the rate at which mortality decreases or increases with age; α_1 is the "force of mortality resulting from immaturity at the moment of birth", α_2 is the "force of mortality that is constant with respect to age" and α_3 is the "force of mortality resulting from senescence at the moment of birth". β_1 is "the rate at which immature mortality decreases with respect to age" and β_3 the rate at which senescent mortality increases with age (Gage 1988:430). The first component of the equation $\alpha_1 \exp(-\beta_1 a)$ is a negative Gompertz equation, the hazard parameter representing juvenile mortality. The second component of the equation α_2 represents age independent mortality; here it is excluded, or set to 0, because this parameter is generally not estimable with paleodemographic data, hence making my model a four parameter model, in contrast to the original five-parameter Siler model (Herrmann and Konigsberg 2002). Finally, component $\alpha_3 \exp(\beta_3 a)$ is a Gompertz mortality model for senescent mortality. I used the statistical software *R* to estimate the mortality parameters in Table 13 that I applied below to smooth survivorship. The *R* script to calculate those parameters is available online thanks to Lyle Konigsberg at http://konig.la.utk.edu/ (Konigsberg 2005).

TABLE 13. Estimated Siler model parameters

	Parameters
α_1	0.4990
β_1	0.8505
α_2	0
α_3	0.0119
β_3	0.0229

NAN Life Tables

Tables 14 and 15 represent the NAN demographic profiles of the Classic Period, first grouping neonate and infant deaths to ease comparison with other published life tables and second separating neonate and infant deaths. Additional smoothed, abridged, composite life tables are available in the Appendix E. Two tables break down the

Classic data by room blocks and another represents the whole Classic sample using the same age intervals as Patrick to facilitate comparison with her life tables (Appendix E).

TABLE 14. NAN Ruin abridged, composite life table (Classic burials grouping neonates with other infants), where D_X = number of death, d_x = mortality rate, l_x= survival rate, q_x= probability of death, e_x= life expectancy

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.9	55	55.00	29.27	100	0.2927	85.37	2114.32	21.14
1-4.9	29	33.00	17.56	70.73	0.2483	247.81	2028.95	28.68
5-9.9	15	15.67	8.34	53.17	0.1568	245.02	1781.14	33.50
10-14.9	3	7.67	4.08	44.84	0.0910	213.98	1536.11	34.26
15-19.5	5	4.83	2.57	40.76	0.0631	197.36	1322.13	32.44
20-24.9	6.49	5.56	2.96	38.19	0.0775	183.54	1124.77	29.45
25-29.9	5.19	7.79	4.14	35.23	0.1176	165.78	941.23	26.72
30-34.9	11.68	9.09	4.84	31.08	0.1555	143.34	775.45	24.95
35-39.9	10.39	9.09	4.84	26.25	0.1842	119.16	632.11	24.08
40-44.9	5.19	6.49	3.45	21.41	0.1613	98.44	512.95	23.95
45-49.5	3.89	3.46	1.84	17.96	0.1025	85.20	414.51	23.08
50-54.9	1.30	2.60	1.38	16.12	0.0857	77.14	329.31	20.43
55-59.9	2.60	1.30	0.69	14.74	0.0469	71.96	252.17	17.11
60-64.9	0.00	2.60	1.38	14.05	0.0984	66.78	180.21	12.83
65-69.9	5.19	5.62	2.99	12.66	0.2363	55.84	113.43	8.96
70-74.9	11.68	8.22	4.37	9.67	0.4522	37.43	57.59	5.95
75-79.9	7.79	7.36	3.91	5.30	0.7389	16.70	20.16	3.81
80+	2.60	2.60	1.38	1.38	1.0000	3.46	3.46	2.50

TABLE 15. NAN Ruin abridged, composite life table (Classic burials separating neonates from other infants), where D_X = number of death, d_x = mortality rate, l_x= survival rate, q_x= probability of death, e_x= life expectancy

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.17	27	27.00	15.09	100	0.1509	28.41	2168.73	21.69
0.18-0.9	28	28.00	15.65	84.91	0.1843	19.37	2140.32	25.21
1-4.9	29	24.00	13.41	69.26	0.1937	250.22	2120.95	30.62
5-9.9	15	15.67	8.76	55.85	0.1568	257.35	1870.73	33.50
10-14.9	3	7.67	4.28	47.09	0.0910	224.75	1613.38	34.26
15-19.5	5	4.83	2.70	42.81	0.0631	207.29	1388.63	32.44
20-24.9	6.49	5.56	3.11	40.11	0.0775	192.77	1181.35	29.45
25-29.9	5.19	7.79	4.35	37.00	0.1176	174.12	988.58	26.72
30-34.9	11.68	9.09	5.08	32.65	0.1555	150.55	814.45	24.95
35-39.9	10.39	9.09	5.08	27.57	0.1842	125.15	663.91	24.08
40-44.9	5.19	6.49	3.63	22.49	0.1613	103.39	538.75	23.95
45-49.5	3.89	3.46	1.93	18.86	0.1025	89.49	435.36	23.08
50-54.9	1.30	2.60	1.45	16.93	0.0857	81.02	345.88	20.43
55-59.9	2.60	1.30	0.73	15.48	0.0469	75.58	264.85	17.11
60-64.9	0.00	2.60	1.45	14.75	0.0984	70.14	189.27	12.83
65-69.9	5.19	5.62	3.14	13.30	0.2363	58.65	119.14	8.96
70-74.9	11.68	8.22	4.59	10.16	0.4522	39.31	60.49	5.95
75-79.9	7.79	7.36	4.11	5.56	0.7389	17.54	21.18	3.81
80+	2.60	2.60	1.45	1.45	1.0000	3.63	3.63	2.50

Mortality rate d_x

Column d_x represents the mortality rate by age interval. It is the percentage of people dying between two adjacent age intervals. Figure 7 compares the mortality rate from my age estimates on the whole Classic sample to that of Patrick (1988) on the Classic burials from the first five years of excavation only. Based on Table 14, I found that the infant mortality rate for the entire Classic population at NAN was high as expected, with 46.83% of individuals dying before reaching five years. Most of these deaths occurred before one year of age (29.27%). This is similar to what Patrick had found using a smaller sample (47%). High infant mortality is common in prehistoric societies, due to lack of medication and proper sanitation. In subsequent years, the mortality rate drops drastically to 8.30% for those between ages 5-10 and continues to drop and remain close to or less than 5% in subsequent age intervals until it reaches its lowest point between 55-60 years old. After 60 years it starts increasing again by several percent. This is a little different from Patrick's results (1988), in that she found that the

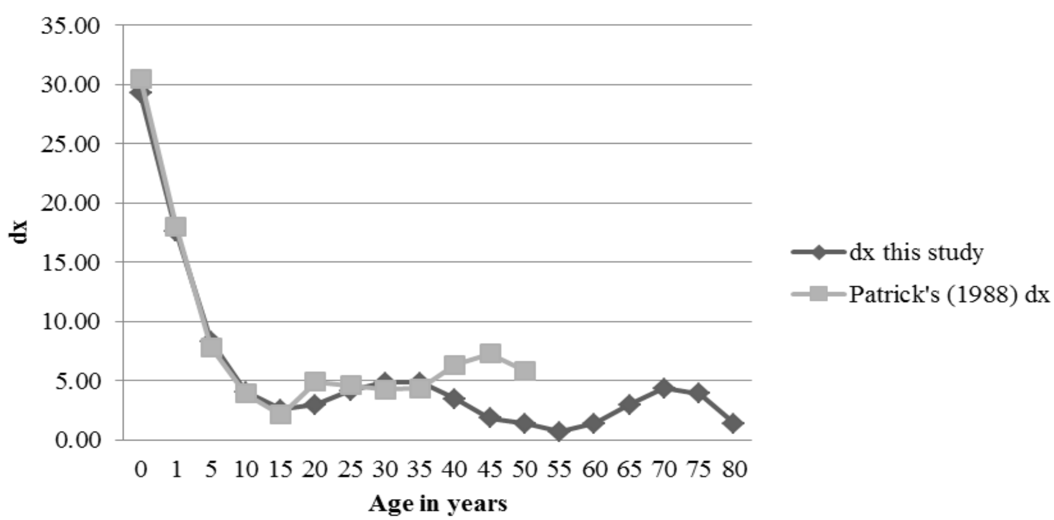

Fig. 7. NAN Ruin Classic Period mortality rate comparing the result of this study to that of Patrick (1988).

lowest mortality rate occurred in subadult years between 10 and 20 years old, and that her maximum age interval ended with the open ended category of 50 or more years old.

Survivorship l_x

The survivorship rate is a reflection of the percentage of individuals that will survive to the beginning of the next age interval, following the mortality rate established in the previous column. Figure 8 shows the survivorship rate from both my age estimates on the whole Classic sample with that of Patrick's on the Classic burials from the first five years of excavation only. When comparing my estimates to that of Patrick's (1988) the survivorship curve is very similar. The data diverge slightly between 1 and 20 years old and more prominently after 25 years old. For the senescent portion of the population, the survivorship rate stabilizes at 55-65 shortly before falling steadily in the

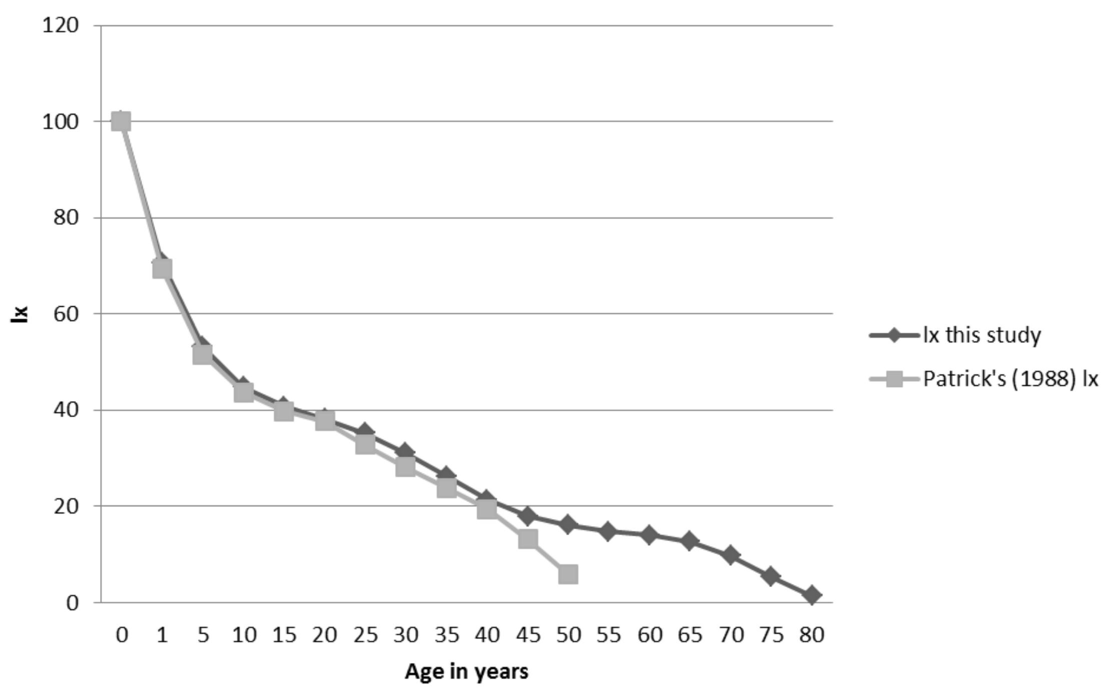

Fig. 8. Survivorship curve comparing the result of this study to that of Patrick (1988).

remaining years of life.

Competing hazard model. Following Herrmann and Konigsberg (2002; Konigsberg 2005), I constructed a hazard function for the paleodemographic reconstruction of the NAN series, represented in Figure 9. The function predicts a high death rate in the early years of life, which drastically declines in following years. It reaches a low point between 1-5 years old and then continues to decrease steadily after that. This is a reasonable mortality pattern for this sample, where mortality decreases swiftly after the first few years of life. Subsequently I fitted the NAN Classic survivorship curve from figure 8 to the mortality hazard model from figure 9, which shows a similar trends. Figure 10 represents both the fitted (dark gray) and the original survivorship curve (light gray).

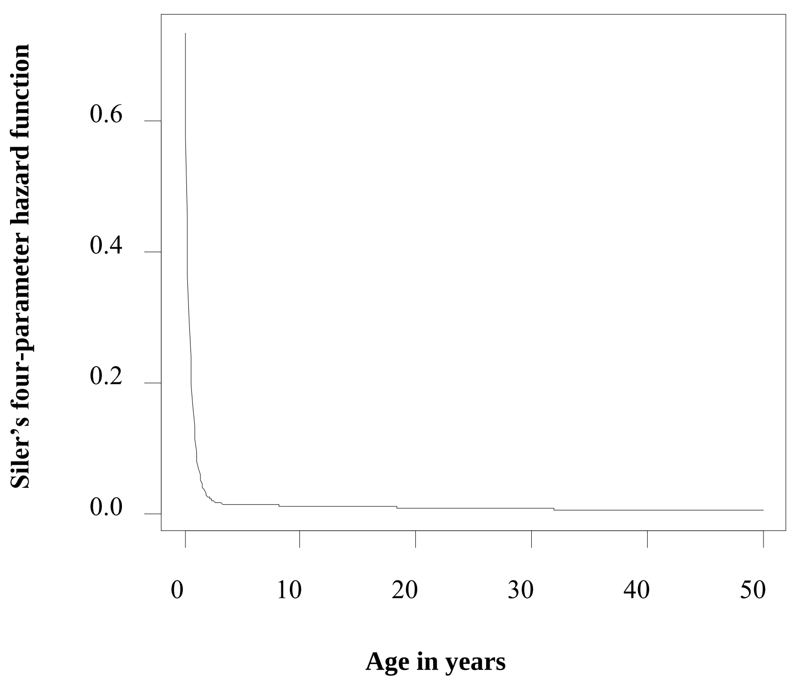

Fig. 9. Siler mortality hazard function for the paleodemographic reconstruction of the NAN Ruin.

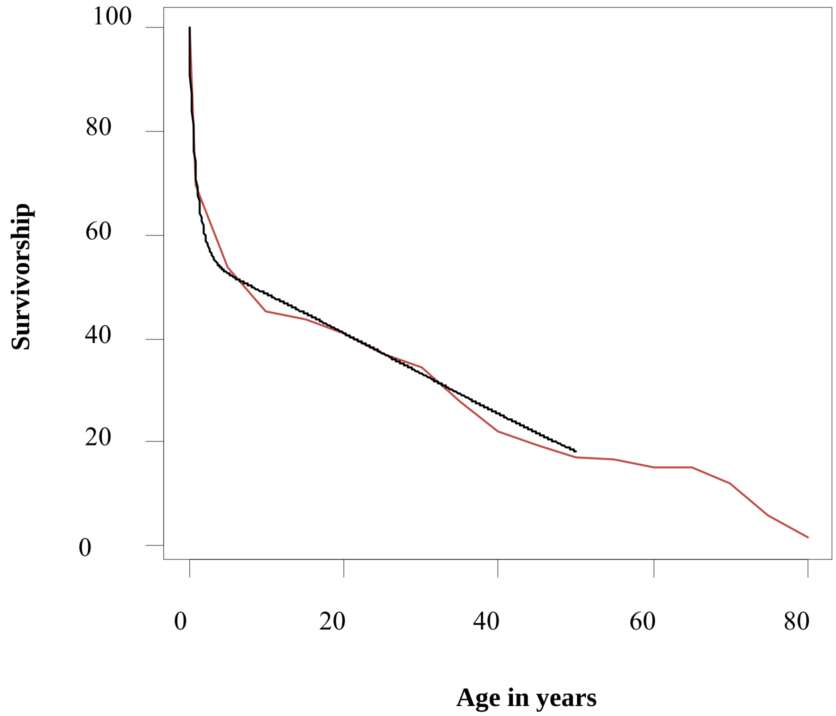

Fig. 10. Fitted (dark gray) and original (red) age-specific survivorship curves for NAN Ruin.

Both the fitted and original survivorship curves decline at the same rate at the beginning of life and during adulthood. The rates differ for adolescents and again for those in late adulthood, where the original survivorship declines more drastically. The close fit between the original and fitted survivorship curve shows that the mortality pattern observed at NAN is biologically sound.

Probability of death q_x

The probability of death displays the likelihood that an individual entering a specific age interval, will die before reaching the end of that age interval (Figure 11).

Almost thirty percent (29.27%) of individuals born were expected to die before reaching age 1, which is similar to Patrick's findings (30.51%).

Patrick also found that the lowest probability of death occurred between the ages of 10-20 years, when it falls below a 10% chance of dying, after which it steadily increases, with a slight jump after 40 years. This is different from what I found analyzing the entire Classic sample. The probability of dying falls below 10% between 10-25 years of age and again after 50-65 years of age. Hassan (1981) suggested that during adulthood occupational hazard and lowering of "resistance" to disease influences mortality. The hump in mortality between 25 and 50 years old that we see at NAN may reflect occupational hazards and accidental deaths and perhaps a marked decreased resistance to environmental factors for the senescent part of the population after 60 years old (Hassan 1981; Manton et al. 1986; Mode and Busby 1982).

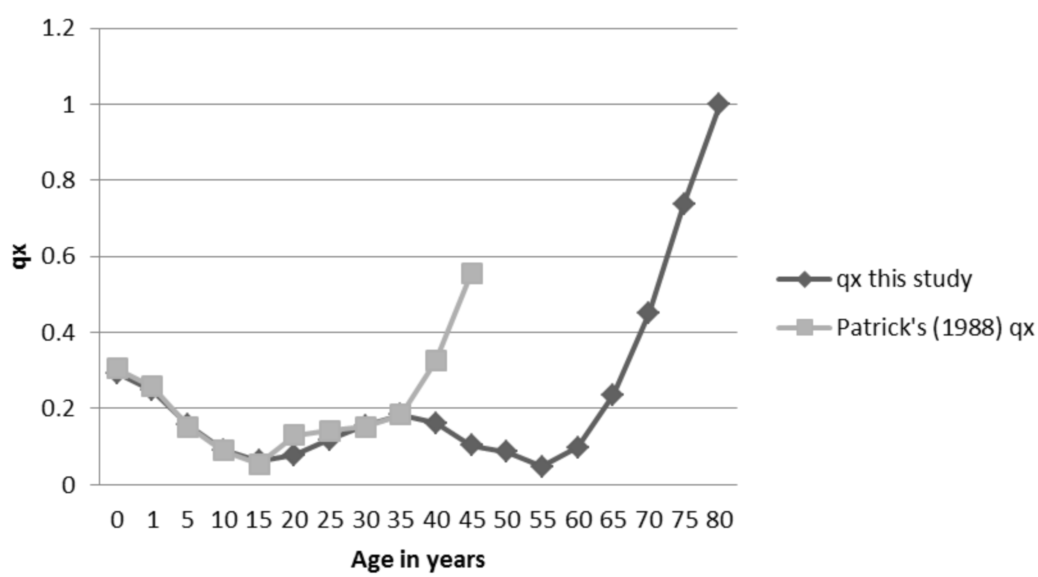

Fig. 11. Probability of death comparing my sample to that of Patrick (1988).

Sex ratios

Ninety percent of adult skeletons were sexed; therefore we can attempt to make inferences on the different demographic indicators by sex. Table 16 represents the number of deaths by sex. The sex ratio (number of males/number of females) x 100, for the entire Classic sample is 103 (34 men for 33 women), which is not unusual. While it is expected to find a higher adult mortality rate among women of childbearing age (15 to 40 years), I do not find that it is the case here. Patrick found that during childbearing

TABLE 16. Number of deaths by sex in the Classic Period (unsmoothed, childbearing years shaded)

Intervals	Years	# Males	% Males	# Females	% Females	# Undetermined Sex	% Undetermined Sex	Total
1	0-0.29					27	14.92%	27
2	0.3-0.9					28	15.47%	28
3	1-4.9					29	16.02%	29
4	5-9.9					15	8.29%	15
5	10-14.9					3	1.66%	3
6	15-19.5	2	1.10%	2	1.10%	1	0.55%	5
7	20-24.9	2	1.10%	3	1.66%			5
8	25-29.9	1	0.55%	3	1.66%			4
9	30-34.9	7	3.87%	2	1.10%			9
10	35-39.9	4	2.21%	4	2.21%			8
11	40-44.9	3	1.66%	1	0.55%			4
12	45-49.5	2	1.10%	1	0.55%			3
13	50-54.9	1	0.55%		0.00%			1
14	55-59.9	1	0.55%	1	0.55%			2
15	60-64.9		0.00%		0.00%			0
16	65-69.9	1	3.70%	3	1.66%			4
17	70-74.9	2	1.10%	5	2.76%	2	1.10%	9
18	75-79.9	2	1.10%	3	1.66%	1	0.55%	6
19	80+	1	3.70%	1	0.55%			2
20	?	5	2.76%	4	2.21%	8	4.42%	17
Total		34	18.78%	33	18.23%	114	62.98%	181

years old although they died during the younger childbearing years 15-30 years old (7.5 %) or after the age of 40 (7.5% also), but I do not observe the same pattern of mortality among the large Classic sample I used for this study. Instead I find that adult females experienced a fairly constant mortality rate, with an increase after 35. On the other hand, adult male mortality appears to peak at 30-34.9 (3.87%), 65-69.9 (3.70%) and after 80 (3.70%), while remaining otherwise relatively constant.

Life expectancy e_x

Life expectancy is the number of years one may expect to live if he/she reaches a given age. More specifically, life expectancy at birth e_o is a widely cited demographic indicator. It is the mean number of years a newborn is expected to live given the mortality schedule of the population. Figure 12 shows the life expectancy curves for e_x as calculated by Patrick and myself as well as including different subsample from the NAN Classic collection.

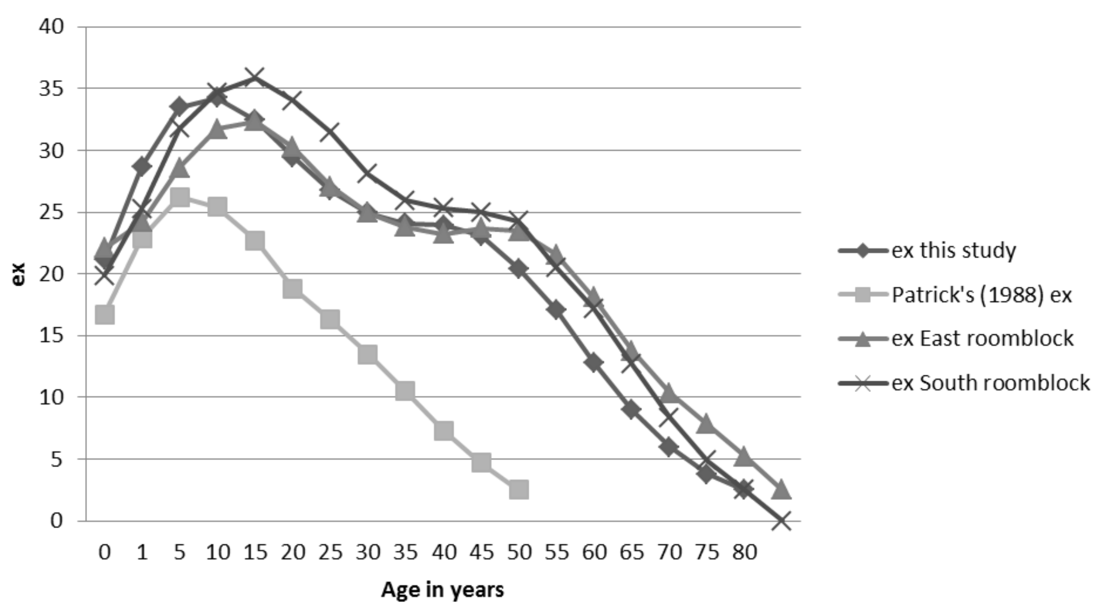

Fig. 12. Life expectancy at NAN as computed by Patrick (1988) and myself (including the entire Classic sample and the East and South room blocks separately).

Life expectancy at birth e_o. I found that e_o at NAN was 21.14 years, while Patrick's found it to be much lower at 16.77 years. She warns that life tables with a greater number of age intervals will yield different life expectancy values. Even when using similar age intervals to hers (APPENDIX E), I found the life expectancy at birth to be 20.45 years, which is still greater than her finding by several years and expected since this study yielded older adults.

Life expectancy in subsequent years. Once reaching the age of five years, I found that individuals could expect to live an additional 33.50 years, while Patrick found that they could expect to live only another 26.20 years. Similarly once reaching age 25, I found one could expect to live another 26.72 years, while Patrick only found 16.30 years. This difference is almost certainly due to the different aging methods used to estimate age as well as from the archaeological differences between our samples. As a matter of fact, the first five years of excavation mainly focused on the eastern room block of the NAN Ruin, while subsequent years of excavation added a number of individuals from the southern room block. When comparing the life expectancy at birth from the two room blocks, I found that people from the East room block could expect to live 20.98 years after birth, while those of the South room block could expect to live to just 19.87 years. But once reaching one year of age the pattern changed between room blocks, with people from the South room block enjoying higher life expectancy until reaching old age. However, I did not find that the difference in life expectancy between the East and South room blocks was statistically different ($t=-0.98$, $p=0.34$), therefore the difference between this study and Patrick's (1988) study must be due to the different aging methods rather than to sample differences.

Birth rate and crude death rate

Birth rate. Though life expectancy at birth is commonly described as an indicator of how many years one is expected to live based on a population mortality schedule, it is also the mean age at death of that population. One can also use the mean age at death to calculate the birth rate of that population, hence providing valuable information about fertility (Sattenspiel and Harpending 1983). The birth rate is equal to the inverse of the mean age at death (here: $1/e_o$). I found that the birth rate for the overall Classic sample is 47.3, in contrast to the birth rate from Patrick's reduced Classic sample of 59.63. A low mean age at death can be as much a result of high fertility as it is a result of high mortality depending on the level of stationarity. In this case, the low mean age at death is likely a result of high fertility.

Crude mortality rate. The crude mortality rate calculated as $1000/e_o$ is the total number of deaths per 1000 (Ubelaker 1978). In a stationary population the birth rate and crude mortality rate are essentially the same. I found that the CMR at NAN is 47.1, which is much lower than what Patrick had found (56.75). This variation may also be a reflection of the difference between our samples. When looking at the difference CMR for the two room blocks, we can see that the East room block had a CMR of 47.7, which is much lower than that of the southern room block at 51.9. Ubelaker (1974) stated that there were limitations to comparing the crude mortality rates of different samples because it may reflect a different degree of completeness rather than a true difference in mortality.

Summary

As expected, I found that overall the NAN Ruin population had a low life expectancy, with a high infant mortality. However, unlike Patrick, I did not find that there was a marked increase in mortality for women during childbearing years.

Infant mortality for the entire Classic sample was 46.3% for those younger than five years, 26.3% of whom died in the first year of infancy. When comparing infant mortality between the two main room blocks that constitute the main part of NAN Ruin, we can see that the South room block had a higher infant mortality rate (53.3% died before five years, 35.2% of which before 1 year), than the East room block (44.7% before 5 years, 26.8% before 1 year). There is a similar trend when looking at the crude mortality rate and the birth rate, where the South room block has a high birth rate and crude mortality rate of 51.9, as opposed to 47.7 for the East room block. Based on the demographic indicators, it appears as though the East room block had a better overall longevity though the difference between the two room blocks does not appear to be statistically meaningful. Similarly, in her analysis of different health indicators, Diane Young Holliday (1996) had found that the East room block may have enjoyed a healthier life than the South room block, though the difference was not significant for the most part.

Overall we can see that the more complete Classic sample suggests a higher life expectancy and longer lifespan with some subtle differences between room blocks.

Given that both samples were analyzed using different aging methods, one may wonder whether the difference between my demographic indicators and Patrick's (1988) are the result from the nature and size of our sample or whether using the Transition Analysis had a significant impact on the NAN demography. Whereas Patrick's sample included only skeletons from the East room block, my sample added nearly 100 skeletons to the study, including 76 from the South room block. To determine whether the difference in demographic indicators between the two studies is due to a difference in sample we can look at the difference between room blocks. I found no significant difference between the two main room blocks; therefore the difference between our two analyses is most likely due to using Transition Analysis to more accurately estimate age-at-death, especially for the senescent part of the population rather than a sample difference. Our analyses demonstrate similar trends in the younger years of life, but diverge drastically once reaching mid adulthood and old age. This shows how the limitations of older aging methods have clouded our interpretation of adult mortality.

CHAPTER VII

DISCUSSION

The purpose of this study was twofold. By reanalyzing all adult skeletons from NAN Ranch using the Transition Analysis method (Boldsen et al. 2002), I wanted to determine if a different aging approach would yield more precise results, especially in the context of fragmentary remains. Older aging methods that do not rely on Bayesian statistics have been reported to mimic age distribution pattern from the reference sample that was used to create them and to have a tendency to overage young adults and underage old adults (Bocquet-Appel and Masset 1982). Using this method, I hoped to provide more precise age estimates and to shed light on the senescent portion of the population, often overshadowed by the shortcomings of those older aging methods. In addition, the previous demographic study performed by Patrick (1988) only considered the first five years of excavated materials, suggesting demographic trends, but offered an incomplete picture of the NAN Ranch demography. In my analysis of the entire NAN skeletal sample, I hoped to provide a more complete demographic profile of the population and confirm or refute some of the trends suggested by Patrick.

Nan Ranch Demography

There are two main differences between my analysis and that of Patrick's (1988), the sample size and the method used to estimate adult age-at-death. Both Patrick and I used a multifactorial approach to age adult skeletons, which has been highly recommended as opposed to using one aging method that focuses on one skeletal element (Bedford et al. 1993; Lovejoy et al. 1985a). The methods used by Patrick are listed in Chapter VI and for this study the Transition Analysis (Boldsen et al. 2002) combines elements from the cranium, pubic symphysis and the auricular surface of the ilium. Though Transition Analysis is helpful in terms of fragmentary remains, I was not able to age a greater proportion of individuals than Patrick. Some remains were simply too fragmentary to yield any age or sex information.

Classic period

During the first five years of excavation at NAN, 95 burials were recovered, 81 of which from the Classic Period. Of those 81, Patrick was unable to age six adult skeletons which she apportioned to existing age intervals (Patrick 1988). Today, the NAN skeletal sample counts at least 243 individuals, 185 of which were assigned to the Classic Period, 44 to the Transitional Period, eleven to the Late Pithouse Period and three came from undetermined periods. Of those 185 Classic burials, I was unable to estimate the age of 21 adults, four were excluded from the study because they were secondary deposits of cremated remains and the remaining 17 unaged skeletons were apportioned to existing age intervals.

Both, Patrick and I started our analysis with the same expectations in regards to prehistoric populations. That is, we expected to find a high infant mortality rate, and a higher mortality rate for females of childbearing age as compared to that of males, and a relatively low life expectancy at birth (Bennett 1975; Hassan 1981; Weiss 1973). Patrick's results fit those expectations, as she found a high infant mortality rate, where 47% of the population died prior to reaching age five, including 32% that died before one year old. Based on her limited sample, she also found that females of childbearing age died more frequently than males. Though, the proportion of females likely dying of childbearing complications was not as high as anticipated. She conceded that this finding could be a result of sampling or of young male and/or female migration. Finally she found that life expectancy at birth was low (16.77 years) as expected. In my analysis, based on a NAN skeletal population double the size of that used in Patrick's study, I also found a high infant mortality rate (46.83%) and low life expectancy at birth (21.14 years); however I could not confirm that there was a higher mortality rate for women of childbearing age. Patrick made some assertions in regards to the different periods within the Classic era. For instance, she found that there may have been greater stress during the middle Classic period. I could not substantiate or refute her findings because temporal data for the entire NAN sample are not available. However, thanks to the larger sample size, I detected some differences between room blocks, where the East room block population may have experienced marginally better longevity than the South room block, however the difference was not statistically significant ($t = 0.98$, $p = 0.34$).

Other periods

In this study, I also estimated the age of adult skeletons from other periods, including those from the Transitional Phase, with the initial intent to provide temporal evolution of NAN demography between the Transitional Phase and the Classic Period. However, the sample is too small to make any pertinent inference and it also reflects sample bias. Of the 44 Transitional burials, I excluded eleven skeletons because they were fragmentary secondary cremation deposits and I was unable to estimate the age of six skeletons, which I apportioned to existing age intervals. A smoothed, composite abridged life table (APPENDIX E) for this phase yielded a higher than expected life expectancy at birth of 24.91 years and a life expectancy of 27.28 years for those reaching age five. In addition, the child mortality rate is much lower than anticipated, with only 24.37% of children dying before age five, of whom 9.14% died before one year. These demographic indicators deviate drastically from what is expected of prehistoric populations (low life expectancy at birth and high infant mortality) and reflect infant underenumeration. In addition, it is still debated that the Mimbres maintained some level of mobility during the phases that preceded the Classic Period, so infant underenumeration could result from the possible seasonal use of the site, as well as excavation or preservation issues. This sample bias does not allow us to make any significant inference about demographic changes between the Transitional Phase and the Classic Period.

In addition to the sample size, the main difference between my study and that of Patrick is the aging method used. Transition Analysis allows one to estimate the age-at-death of individuals well into their senescent years, past the usual 50 + year category that has been the most common cut off age category in previous demographic studies. Older methods seem to affect young and mid adult mortality patterns (Bocquet-Appel and Masset 1982; Buikstra and Konigsberg 1985; Konigsberg and Frankenberg 1992; Konigsberg and Frankenberg 1994; Van Gerven and Armelagos 1983).

We can see from Patrick's (1988) mortality rate (d_x) and probability of death (q_x) that 35 years of age is a turning point. In her analysis the mortality rate increases around age 35 and that the probability of death skyrocks after 35 years of age as well. In my analysis, I found that the mortality rate for the NAN sample actually decreased for those 35 to 55 years old before it increased in the 50-70 year range. Similarly, I found that the probability of death decreased in the same age range, 35-55 years old, and then increased after 55 years of age (see figures 7 and 11). This shows that using different aging methods, especially those that do not allow age estimates for older adults, oversimplify adult mortality patterns, producing unimodal patterns as opposed to multimodal ones, as it is the case in my analysis.

The same pattern is observable when looking at the survivorship curves (l_x) and life expectancy (e_x) curves for our analyses (see figures 8 and 12). Patrick (1988) found unimodal survivorship and life expectancy curves, while I found bimodal ones. Our patterns are similar in younger years, but patterns of adult mortality and survivorship are highly influenced by our aging methods, where older aging methods lead to the common assumption that ancient populations did not live to be very old and where mortality increased drastically in mid adulthood.

One can also look at health and nutrition patterns to help corroborate demographic patterns (Steckel and Rose 2002). However, Young Holliday's (1996) analysis of pathology and trauma at NAN does not yield age pertinent information in regards to the overall health and nutrition status of the NAN population that can be correlated to the mortality and survivorship data observed by myself or Patrick (1988). She found evidence of subadult anemia in the form of cribra orbitalia and porotic hyperostosis which indicate insufficient absorption or malabsorption of iron. However in her analysis on dental health and on signs of infections and trauma, she did not find any lesions that can be consistently associated with a particular age group that would account for the mortality patterns we see among adults.

As suggested in Chapter VI, the adult mortality pattern we see at NAN could be a reflection of occupational hazards and the lowering of resistance to disease with advanced age (Hassan 1981). The pattern of mortality observed in Patrick's analysis does not allow for a differentiation between the two. Whereas in my analysis, we can see that the hump in mortality in mid adulthood can be a result of occupational hazards while senescent death is likely related to decreasing disease resistance, though this remains speculative.

Future studies on the NAN skeletal sample could shed light on some of the differences between our two analyses. One could continue the work of tentatively assigning temporal affiliation for all the Classic burials using ceramic microstylistic changes to better grasp population evolution within the Classic period (Shafer and Brewington 1995). In addition, one could look at the number of deceased females of childbearing years and see if they were associated with neonatal remains or if fetal remains were found in their pelvic cavities, as performed by Owsley and Bradtmiller (1983) on the Arikara sample. In addition, further refinement of aging methods, especially of fragmentary, poorly preserved or of cremated remains, may yield a more complete picture of NAN demography.

Intrasite Comparison

Intrasite comparison is essential in trying to establish demographic patterns at the regional, temporal or subsistence level. However, such comparisons are particularly difficult when different methods and representation of the data are not standardized. The calculation of life tables is standardized, but the methods used to estimate age-at-death vary greatly therefore affecting the age distribution of a sample. The demographic element that is most subject to variation in age estimates is life expectancy (e_x), particularly life expectancy at birth (e_o). It is the equivalent to the average age-at-death of a population under stationary conditions; therefore it is highly influenced by the overall age distribution of the population. Using different aging methods with different cut off ages will consequently influence such indicators.

For example, in his study at Point of Pines, Arizona, a western pueblo site occupied from 400 A.D. to 1450 A.D., Bennett (1973) found that increasing the terminal age interval from 50 to 90 years old, increased life expectancy at birth by 4 years for females and 2.92 years for males, though he did not find the difference to be statistically different. In a reconstruction of Cochiti life tables, a historic pueblo in New Mexico, Patrick (1988:85-86) found a life expectancy at birth of 15.20 years for the unsmoothed life table she calculated with the same age intervals as her study, and a life expectancy at birth of 16.61 for the life tables she calculated with 17 age intervals reflecting the actual historical data reported by Lange (1959). Keeping in mind the effect of additional age intervals in life tables on life expectancy, we can attempt some comparisons between sites. Table 17 lists the names, dates of occupation and location of southwestern sites that are discussed in this intrasite comparison (Bennett 1973; Berry 1985; Lange 1959; Mitchell 1992; Mobley 1980 ; Nelson et al. 1994; Palkovich 1980; Palkovich 1985; Patrick 1988; Stodder et al. 2002). Most sites are those of populations that enjoyed comparable environment, subsistence and/or social organization. Though Cochiti is more recent and made use of European crops and livestock, its social organization and communal use of agricultural land is similar to that of southwestern prehistoric sites. I also selected Weiss model life table (MT 32.5-40) where l_{15}= 32.5 and e_{15} = 40, for its strong similarity with the Classic NAN sample, for added control over the biological fitness of my sample (Weiss 1973).

TABLE 17 Name, date of occupation and location of sites referred to in the comparison below (sorted by regions)

Site Name	Date	Location
Point of Pines	400-1450 A.D	East Central Arizona
Black Mesa	800-1150 A.D.	North East Arizona
Pueblo Grande	1150-1450 A.D.	near Salt River, Arizona
Turkey Creek	1200s A.D.	East Central Arizona
Grasshopper Pre Abandonment	1275-1300 A.D.	Central Arizona
Dolores	600-980 A.D.	SW Colorado
Mesa Verde (Dolores, Mesa Verde Nat'l Park, Mancos, Johnson and Lion Canyon)	600-975 A.D. (Early Sample) 975-1300 A.D. (Late Sample)	Colorado Plateau
Chaco Canyon	900-1140 A.D.	Colorado Plateau, New Mexico
Salmon Ruin	1088-1105 A.D.	Colorado Plateau, New Mexico
Pecos	1150-1838 A.D.	New Mexico
Arroyo Hondo	1300-1345 A.D.	Northern Rio Grande, New Mexico
San Cristobal	1350-1680 A.D.	Galisteo Basin, New Mexico
Hawikku	1400-1680 A.D.	Western New Mexico
Cochiti	Historic Pueblo	Northern Rio Grande, New Mexico
Casas Grandes	1200-1400 A.D.	Northwestern Chihuahua, Mexico

Life expectancy in the North American Southwest

Life expectancy at birth is the most commonly cited demographic indicator for comparison purposes. Table 18 lists life expectancy at birth (e_o) for a number of southwestern sites, including the sample size and the oldest age interval used to calculate e_o. We can see that there is wide range of life expectancies but that most remain within the expected range for prehistoric populations. Sites displaying life expectancy in the higher range (Black Mesa, Pecos and Pueblo Bonito) suffer from some infant underenumeration and are interpreted as reflecting a growing population (Mobley 1980 ; Nelson et al. 1994).

TABLE 18. Life expectancy at birth for prehistoric and historic southwestern sites, including sample size and oldest age interval in the life table as available

Site Name	n	Oldest Age Interval	e_o	Reference
Salmon Ruin			12.8	Berry (1985)
Pueblo Grande	856	30+	15	Mitchell (1995)
Arroyo Hondo	108	50+	16.2	Palkovich (1980)
Cochiti	451	75 +	16.6	Patrick (1988)
Mesa Verde Late Sample	178	51-55	18.4	Nelson et al. (1994)
Turkey Creek			19.6	Berry (1985)
Grasshopper Pre Abandonment	434	50-54.9	19.7	Berry (1985)
Casas Grandes	612	50-59.9	20.2	Nelson et al. (1994)
Weiss MT 32.5-40		80	20.7	Weiss (1973)
NAN Ranch Classic Sample	181	80+	21.1	This study
Mesa Verde Early Sample	150	51-55	21.3	Nelson et al. (1994)
Hawikku			21.5	Stodder et al. (2002)
Point of Pines	428	41-50	21.9	Bennett (1973)
San Cristobal			22.2	Stodder et al. (2002)
Dolores	64	40+	24.2	Stodder et al. (2002)
Black Mesa	172	50-60	25.2	Nelson et al. (1994)
Chaco Canyon Pueblo Bonito	94	50-54.9	26.4	Nelson et al. (1994)
Pecos	1722	50-80	27.4	Mobley (1980)

The NAN Ranch Classic skeletal sample fits closely with Turkey Creek, Grasshopper, Casas Grandes, Mesa Verde Early sample, Hawikku, and Point of Pines, which experienced similar environmental constraints, but at different times. Similarly sites with life expectancy in the lower range (Salmon Ruin, Pueblo Grande, Arroyo Hondo) either suffer from adult underenumeration, infant overenumeration or may reflect population in decline. Looking at life expectancy at birth is not enough to appreciate the full extent of life expectancy patterns. When graphing e_x data we can see the fluctuations of life expectancy by age and even more strongly that the extent of the life table age intervals influences e_x numbers greatly. Figure 13 shows the life expectancy curve for NAN, Weiss MT, Cochiti as well as for Casas Grandes and Mesa Verde Early Sample because they closely matched NAN e_o, though they were not contemporaneous with NAN; and Pueblo Bonito which was contemporaneous with NAN. We can see that NAN, Cochiti and Weiss MT, each have age intervals going up to 80 years of age have very similar life expectancy patterns. However, if we look at Pueblo Bonito or at Casas Grandes and the Mesa Verde Early sample, we can see that the life expectancy curve is much shorter, lower and steeper than curves with more age intervals and do not exhibit a pattern similar in shape to NAN. Graphing all other life expectancy curves for the remaining of the sites would show similarly shorter, lower and steeper curves as well. One may wonder if this a true reflection of demographic patterns or an artifact of the shortcoming of our aging methods, which limit age estimates past a certain age. Similar patterns occur when graphing survivorship curves (l_x) and probability of death curves (q_x).

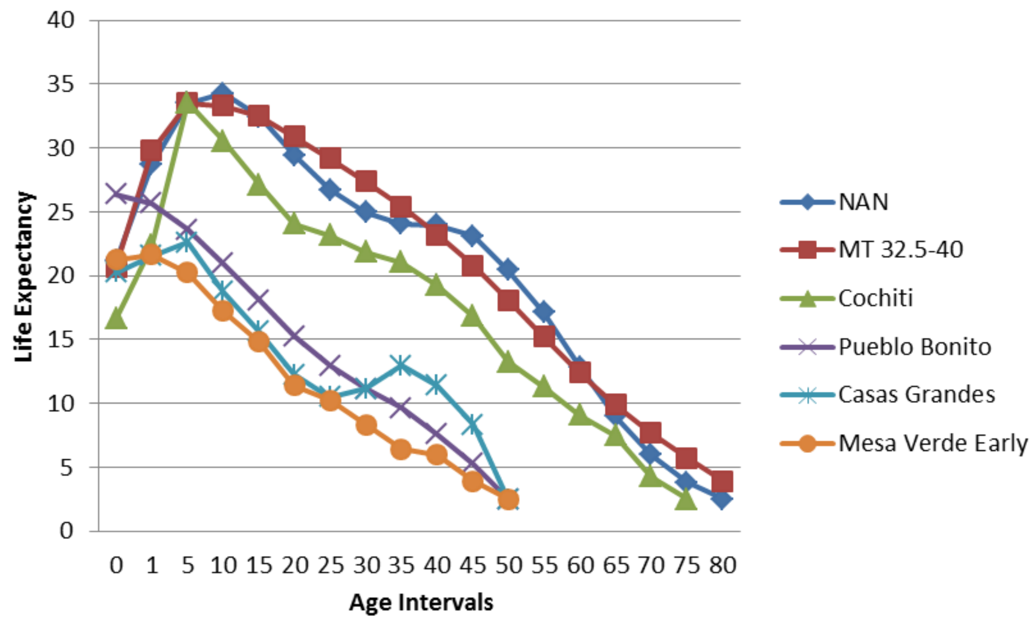

Fig. 13. Life expectancy curves for NAN Classic Sample, Weiss MT, Cochiti, Pueblo Bonito, Casas Grandes and Mesa Verde Early Sample.

Survivorship

Also I find a close fit between the survivorship curves for the NAN Classic sample, Weiss MT and the historical Cochiti sample. Figure 14 shows the survivorship curve for all three samples. When comparing the survivorship curves for NAN and other southwestern samples as seen in Figure 15, I found similarity with Arroyo Hondo and Grasshopper, where the survivorship curve for children and adolescents is convex, but where Casas Grandes and Mesa Verde Early Sample which had similar life expectancy at birth estimates, display different survivorship patterns. Black Mesa, which was contemporaneous to NAN also displays a mildly concave curve for children and adolescents, however, the pattern is less obvious.

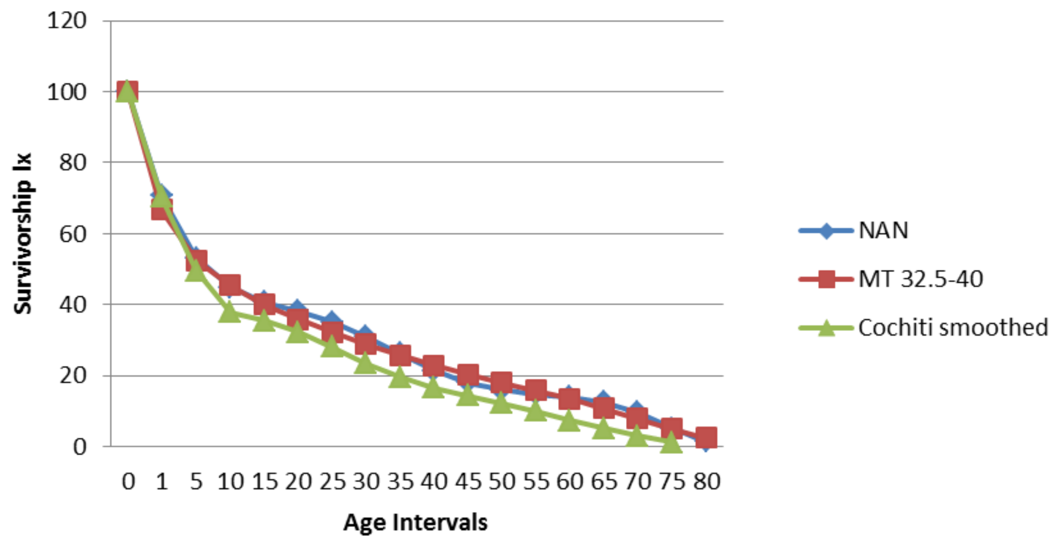

Fig. 14. Survivorship curve for the NAN classic Sample, Weiss Model Life Table and Cochiti historical pueblo.

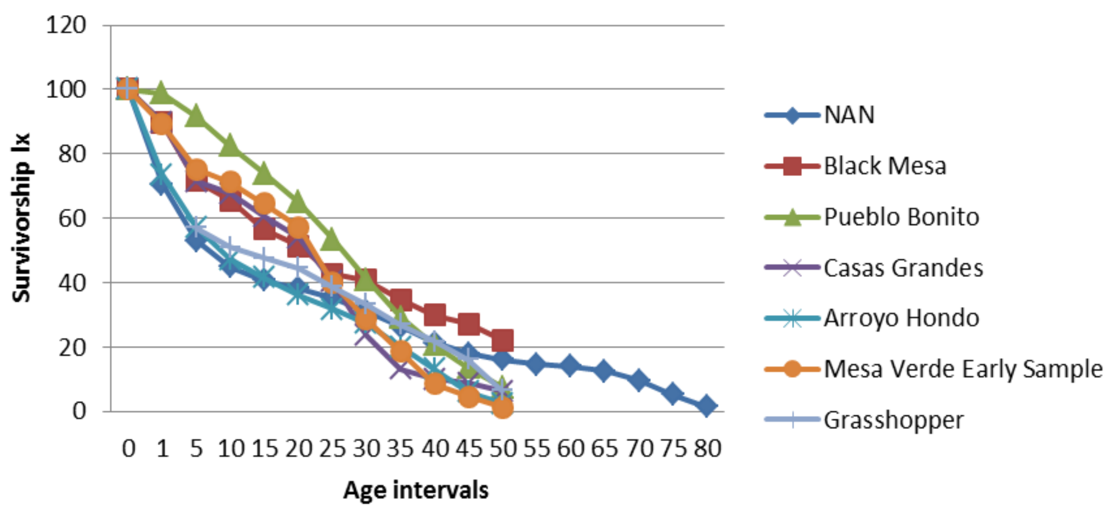

Fig. 15. Survivorship curve comparing several Southwestern sites to the NAN Ranch Classic survivorship patterns.

Though, it is less obvious here, we can see that the difference in age distribution and in the number of age intervals used to generate those data, likely affects the outcome of the survivorship curve.

Probability of death

Similarly to life expectancy and survivorship data, I found that the probability of death curve for NAN closely fits that of Weiss MT and that of Cochiti, though the probability of death between 45 and 65 years at NAN is relatively lower, as seen in Figure 16. In Figure 17, the probability of death at Casas Grandes shows a similar pattern to NAN, with a hump in early adulthood, though more drastic, which has been attributed to a high mortality among women of childbearing age (Nelson et al. 1994), followed by a decreased probability of death in subsequent decades which then increased drastically in old age. Black Mesa and Point of Pines males and females also show a hump in mortality among young to mid adult. However, assuming that sex estimates for NAN are correct, I could not find a difference in mortality among males and females for that age range, hence I cannot confirm that this pattern at NAN is attributable to higher female mortality related to childbirth complications.

However, one may wonder, again, if this hump in mortality is a true reflection of increased mortality among young and mid adulthood or is a reflection of the aging methods that were used to build the life tables. Older methods have been shown to have a tendency to overage young adults and to under age old adults, resulting in a concentration of deaths in mid adulthood. Given the paucity of paleodemographic studies on southwest populations since the advent of newer aging methods allowing a

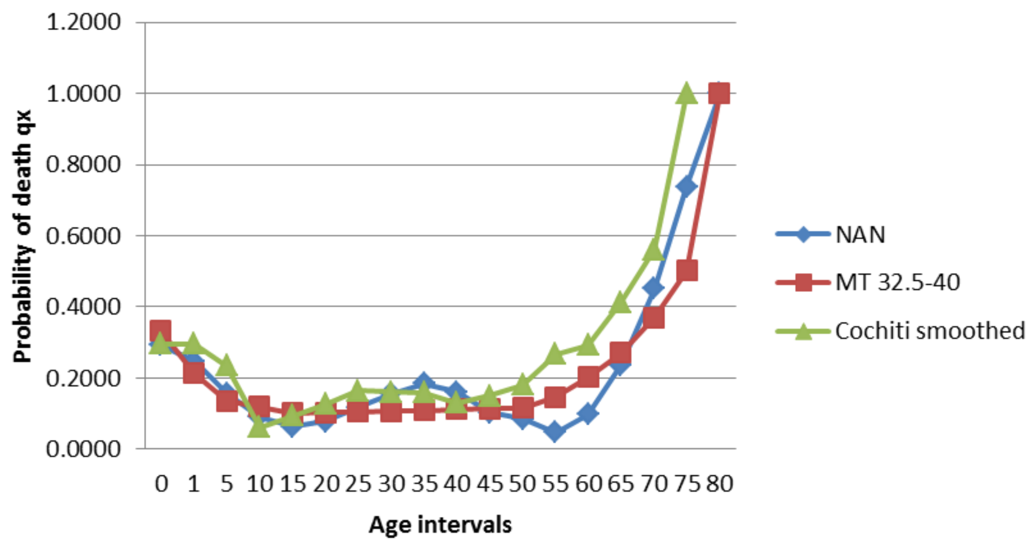

Fig. 16 Probability of death curve for the NAN classic Sample, Weiss Model Life Table and Cochiti historical pueblo.

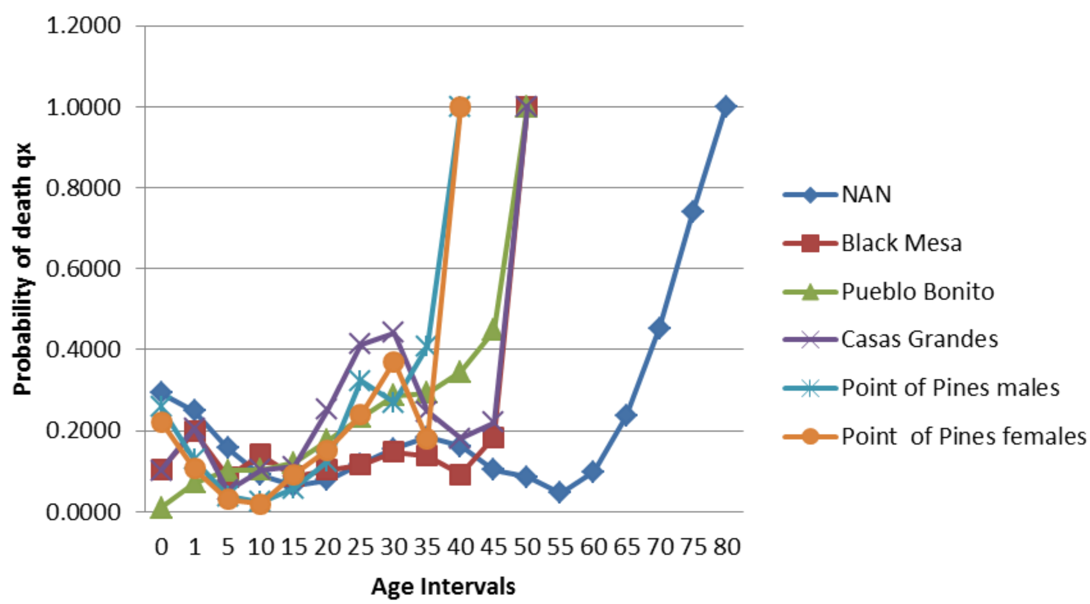

Fig. 17 Probability of death curve for several Southwestern sites as compared to NAN Ranch Classic sample.

better estimate of age for the senescent portion of the population, it is difficult to draw conclusions on the true demographic patterns of southwestern horticulturalists. One can only hope for the reanalysis of older skeletal samples to better grasp the extent to which aging methods continue to hinder our understanding of ancient demography.

Two questions remain when considering adult mortality. What does mid adult mortality patterns truly reflect and how old could ancient horticulturalists really expect to live? The hump in mortality among mid adults can be attributed to aging methods, occupational hazard, childbearing related deaths or migration of males and females. It has been determined that the migration of females for marriage purposes may not have a strong impact on local demographic patterns (Johannson and Horowitz 1986). On the other hand, based on studies in medieval Europe, male and female migration to urban centers from rural villages had a tendency to affect demographic patterns at both locations (Boldsen 1995; Boldsen and Paine 1995). However, there is no evidence of large urban centers in the Mimbres region that would have fostered this type of migration, or at a scale that would have influenced demographic patterns. In addition, such migration is more likely to occur during young adulthood than it is in mid-adulthood which is the focus of the NAN mortality hump and I did not find different mortality patterns between males and females of that age group at NAN that would point towards migration of either sex.

In regards to longevity in prehistoric societies, it was not uncommon for people to live well past 50 or 60 years old, though their numbers remained low. It is difficult to estimate a true proportion of old adults in the living population at a given time when only skeletal remains are available. However, based on life expectancy estimates from various high mortality populations, Wilmoth (1995) found that although mortality declined drastically in the past 200 to 300 years, there was no significant evidence to suggest that human life expectancy improved notably before the 17th century. In fact, it remains low for the better part of human history, with life expectancy at birth consistently hovering in the low to mid-twenties and life expectancy for those who reach age 50 averaging at 14 years. At NAN, I found that life expectancy for those reaching age 50 was around 20 years, while life tables with fewer age intervals like that of Patrick (1988) usually show a life expectancy at age 50 to be 2.5 years, which is different from Wilmoth's (1995) estimates.

To resolve those discrepancies, we need to continue to try to improve aging methods and to find a consensus for the application of those methods. Paleodemographers have gone a long way in the past 30 years to improve those methods, though a wide spread consensus has yet to be found. In terms of southwestern ancient demography, a reanalysis of skeletal collections using more up to date aging methods is needed in order to make meaningful comparisons and to better understand mortality, especially that of adults and of the senescent part of the population.

CHAPTER VIII

SUMMARY AND CONCLUSION

The NAN Ranch Ruin overlooks the Mimbres River in Grant County in southern New Mexico. It was occupied from about 600 A.D. to the middle of the twelfth century. Initial settlement began in the Late Pithouse period and continued until the region was mostly abandoned following the disruption of agriculture output. It has been estimated that about 75 to 100 pithouses, which were in use intermittently, lay underneath the Classic Pueblo. During the Classic Period at least three room blocks were in use.

In this case study, I reconstructed the demographic profile of the NAN population. The skeletal sample consists of at least 243 individuals, 185 of which belong to the Classic Period, 44 from the Transitional Phase, eight from the Three Circle Phase and one from the San Francisco Phase. A previous attempt at drawing the demographic structure of the site was performed twenty years ago, on a small sample of 81 Classic burials by Suzanne Patrick (1988). In my analysis, I estimated the age at death of all adult skeletons, using Transition Analysis (Boldsen et al. 2002). This method is a multifactorial approach that was established after paleodemography came under much criticism in the 1980s. It consists of scoring 19 components of the cranium, pubic symphysis and of the auricular surface of the ilium. The scores are then entered in software that provides the maximum likelihood that an individual is a certain age given that it displays a certain combination of traits. This method is of particular interest because it does not have the tendency to imitate age distribution patterns from the reference sample used to create the method; it takes into account sexual dimorphism and does not overlook the senescent portion of the population, allowing more accurate age estimates for adults, including those that are past the 50 year old mark. This is different from previous osteological methods that did not allow accurate age estimation past 50 years of age, which produced biased age structures.

Following the scoring of adult skeletons, I excluded some skeletal components from the final age estimates because they produced questionable results. As suggested by the creators of the method, I excluded the scores from the symphyseal texture of the pubic symphysis because they found that Native American skeletons exhibited microporosity more often and earlier than the medieval European skeletons that were used to establish the archaeological prior. I also excluded cranial scores because cranial sutures tend to close in less predictable and reliable ways than other age indicators. Here it appears that cradle boarding may have affected cranial sutures. Finally, I excluded 15 cremated burials form the Eastern Plaza because they were too fragmentary to yield any sex or age information. For ease of comparison, I tabulated my results into abridged, composite life tables, with five-year intervals, except for neonates and infants which were put in a one year interval. I also checked the biological soundness of my results, using competing hazard model and model life table fittings.

As expected for a prehistoric population, I found that the NAN Classic sample exhibited a high infant mortality rate of 46.83% and a low life expectancy at birth (e_o) of 21.14 years. This is similar to what Patrick (1988) had found in her study, though I did not find a higher mortality rate for females between 15-30 years old, which she attributed to childbearing complications.

In addition, other demographic characteristics differ from Patrick's findings. I found that life expectancy for subsequent years culminated between 10-15 years old, decrease until it stabilized in the mid adulthood (30-40 years old) and then decreased until it reached its lowest point after 80 years old. Similarly to other southwest demographic studies, Patrick had found that life expectancy culminated between 5-10 years of age and decreased steadily after that. In terms of mortality rate and probability of death, I found that those were at their highest point during infancy, decreased to a low point around age 15. Subsequently, mortality increased slowly in early and mid-adulthood and decreased again between 35 and 55 years of age before it increased until age 70-75 and then decreased again. This is very different from the patterns found in Patrick's analysis or in other southwestern samples. Demographic patterns are similar in infancy and childhood but diverge drastically among adults. These differences can be attributed to the number of age intervals that were used to construct life tables and the younger final age category. It has been shown that the number of age intervals in a life tables reflecting a different age distribution affected demographic indicators.

In this case study, the number of age intervals was improved thanks to the use of Transition Analysis, which allowed for more accurate age estimates of the adult population. This is especially true for the senescent portion of the population which has been overlooked in other southwestern studies, due to the use of older aging methods. The Classic NAN demographic data closely matches those from Cochiti, a historic pueblo, and Weiss Model Life Table 32.5-40, both of which contain similar age intervals to my analysis.

Although I was not able to find a close match among other prehistoric southwestern population, Casas Grandes (Northwestern Chihuahua, Mexico) and Black Mesa (Northeastern Arizona) most often display demographic curves that are similar in shape (save the length) to that of NAN. This is interesting because there is evidence that people east of the Mimbres Valley had some influence on the Mimbres. Also in the case of Casas Grandes, it had been suggested that some descendants of the Mimbres had reaggregated in northern Mexico during the Postclassic period (LeBlanc 1983; Nelson 2010a; Nelson 1999; Shafer 2003).

In addition, I found some pertinent information regarding the NAN demographic profile. In an attempt to make diachronic comparison between periods, I built a life table for the Transitional Phase and for the Classic Period. I found that the Transitional sample exhibited a higher than expected life expectancy at birth due to apparent infant underenumeration, where only 9% of the population would have died prior to age one and 25% before age five. However, the Transitional sample (n=33 after exclusions) is too small to make a relevant comparison and suffers from strong sampling bias. For the Classic NAN skeletal sample I could not make chronological differentiation between the early, middle and late phase within the period, like Patrick (1988), but I was able to separate the sample between the East and South roomblock. In doing so, I found that the East roomblock may have experienced a slightly better longevity than the South roomblock, however, the difference is not statistically significant. This is similar to what Diane Young Holliday (1996) found in her paleonutrition and paleopathology analyses, where the East roomblock appeared to be healthier that the South roomblock, though the difference was not statistically significant either.

This study highlights the fact that the choice of aging methods and their accuracy greatly influence the demographic profile of the population in question. Older aging methods, do not allow for accurate age estimate of old individuals which in turns affect the construction of life tables which are used to compare the demographic structure of ancient populations. A great deal of progress has been made in the field of paleodemography in recent years to try to smooth out the bias tendency of older aging method. More research is necessary to continue to refine aging methods and to come to a consensus amongst those new methods. Until then, one can hope for a reanalysis of skeletal samples from ancient populations to better understand the different demographic patterns we see and to have a better grasp of how different methods affect those patterns, in order to better direct further research.

In the North American Southwest, skeletal samples benefit from relatively good preservation but their analysis was performed mostly with older aging methods. It would be useful to reanalyze those samples using more modern methods to have a better, clearer picture of Southwestern demography. In addition, we can see population growth and decline from a village perspective, but there is too little evidence with secured chronology to determine the evolution of Mimbres population through time. Better chronological data and advancement in aging and sexing methods in the future will contribute to our understanding of southwestern population dynamics and will shed light on population movement in and out of the Mimbres region.

LITERATURE CITED

Acsàdi G, and Nemeskéri J. 1970. History of human life span and mortality. Budapest, Hungary: Akademiai Kiado.

Adovasio JM, Hyland DC, and Andrews R. 2005. Perishable industries from NAN Ranch Ruin, New Mexico: a unique window into Mimbreno fiber technology. North American Archaeology 26(2):165-207.

Ammerman A, Cavalli-Sforza LL, and Wagener D. 1976. Toward the estimation of population growth in old world prehistory. In: Zubrow E, editor. Demographic anthropology: quantitative approaches. Albuquerque: University of New Mexico Press. p 27-61.

Angel JL. 1969. The bases of paleodemography. American Journal of Physical Anthropology 30:427-437.

Anyon R, Gilman P, and LeBlanc S. 1981. A reevaluation of the Mogollon-Mimbres archaeological sequence. Kiva 46(4):209-225.

Anyon R, and LeBlanc S. 1980. Architectural evolution of Mogollon-Mimbres communal structures. Kiva 45:253-277.

Anyon R, and LeBlanc S. 1984. The Galaz Ruin: a prehistoric Mimbres village in southwestern New Mexico. Albuquerque, New Mexico: Maxwell Museum of Anthropology and New Mexico University Press.

Baccino E, Ubelaker DH, Hayek LA, and Zerilli A. 1999. Evaluation of seven methods of estimation age at death from mature human skeletal remains. Journal of Forensic Science 44:931-936.

Baker B, Dupras T, and Tocheri M. 2005. The osteology of infants and children. College Station: Texas A&M University Press.

Bass WM. 1971. Human osteology: a laboratory and field manual of the human skeleton. Columbia, Missouri: Missouri Archaeological Society.

Bayes T. 1763. An essay towards solving a problem in the doctrine of chances. Philosophical Transactions of the Royal Society 53:370-418.

Bedford M, Russell K, Lovejoy C, Meindl R, Simpson S, and Stuart-Macadam P. 1993. Test of the multifactorial aging method using skeletons with known age-at-death from the Grant collection. American Journal of Physical Anthropology 91:287-297.

Bello S, Thomann A, Signoli M, Dutour O, and Andrews P. 2006. Age and sex bias in the reconstruction of past population structures. American Journal of Physical Anthropology 129:24-38.

Bennett KA. 1965. The etiology and genetics of wormian bones. American Journal of Physical Anthropology 23:255-260.

Bennett KA. 1973. On the estimation of some demographic characteristics of a prehistoric population from the American Southwest. American Journal of Physical Anthropology 39:223-232.

Bennett KA. 1975. Skeletal remains from Mesa Verde National Park, Colorado. In: Studies WM, editor. National Park Services Publications in Archaeology 7F. Washington, D.C.

Benson L, and Berry M. 2009. Climate change and cultural response in the prehistoric American Southwest. Kiva 75(1):89-117.

Bentzen R. 1929. Dental conditions among the Mimbres people of southwestern United States previous to the years 600 A.D. Dental Cosmos 71:1068-1073.

Berry AC, and Berry RJ. 1967. Epigenetic variation in the human cranium. Journal of Anatomy 101:361-379.

Berry DR, editor. 1985. Aspects of paleodemography at Grasshopper Pueblo, Arizona. Tempe, Arizona: Arizona State University Anthropological Research Papers.

Bettison C, Shook R, Jennings R, and Miller D. 1996. New identification of naturalistic motifs on Mimbres pottery. In: Whittlesey S, editor. Sixty Years of Mogollon Archaeology: Papers from the Ninth Mogollon Conference, Silver City, New Mexico. Tucson, Arizona: SRI Press.

Black TK. 1978. A new method for assessing the sex and fragmentary skeletal remains: femoral shaft circumference. American Journal of Physical Anthropology 48:227-231.

Blake M, LeBlanc S, and Minnis P. 1986. Changing settlement and population in the Mimbres Valley, Southwest New Mexico. Journal of Field Archaeology 13(4):439-464.

Bocquet-Appel J-P, editor. 2008. Recent advances in paleodemography: data, techniques, patterns. Dordrecht, The Netherlands.

Bocquet-Appel J-P, and Masset C. 1982. Farewell to paleodemography. Journal of Human Evolution 11:321-333.

Bocquet-Appel J-P, and Masset C. 1985. Paleodemograhy: resurrection or ghost? Journal of Human Evolution 14:107-111.

Boldsen J. 1995. Patterns of advanced age mortality in the medieval village of Tirup. In: Jeune B, and Vaupel J, editors. Exceptional longevity: from prehistory to the present. Odense, Denmark: Odense University Press. p 37-45.

Boldsen J, and Paine RR. 1995. The evolution of human longevity from the mesolithic to the middle ages: an analysis based on skeletal data. In: Jeune B, and Vaupel J, editors. Exceptional longevity: from prehistory to the present. Odense, Denmark: Odense University Press. p 25-36.

Boldsen JL, Milner GR, Konigsberg L, and Wood J. 2002. Transition analysis: a new method of estimating age from skeletons. In: Hoppa R, and Vaupel J, editors. Paleodemography: age distributions for skeletal samples. Cambridge: Cambridge University Press. p 73-109.

Bradfield W. 1929. Cameron Creek Village, a site in the Mimbres area of Grant County, New Mexico. School of American Research. Santa Fe, New Mexico.

Brandt E. 1994. Egalitarianism, hierarchy and centralization in the Pueblos. In: Wills WH, and Leonard R, editors. The ancient southwestern community: models and methods for the study of prehistoric social organization. Albuquerque, New Mexico: University of New Mexico Press. p 9-23.

Brewington R, Shafer HJ, and James WD. 1996. Production and distribution of Mimbres black-on-white ceramics: evidence from instrumental neutron activation analysis (INAA). 62nd Annual Meeting of the Society for American Archaeology. Nashville, Tennessee.

Brody JJ. 1977. Mimbres painted pottery. Santa Fe, New Mexico: School of American Research Press.

Brody JJ. 2004. Mimbres painted pottery. Santa Fe, New Mexico: School of American Research Press.

Brody JJ, Scott C, and LeBlanc S. 1983. Mimbres painting: ancient art of the American Southwest. New York: Hudson Hills Press. 69-125 p.

Brody JJ, and Swentzell R. 1996. To touch the past: the painted pottery of the Mimbres people. New York: Hudson Hills.

Brooks ST. 1955. Skeletal age at death: the reliability of cranial and pubic age indicators. American Journal of Physical Anthropology 13:567-589.

Brooks ST, and Suchey JM. 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suckey-Brooks methods. Human Evolution 5:227-238.

Brothwell DR. 1972. Digging up bones. London: Trustees of the British Museum.

Brown G. 1996. Rural land-use patterns in the Mimbres region: a view from the uplands in the western periphery. In: Whittlesey S, editor. Sixty years of Mogollon archaeology: papers from the ninth Mogollon conference, Silver City, New Mexico. Tucson, Arizona: SRI Press.

Bryan B. 1931a. Excavations of the Galaz Ruin. The Masterkey 4(6):179-189.

Bryan B. 1931b. Excavations of the Galaz Ruin. The Masterkey 4(7):221-226.

Buck CE. 2001. Applications of the Bayesian statistical paradigm. In: Brothwell DR, and Pollard AM, editors. Handbook of archaeological science. Chichester, U.K.: John Wiley and Sons. p 695-702.

Buckberry JL, and Chamberlain AT. 2002. Age estimation from the auricular surface of the ilium: a revised method. American Journal of Physical Anthropology 119:231-239.

Buikstra J, and Konigsberg L. 1985. Paleodemography: critiques and controversies. American Anthropologist 87:316-333.

Buikstra J, and Ubelaker D, editors. 1994. Standards for data collection from human skeletal remains. Fayetteville, Arkansas: Arkansas Archaeological Survey.

Burden D. 2001. Reconstructing the past: an architectural analysis of communal structures from the NAN Ranch Ruin (LA2465), Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Cameron C. 1990. The effect of varying estimates of pit structures use-life on prehistoric population estimates in the American Southwest. Kiva 55(2):155-166.

Carmichael DL. 1990. Patterns of residential mobility and sedentism in the Jornada Mogollon area. In: Minnis P, and Redman CL, editors. Perspectives on southwestern prehistory. Boulder, Colorado: Westview. p 122-134.

Carr C. 1995. A unified middle-range theory of artifact design. In: Carr C, and Neitzel JE, editors. Style, society, and person: archaeological and ethnological perspectives. New York: Plenum. p 171-258.

Casselbury S. 1974. Further refinement of formulas for determining population from floor area. World Archaeology 6:117-122.

Chamberlain AT. 2001. Palaeodemography. In: Brothwell DR, and Pollard AM, editors. Handbook of archaeological science. Chichester, U.K.: John Wiley and Sons. p 259-268.

Chamberlain AT. 2006. Demography in archaeology. Cambridge: Cambridge University Press.

Clark JJ. 2001. Tracking prehistoric migrations: pueblo settlers among the Tonto Basin Hohokam. Anthropological Papers of the University of Arizona 65. Tucson: University of Arizona Press.

Clayton S. 2006. Ritual and residence: the social implications of classic Mimbres ceremonial spaces. Kiva 72(1):71-92.

Cobbs WM. 1952. Skeleton. In: Lansing AI, editor. Cowdry's problems of ageing. 3rd ed. Baltimore, Maryland: Williams & Wilkins, Co.

Cordell L. 1997. Archaeology of the Southwest. San Diego: Academic Press, Inc.

Cordell L, and Plog F. 1979. Escaping the confines of normative thoughts: a reevaluation of puebloan prehistory. American Antiquity 44:405-429.

Cosgrove H, and Cosgrove C. 1932. The Swarts Ruin, a typical Mimbres site in southwestern New Mexico. Papers of the Peabody Museum of American Archaeology and Ethnology Cambridge, Massachusetts: Harvard University.

Creel D. 1989. A primary cremation at the NAN Ranch Ruin, with comparative data on other cremations in the Mimbres area, New Mexico. Journal of Field Archaeology 16(3):309-329.

Creel D. 1997. Status report on excavations at the Old Town site (LA1113), Luna County, New Mexico, summer 1996. Submitted to the US Bureau of Land Management, New Mexico State Office. Austin: Texas Archaeological Research Laboratory, University of Texas.

Creel D. 1999. The black mountain phase in the Mimbres area. In: Schaafsma CF, and Riley CL, editors. The Casas Grandes world. Salt Lake City: University of Utah Press. p 107-120.

Creel D. 2006. Evidence of Mimbres social differentiation at the Old Town site. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 32-44.

Creel D, and Anyon R. 2003. New interpretations of Mimbres public architecture and space: implications for cultural change. American Antiquity 68(1):67-92.

Creel D, and Anyon R. 2010. Burning down the house: ritual architecture of the Mimbres late pithouse period. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 29-38.

Creel D, and McKusick C. 1994. Prehistoric macaws and parrots in the Mimbres area, New Mexico. American Antiquity 59(3):510-524.

Crown P. 1991. Evaluating the construction sequence and population of Pot Creek Pueblo. American Antiquity 56:291-314.

Crown P. 1994. Ceramic and ideology: Salado polychrome pottery. Albuquerque: University of New Mexico Press.

Crown P. 2001. Learning to make pottery in the prehispanic American Southwest. Journal of Anthropological Research 57(4):451-470.

Crown P. 2007. Life histories of pots and potters: situating this individual in archaeology. American Antiquity 72(4):677-690.

Crumley CL. 1995. Heterarchy and the analysis of complex societies. In: Crumley CL, and Levy JE, editors. Heterarchy and the analysis of complex societies. Washington, D.C.: American Anthropological Association. Archaeological Papers 6. p 1-6.

Dahlin E. 2003. INAA and distribution patterns of classic Mimbres black-on-white vessels during the classic period [M.A. thesis]. College Station: Texas A&M University.

Debono L, Mafart B, Guipert G, and Jeusel E. 2004. Application pratique de la méthode d'estimation de l'âge au décès de Schmitt et Broqua (2000). Bulletins et Mémoires de la Société d'Anthropologie de Paris 16(1-2):115-120.

Dennis W, and Dennis MG. 1940. Cradles and cradling practices of the Pueblo Indians. American Anthropologist 42(1):107-115.

Diehl M. 1994. Subsistence economics and emergent social differences: a case study from the prehistoric north American Southwest [PhD Dissertation]. Buffalo: State University of New York.

Diehl M. 1996. The intensity of maize processing and production in upland Mogollon pithouse villages A.D. 200-1000. American Antiquity 61(1):102-115.

Diehl M. 1997. Changes in architecture and land use strategies in the American Southwest: upland Mogollon pithouse dwellers. Journal of Field Archaeology 24(2):179-194.

Diehl M. 2001. Competing models of upland mogollon pithouse period life-style. In: Diehl M, and LeBlanc S, editors. Early pithouse villages of the Mimbres Valley and beyond. Cambridge, MA: Papers of the Peabody Museum of Archaeology and Ethnology.

Diehl M, and LeBlanc S, editors. 2001. Early pithouse villages of the Mimbres Valley and beyond. Cambridge, MA: Papers of the Peabody Museum of Archaeology and Ethnology.

Dockall JE. 1991. Chipped stone technology at NAN Ruin, Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Dorsey GA. 1897. Wormian bones in artificially deformed Kwakiutl crania. American Anthropologist 10:169-173.

Dwight T. 1890. The closure of the cranial sutures as a sign of age. The Boston Medical and Surgical Journal 122(17):389-392.

Earle T. 2001. Economic support of Chaco Canyon society. American Antiquity 66:26-35.

El-Najjar M, and Dawson G. 1977. The effect of artificial cranial deformation on the incidence of wormian bones in the lambdoidal suture. American Journal of Physical Anthropology 46:155-160.

Eshed V, Gopher A, Gage T, and Hershkowitz I. 2004. Has the transition to agriculture reshaped the demographic structure of prehistoric populations? New evidence from the Levant. American Journal of Physical Anthropology 124:315-329.

Espenshade C. 1997. Mimbres pottery, births, and gender: a reconsideration. American Antiquity 62(4):733-736.

Fagan B. 2000. Ancient North America: the archaeology of a continent. London: Thames and Hudson.

Fazekas IG, and Kósa F. 1978. Forensic fetal osteology. Budapest, Hungary: Akademiai Kiado.

Feinman G. 2000a. Corporate/network: new perspectives on models of political action and the puebloan Southwest. In: Schiffer MB, editor. Social theory in archaeology. Salt Lake City: University of Utah Press. p 31-51.

Feinman G. 2000b. Dual-processial theory and social formations in the Southwest. In: Mills B, editor. Alternative leadership strategies in the prehispanic Southwest. Tucson: University of Arizona Press. p 216-222.

Feinman G, Lightfoot K, and Upham S. 2000. Political hierarchies and organizational strategies in the puebloan Southwest. American Antiquity 65:449-470.

Fewkes JW. 1914. Archaeology of the lower Mimbres Valley, New Mexico. Smithsonian Miscellaneous Collections 63(10):1-53.

Fewkes JW. 1916. Animal figure in prehistory pottery from the Mimbres Valley, New Mexico. American Anthropologist 18(4):535-545.

Fewkes JW. 1923. Designs on prehistory pottery from the Mimbres Valley, New Mexico. Smithsonian Miscellaneous Collections 74(6):1-47.

Fish SK, Fish PR, and Madsen J. 1990. Sedentism and settlement mobility in the Tuscon Basin prior to A.D. 1000. In: Minnis P, and Redman CL, editors. Perspectives in southwestern prehistory. Boulder, Colorado: Westview. p 76-91.

Frédéric J. 1906. Untersuchungen über die normale Obliteration der Schädelnähte. Zeitschrift für Morphologie und Anthropologie 9:373-456.

Gage T. 1988. Mathematical hazard models of mortality: an alternative to model life tables. American Journal of Physical Anthropology 76:429-441.

Gage T. 1989. Bio-mathematical approaches to the study of human variation in mortality. Yearbook of Physical Anthropology 62:589-617.

Gage T. 1990. Variation and classification of human age patterns of mortality: analysis using competing hazards model. Human Biology 62(5):589-617.

Gage T. 1991. Causes of death and the components of mortality: testing the biological interpretations of competing hazards model. American Journal of Human Biology 3:289-300.

Gage T, and Dyke B. 1986. Parameterizing abridged mortality tables: The Siler three-component hazard model. Human Biology 58(2):275-291.

Galinat WC. 1988. The origin of maiz de ocho. American Anthropologist 90:682-683.

Garst S. 2003. A blind test of the auricular surface aging technique on a known age at death and sex skeletal collection. American Journal of Physical Anthropology suppl. 30:99-100.

Genovés S, and Messmacher M. 1959. Valor de los patrones tradicionales para la determinación de la edad por medio de las suturas en cráneos mexicanos (indigenas e mestizos). Cuadro del Instituto de Historia Anthropologia 7:1-53.

Gerszten P. 1993. An investigation into the practice of cranial deformation among the Pre-Columbian people of northern Chile. International Journal of Osteoarchaeology 3(2):87-98.

Gilbert BM. 1973. Misapplication to females of the standard for aging the male os pubis. American Journal of Physical Anthropology 38:39-40.

Gilbert BM, and McKern TW. 1973. A method for aging the female os pubis. American Journal of Physical Anthropology 38:31-38.

Giles E, and Elliot O. 1963. Sex determination by discriminant function analysis of crania. American Journal of Physical Anthropology 21:53-68.

Gilman P. 1987. Architecture as an artifact: pit structures and pueblos in the American Southwest. American Antiquity 52:538-564.

Gilman P. 1990. Social organization and classic Mimbres period burials in the southwestern United States. Journal of Field Archaeology 17(4):457-469.

Gilman P. 1995. Multiple dimensions of the archaic-to-pit structure period transition in southeastern Arizona. Kiva 60(4):619-632.

Gilman P. 2006. Social differences at the classic period Mattocks site in the Mimbres Valley. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 66-84.

Gilman P. 2010a. Settling in. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 17-28.

Gilman P. 2010b. Substantial structures, few people, and the question of early villages in the Mimbres region of the North American Southwest. In: Bandy MS, and Fox JR, editors. Becoming villagers: comparing early villages societies. Tucson: University of Arizona Press. p 119-139.

Gilman P, Canouts V, and Bishop R. 1994. The production and distribution of classic Mimbres black-on-white pottery. American Antiquity 59(4):695-709.

Gilman P, and Whalen M. 2011. Moving on the landscape: mobility and migration. In: Nelson M, and Strawhacker C, editors. Movement, connectivity and landscape change in the Ancient Southwest. Boulder: University Press of Colorado. p 45-56.

Goldstein LG. 1980. Mississippian mortuary practices: a case study of two cemeteries in the lower illinois valley. Evanston, Illinois: Northwestern University Archaeological Program Scientific Papers No.4.

Goldstein LG. 1981. One-dimensional archaeology and multidimensional people: social organization and mortuary analysis. In: Chapman R, Kinnes I, Randsborg K, and Kinnes I, editors. The archaeology of death. Cambridge: Cambridge University Press. p 53-69.

Gordon CG, and Buikstra J. 1981. Soil pH, bone preservation and sampling at mortuary sites. American Antiquity 46(3):566-571.

Gottlieb K. 1978. Artificial cranial deformation and the increased complexity of the lambdoidal suture. American Journal of Physical Anthropology 48:213-214.

Gregory DA, and Dielh MW. 2002. Duration, continuity, and intensity of occupation at a late cienaga phase settlement in the Santa Cruz river flooplain. In: Schlanger S, editor. Traditions, transitions, and technologies: themes in southwestern archaeology. Boulder: University Press of Colorado. p 200-223.

Gustafson G. 1950. Age determination on teeth. Journal of the American Dental Association 41:45-54.

Halstead P, and O'Shea J. 1989 Bad year economics. New York: Cambridge University Press.

Ham EJ. 1989. Analysis of the NAN Ruin (LA15049) burial patterns: an examination of Mimbres social structure [M.A. thesis]. College Station: Texas A&M University.

Hanihara K, and Suzuki T. 1978. Estimation of age from the pubic symphysis by means of multiple regression analysis. American Journal of Physical Anthropology 48:233-240.

Hard RJ. 1990. The transition to farming on the Rio Casas Grandes and in the southern Jornada Mogollon region. In: Minnis P, and Redman CL, editors. Perspectives on southwestern prehistory. Boulder, Colorado: Westview. p 135-149.

Hard RJ, Mauldin R, and Raymond G. 1996. Mano size, stable carbon isotope ratios, and macrobotanical remains as multiple lines of evidence of maize dependence in the American Southwest. Journal of Archaeological Method and Theory 3:253-318.

Hassan FA. 1981. Demographic archaeology. New York: Academic Press, Inc.

Haury E. 1936. The Mogollon culture of the southwestern New Mexico. Medallion Papers 20.

Haury E, and Sayles EB. 1947. An early pithouse village of the Mogollon culture, Forestdale Valley, Arizona. Social Sciences Bulletin 16, University of Arizona, Tucson 18(4).

Hayes A, Young JN, and Warren AH. 1981. Excavation of mound 7, Gran Quivira National Monument, New Mexico. Washington, D.C.: U.S. Department of Interior, National Park Service.

Hays-Gilpin K. 2000. The flower world in prehistoric Southwest material culture. In: Hegmon M, editor. The archaeology of regional interaction: religion, warfare, and exchange across the American Southwest and beyond. Boulder: University of Colorado Press. p 411-428.

Hays-Gilpin K. 2006. Icons and ethnicity: Hopi painted pottery and murals. In: VanPool C, VanPool T, and Phillips D, editors. Religion in the prehispanic Southwest. Lanham, Maryland: Altamira Press.

Headrick A. 1998. The street of the dead... it really was: mortuary bundles at Teotihuacan. Ancient Mesoamerica 10(1):69-85.

Hegmon M. 2002. Recent issues in the archaeology of the Mimbres region of the North American Southwest. Journal of Archaeological Research 10(4):307-357.

Hegmon M. 2010. Mimbres society: another way of being. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 39-46.

Hegmon M, Brady J, and Nelson M. 2006. Variability in classic Mimbres room suites: implications for household organization and social differences. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 45-65.

Hegmon M, Nelson M, Anyon R, Creel D, LeBlanc S, and Shafer HJ. 1999. Scale and time-space systematics in the post A.D. 1100 Mimbres region of the North American Southwest. Kiva 65(2):143-166.

Hegmon M, Nelson M, and Ruth S. 1998. Abandonment and reorganization in the Mimbres region of the American Southwest. American Anthropologist 100(1):148-162.

Hegmon M, and Trevathan W. 1996. Gender, anatomical knowledge and pottery production: implications of an anatomically unusual birth depicted on Mimbres pottery from southwestern New Mexico. American Antiquity 61(4):747-754.

Herrmann N, and Konigsberg LW. 2002. A re-examination of the age-at-death distribution of Indian Knoll. In: Hoppa R, and Vaupel J, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge University Press. p 243-257.

Hill E. 2000. The contextual analysis of animal interments and ritual practice in southwesten north america. Kiva 65(4):361-398.

Hill MD. 1997. Sociocultural implications of large Mimbres sites: architectural and mortuary behavior at Swarts Ruin, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Hinton D, Becker L, Muakkassa K, and Hoffman H. 1984. Lambdoidal synostosis: normal development and pathology of "synostosis". Journal of Neurosurgery 61(2):333-339.

Hoggs DJ. 1977. Report on the excavation of three Mogollon pit houses on the upper Mimbres River, New Mexico [M.A. thesis]. Portales: Eastern New Mexico University.

Hoppa R, and Vaupel J, editors. 2002. Paleodemography: age distributions from skeletal sample. New York: Cambridge University Press.

Howell N. 1976. Toward a uniformitarian theory of paleodemography. In: Ward RH, and Weiss K, editors. Demographic evolution of human populations. London, England: Academic Press.

Howells W. 1932. The skeletal material from the Swarts Ruin, a typical Mimbres site in southwestern New Mexico. Papers from the Peabody Museum of American Archaeology and Ethnology. Cambridge, Massachusetts: Harvard University. p 115-170.

Howells W. 1960. Estimating population numbers through archaeological and skeletal remains. In: Heizer R, and Cook S, editors. The application of quantitative methods in archaeology. Chicago, Illinois: Quadrangle Books. p 158-185.

Hoyme L, and Isçan M. 1989. Determination of sex and race: accuracy and assumptions. In: Isçan M, and Kennedy K, editors. Reconstruction of life from the skeleton. New York: Alan-Liss. p 53-93.

Hrdlička A. 1920. Anthropometry. Philadelphia, Pennsylvania: Lea & Febiger.

Hrdlička A, editor. 1952. Hrdlička's practical anthropometry. Philadelphia, Pennsylvania: Wistar Institute of Anatomy and Biology.

Hunter-Anderson R. 1986. Prehistoric adaptations in the American Southwest. Cambridge: Cambridge University Press.

İşcan MY, and Miller-Shaivitz P. 1984. Determination of sex from the tibia. American Journal of Physical Anthropology 64:53-58.

Jackes M. 2000. Building the bases for paleodemographic analysis: adult age determination. In: Katzenberg MA, and Saunders SR, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 417-466.

Jett S, and Moyle P. 1986. The exotic origins of fishes depicted on prehistoric Mimbres pottery from New Mexico. American Antiquity 51(4):688-720.

Jewett R, and Lightfoot K. 1986. The intra-site spatial structure of early Mogollon villages: a comparison of seasonal and year round settlements. In: Benson C, and Upham S, editors. Mogollon variability. Las Cruces, New Mexico: New Mexico State University Museum Occasional Papers 15. p 45-77.

Johannson SR, and Horowitz S. 1986. Estimating mortality in skeletal populations: influence of the growth rate on the interpretation of levels and trends during the transition to agriculture. American Journal of Physical Anthropology 71:223-250.

Katz D, and Suchey JM. 1986. Age determination of the male os pubis. American Journal of Physical Anthropology 69:427-435.

Katz D, and Suchey JM. 1989. Race differences in pubic symphyseal aging patterns in the male. American Journal of Physical Anthropology 80:167-172.

Katzenberg A, and Saunders S, editors. 2000. Biological anthropology of the human skeleton. New York: Wiley-Liss.

Katzenberg M, and Saunders S, editors. 2008. Biological anthropology of the human skeleton. 2nd Edition ed. New York: Wiley-Liss.

Kemkes-Grottenthaler A, editor. 2002. Aging through the ages: historical perspectives on age indicator methods. Cambridge: Cambridge University Press.

Key C, Aiello LC, and Molleson TI. 1994. Cranial suture closure and its implications for age estimation. International Journal of Osteoarchaeology 4:193-207.

Kimmerle E, Konigsberg L, Jantz R, and Baraybar JP. 2008. Analysis of age-at-death estimation through the use of pubic symphyseal data. Journal of Forensic Science 53(3):558-568.

Kohler T, Glaude MP, Bocquet-Appel J-P, and Kemp B. 2008. The neolithic demographic transition in the U.S. Southwest. American Antiquity 73(4):645-669.

Kohn LAP, Leigh SR, and Cheverud JM. 1995. Asymmetric vault modification in Hopi crania. American Journal of Physical Anthropology 98(2):173-195.

Konigsberg L, and Frankenberg S. 1992. Estimation of age structure in anthropological demography. American Journal of Physical Anthropology 89:235-256.

Konigsberg L, and Frankenberg S. 1994. Paleodemography: "not quite dead". Evolutionary Anthropology:92-105.

Konigsberg L, and Frankenberg S. 2002. Deconstructing death in paleodemography. American Journal of Physical Anthropology 117:297-309.

Konigsberg LW. 2005. Hazard model in paleodemography: functions in "R" with Crow Creek and Libben. LW Konigsberg's Homepage http://koniglautkedu/. Knoxville: University of Tennessee at Knoxville.

Konigsberg LW, and Hermann NP. 2002. Marchov chain Monte Carlo estmation of hazard model parameters in paleodemography. In: Hoppa R, and Vaupel J, editors. Paleodemography Age distributions from skeletal smpales. Cambridge: Cambridge University Press.

Konigsberg LW, and Herrmann N. 2002. Marchov chain Monte Carlo estimation of hazard model parameters in paleodemography. In: Hoppa R, and Vaupel J, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge Univesity Press. p 222-242.

Konigsberg LW, Kohn LAP, and Cheverud JM. 1993. Cranial deformation and nonmetric trait variation. American Journal of Physical Anthropology 90:35-48.

Krogman WM. 1962. The human skeleton in forensic medicine. Springfield, Illinois: Charles C. Thomas.

Kuckelman K, Lightfoot R, and Martin D. 2000. Changing patterns of violence in the northern San Juan region. Kiva 66(1):147-165.

Kuckelman K, Lightfoot R, and Martin D. 2002. The bioarchaeology and taphonomy of violence at Castle Rock and Sand Canyon Pueblos, southwestern Colorado. American Antiquity 67:486-513.

Lange CH. 1959. Cochiti: a New Mexico pueblo, past and present: Austin University Press.

Lange CH, and Riley CL. 1970. The southwestern journals of Adolph Bandelier, 1883-1884. Albuquerque: The University of New Mexico Press.

LeBlanc C. 1981. Late prehistoric Huanca settlement patterns in the Yanamarca Valley, Peru [PhD Dissertation]. Los Angeles: University of California.

LeBlanc S. 1980. The early pit house period. In: LeBlanc S, and Whalen M, editors. An archaeological synthesis of south-central and southwestern New Mexico. Albuquerque: University of New Mexico. p 142-204.

LeBlanc S. 1983. The Mimbres people. London: Thames and Hudson.

LeBlanc S. 1989. Cultural dynamics in the southern Mogollon area. In: Cordell L, and Gumerman G, editors. Dynamics of southwest prehistory. Washington, D.C.: Smithsonian Institution Press.

LeBlanc S. 1999. Prehistoric warfare in the American Southwest. Salt Lake City: University of Utah Press.

LeBlanc S. 2001. Population dynamics at the McAnally and Thompson sites and their valleywide context. In: Dielh MW, and LeBlanc S, editors. Early pithouse villages of the Mimbres Valley and beyond. Cambridge: Papers of the Peabody Museum of Archaeology and Ethnology Harvard University. p 116-119.

LeBlanc S. 2006. Who made the Mimbres bowls? Implications of recognizing individual artists for craft specialization and social networks. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 109-150.

LeBlanc S. 2010. The painters of the pots. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 75-82.

Lekson S. 1988. The mangas phase in Mimbres archaeology. Kiva 53(2):129-146.

Lekson S. 1992. The surface archaeology of southwestern New Mexico. The Artifact 30(3):1-35.

Lekson S. 2006. Archaeology of the Mimbres region, southwestern New Mexico, U.S.A. Oxford: Archaeopress.

Leslie P, and Gage T. 1989. Demography and human population biology: problems and progress. In: M L, and Haas J, editors. Human population biology: a transdisciplinary science. New York: Oxford University Press. p 15-44.

Lippmeier H. 1991. A preliminary assessment of the relative health status between Classic and Post Classic populations of southwestern New Mexico [M.A. thesis]. Buffalo: State University of New York.

Liversidge H, and Molleson T. 2004. Variation in crown and root formation and eruption of human deciduous teeth. American Journal of Physical Anthropology 123:172-180.

Longacre W. 1976. Population dynamics at the Grasshopper Pueblo, Arizona. In: Zubrow E, editor. Demographic anthropology. Albuquerque: University of New Mexico Press. p 169-184.

Lovejoy CO. 1985. Dental wear in the Libben population: its functional pattern and role in determination of adult skeletal age at death. American Journal of Physical Anthropology 68:15-28.

Lovejoy CO, Meindl R, Mensforth R, and Barton T. 1985a. Mutlifactorial determination of skeletal age-at-death: a method and blind tests of its accuracy. American Journal of Physical Anthropology 68(1):1-14.

Lovejoy CO, Meindl R, Pryzbeck T, and Mensforth R. 1985b. Chronological metamorphosis of the auricular surface of the ilium: A new method for determination of adult skeletal age-at-death. American Journal of Physical Anthropology(68):15-28.

Lucas JR. 1996. Three circle phase architecture at Old Town, a prehistoric Mimbres site in Luna County, southwestern New Mexico [M.A. thesis]. Austin: University of Texas.

Lyle RP. 1996. Functional analysis of Mimbres ceramics from the NAN Ruin (LA15049), Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Mabry JB. 2008. Irrigation, short-term sedentism, and corporate organization during the San Pedro phase. In: Mabry JB, editor. Draft report: las capas: early irrigation and sedentism in a southwestern floodplain. Tucson, Arizona: Center for Desert Archaeology. p 293-327.

Mabry JB, Swartz DL, Wocherl H, Clark JJ, Archer GH, and Lindeman MW. 1997. Archaeological investigations of early village sites in the middle Santa Cruz valley: descriptions of the Santa Cruz Bend, Square Hearth, Stone Pipe and Canal sites. Anthropological Papers 18. Tuscon, Arizona: Center for Desert Archaeology.

Malhi R, Mortensen H, Eshleman J, Kemp B, Lorenz J, Kaestle F, Johnson J, Gorodezky C, and Smith D. 2003. Native American mtDNA prehistory in the American Southwest. American Journal of Physical Anthropology 120:108-124.

Manton K, Stallard E, and Vaupel J. 1986. Alternative models for the heterogeneity of mortality risks among the aged. Journal of the American Statistical Association 81(395):635-644.

Marek M. 1990. Long bone growth of Mimbres subadults from the NAN Ranch (LA15049), New Mexico [M.A. thesis]. College Station: Texas A&M University.

Martin D. 1990. Patterns of health and disease: stress profiles for the prehistoric Southwest. The organization and evolution of prehistoric southwestern societies advanced seminar. Santa Fe, New Mexico: School of American Research.

Martin P, Rinaldo J, Bluhm E, Cutler H, and Grange Jr R. 1952. Mogollon cultural continuity and change: the stratigraphic analysis of Tularosa and Cordova Caves. Fieldiana: Anthropology 52.

Martin R. 1928. Lehrbuch der Anthropologie. Jena, Germany: Gustav Fisher.

Masset C. 1982. Estimation de l'âge au décès par les sutures crâniennes [Thèse de Sciences Naturelles]. Paris: Université Paris VII.

Masset C. 1989. Age estimation on the basis of cranial sutures. In: İşcan MY, editor. Age markers in the human skeleton. Springfield, Illinois: Charles C Thomas. p 71-103.

Masset C. 1993. Encore l'âge des adultes. Bulletins et Mémoires de la Société d'Anthropologie de Paris 5:217-224.

Mauldin R. 1993. The relationship between ground stone and agricultural intensification in western New Mexico. Kiva 58:317-330.

McGuire R. 2011. Rethinking social power and inequality in the aboriginal Southwest/Northwest. In: Nelson M, and Strawhacker C, editors. Movement, connectivity and landscape change in the ancient Southwest. Boulder: University Press of Colorado. p 57-72.

McKern TW. 1970. Estimation of skeletal age: from puberty to about 30 years of age. In: Stewart T, editor. Personal identification in mass disaster. Washington, D.C.: Smithsonian Institution Press. p 41-56.

McKern TW, and Stewart TD. 1957. Skeletal age changes in young American males. Technical Report EP-45. Natick, Massachusetts: Quartermaster Research and Development Command.

Meindl R, and Lovejoy CO. 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. American Journal of Physical Anthropology 68:57-66.

Meindl R, Lovejoy CO, Mensforth R, and Don Carlos L. 1985a. Accuracy and direction of error in the sexing of the skeleton: implications for paleodemography. American Journal of Physical Anthropology 68:79-85.

Meindl R, Lovejoy CO, Mensforth R, and Walker R. 1985b. A revised method of age determination using the os pubis, with a review and tests of accuracy of other current methods of pubic symphyseal aging. American Journal of Physical Anthropology 68:29-45.

Mills B, editor. 2000. Alternative leadership strategies in the prehispanic Southwest. Tucson: The University of Arizona Press.

Milner G. 2011. Personal communication: April 20, 2010. College Station, TX: Personal Collection, A.A. Lovings, Texas A&M University, Department of Anthropology, College Station, TX.

Milner G, and Boldsen J. 2007. Transition analysis age estimation skeletal scoring procedure. Unpublished manual: Private Collection, A.A. Lovings,Texas A&M University, Department of Anthropology, College Station, TX

Milner G, Wood J, and Boldsen JL. 2000. Paleodemography. In: Katzenberg MA, and Saunders SR, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 467-497.

Milner G, Wood J, and Boldsen JL. 2008. Advances in paleodemography. In: Katzenberg MA, and Saunders SR, editors. Biological anthropology of the human skeleton. 2nd ed. New York: Wiley-Liss. p 561-600.

Minnis P. 1981. Economic and organizational responses to food stress by non-stratified societies: an example from prehistoric New Mexico [Ph.D. Dissertation]. Ann Arbor: University of Michigan.

Minnis P. 1985. Social adaptation to food stress. Chicago: University of Chicago Press.

Minnis P, and Sandor J. 2010. Mimbres potters' fields. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 83-90.

Mitchell D. 1992. Burial practices and paleodemographic reconstructions at Pueblo Grande. Kiva 58(1):89-105.

Mobley C. 1980 Demographic structure of Pecos Indians: a model based on life tables. American Antiquity 45(3):518-530.

Mode C, and Busby R. 1982. An eight-parameter model of human mortality-the single decrement case. Bulletin of Mathematical Biology 44(5):647-659.

Moulard B. 1984. Within the underworld sky: Mimbers ceramic art in context. Pasadena, California: Twelvetrees Press.

Muller HG, Love B, and Hoppa R. 2002. A semiparametric method for estimating demographic profiles from age indicator data. American Journal of Physical Anthropology 117:1-14.

Munson M. 2000. Sex, gender, and status: human images from the classic Mimbres. American Antiquity 65(1):127-143.

Munson M. 2006. Picturing differences: gender, ritual, and power in Mimbres imagery. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 85-108.

Munson M, and Hays-Gilpin K. 2010. Women and men in black and white. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 57-64.

Murray K, and Murray T. 1991. A test of the auricular surface aging technique. Journal of Forensic Sciences 36(4):1162-1169.

Nagaoko T, Hirata K, Yokota E, and Matsu'ura S. 2006. Paleodemography of a medieval population in Japan: analysis of human skeletal remains from the Yuigahama-Minami site. American Journal of Physical Anthropology 131:1-14.

Necrasov O, Vladescu M, Rudescu A, Schmidt H, and Vulpe C. 1966. Sur l'évolution de la synostose des sutures crâniennes et son application à l'estimation de l'âge. Annuaire Roumain d'Anthropologie 3:23-35.

Neitzel JE. 2000. Gender hierarchies: a comparative analysis of mortuary data. In: Crown P, editor. Women and men in the prehistoric Southwest: labor, power, and prestige. Santa Fe, New Mexico: School of American Research Press.

Nelson B. 2010a. The connected world of the Mimbres. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School of Advanced Research Press. p 9-16.

Nelson B, Martin D, Swedlund A, Fish PR, and Armelagos G. 1994. Studies in disruption: demography and health in the prehistoric American Southwest. In: Gumerman G, and Gell-Mann M, editors. Understanding complexity in the prehistoric Southwest. Reading, Massachussetts: Addison-Wesley. p 59-112.

Nelson M. 1981. Chipped stone analysis in the reconstruction of prehistoric subsistence practice: an example from southwestern New Mexico [Ph.D. Dissertation]. Santa Barbara: University of California.

Nelson M. 1984. Food selection at Galaz: inferences from chipped stone analysis. In: Anyon R, and LeBlanc S, editors. The Galaz Ruin. Albuquerque, New Mexico: Maxwell Museum of Anthropology and University of New Mexico Press.

Nelson M. 1993. Changing occupational pattern among prehistoric horticulturalists in southwestern New Mexico. Journal of Field Archaeology 20(1):43-57.

Nelson M. 1999. Mimbres during the twelfth century. Tucson: University of Arizona Press.

Nelson M. 2010b. Mimbres, the mystery? In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School of Advanced American Research Press. p 99-104.

Nelson M, and Diehl M. 1999. Foraging and farming. In: Nelson M, editor. Mimbres during the twelfth century. Tucson: The University of Arizona Press. p 142-166.

Nelson M, and Lippmeier H. 1993. Grinding tool design as conditioned by land use pattern. American Antiquity 58(2):286-305.

Nemeskéri J, Harsanyi L, and Acsàdi G. 1960. Methoden zur Diagnose des Lebensalters von Skelettfunden. Anthropologisher Anzeiger 24:70-95.

Nesbitt P. 1931. The ancient Mimbrenos, based on investigations at the Mattocks Ruins, Mimbres Valley, New Mexico. Logan Museum Bulletin 4.

O'Loughlin V. 2004. Effects of different kinds of cranial deformation on the incidence of wormian bones. American Journal of Physical Anthropology 123:146-155.

O'Shea J. 1989. The role of wild resources in small-scale agricultural systems: tales from the lakes and the plains. In: Halstead P, and O'Shea J, editors. Bad years economics. New York: Cambridge University Press. p 57-67.

Olive B. 1989. The oral health and dental characteristics of a Mimbres population from southwest New Mexico [M.A. thesis]. College Station: Texas A&M University.

Ortiz A. 1972. Ritual drama and the Pueblo world view. In: Ortiz A, editor. New perspectives on the Pueblos. Albuquerque: University of New Mexico Press. p 135-161.

Ortman S, and Cameron C. 2011. A framework for controlled comparisons of ancient southwestern movement. In: Nelson M, and Strawhacker C, editors. Movement, connectivity and landscape change in the ancient Southwest. Boulder: University of Colorado Press. p 233-252.

Ossenberg N. 1970. The influence of artificial cranial deformation on discontinuous morphological traits. American Journal of Physical Anthropology 33:357-372.

Owsley D, and Bradtmiller B. 1983. Mortality of pregnant females in Arikara villages: osteological evidence. American Journal of Physical Anthropology 61:331-336.

Paine RR. 1989. Model life tables as measure of bias in the Grasshopper Pueblo skeletal series. American Antiquity 54(4):820-824.

Paine RR, editor. 1997. Integrating archaeological demography: multidisciplinary approaches to prehistoric population. Carbondale: Southern Illinois University.

Paine RR. 2000. If population crashes in prehistory, and there is no paleodemographer there to hear it, does it make a sound? American Journal of Physical Anthropology 112:181-190.

Paine RR, and Harpending HC. 1998. Effect of sampling bias on paleodemographic fertility estimates. American Journal of Physical Anthropology 105:231-240.

Palkovich AM. 1978. A model of the dimensions of mortality and its application to palaeodemography [Ph.D Dissertation]. Evanston: Northwestern University.

Palkovich AM. 1980. The Arroyo Hondo skeletal and mortuary remains. Santa Fe, New Mexico: School of American Research Press.

Palkovich AM. 1985. Interpreting prehistoric morbidity incidence and mortality risk: nutritional stress at Arroyo Hondo Pueblo, New Mexico. In: Merbs CF, and Miller RJ, editors. Health and disease in the prehistoric Southwest. Tempe, Arizona: Arizona State University Anthropological Research Papers: 34.

Parks-Barrett MS. 2001. Prehistoric jewelry of the NAN Ranch Ruin (LA15049), Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Patrick S. 1988. Description and demographic analysis of a Mimbres Mogollon population from LA15049 (NAN Ruin) [M.A. thesis]. College Station: Texas A&M University.

Peterson W. 1975. A demographer's view of prehistoric demography. Current Anthropology 16:227-245.

Phenice TW. 1969. A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 30:297-302.

Pommerol F. 1869. Recherches sur la synostose des os du crâne considérée au point de vue normal et pathologique chez les différentes races humaines. Paris, France: Adrien Delahaye, Libraire-Editeur.

Potter J, and Perry E. 2000. Ritual as a power resources in the American Southwest. In: Mills B, editor. Alternative leadership strategies in the prehispanic Southwest. Tucson: The University of Arizona Press.

Powell-Martí V, and Gilman P, editors. 2006. Mimbres society. Tucson: The University of Arizona Press.

Powell-Martí V, and James WD. 2006. Ceramic iconography and social asymmetry in the Classic Mimbres heartland, AD 970-1140. In: Powell-Martí V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 151-176.

Powell V. 2000. Iconography and group formation during the late pithouse and classic periods of the Mimbres society, A.D. 970-1140 [PhD Dissertation]. Norman: University of Oklahoma.

Provinzano J. 1968. The osteological remains of the Galaz Mimbres Amerinds [M.A. thesis]. Minneapolis: University of Minnesota.

Ribbe FC. 1885. Etude de l'ordre d'oblitération des sutures du crâne dans les races humaines [Thèse de Médecine]. Edition Berthier,Paris, France: Université de Paris. 164 p.

Rice G. 1975. A systematic explanation of a change in Mogollon settlement patterns [Ph.D. Dissertation]. Seattle: University of Washington.

Roney JR, and Hard RJ. 2002. Early agriculture in northwestern Chihuahua. In: Schlanger S, editor. Traditions, transitions, and technologies: themes in Southwest archaeology. Boulder: University Press of Colorado.

Sanchez-Lara P, Graham JJ, Hing A, Lee J, and Cunningham M. 2007. The morphogenesis of wormian bones: a study of craniosynostosis and purposeful cranial deformation. American Journal of Medical Genetics 143A(24):3243-3251.

Sandor J, and Homburg J. 2011. Soil and landscape responses to American Indian agriculture in the Southwest. In: Nelson M, and Strawhacker C, editors. Movement, connectivity and landscape change in the ancient Southwest. Boulder: University of Colorado Press. p 141-160.

Sashin D. 1930. A critical analysis of the anatomy and the pathologic changes of the sacro-iliac joints. Journal of Bone and Joint Surgery 12:891-910.

Sattenspiel L, and Harpending H. 1983. Stable populations and skeletal age. American Antiquity 48:489-498.

Saunders S, Fitzgerald C, Rogers T, Dudar C, and McKillop H. 1992. A test of several methods of skeletal age estimation using a documented archaeological sample. Canadian Society of Forensic Science 25:97-118.

Saunders S, and Katzenberg A, editors. 1992. Skeletal biology of past peoples. New York: Wiley-Liss.

Saxe A. 1970. Social dimensions of mortuary practices [PhD Dissertation]. Ann Arbor: University of Michigan.

Schaafsma P. 1994. Kachinas in the Pueblo world. Albuquerque: University of New Mexico Press.

Schlanger S. 1988. Patterns of population movement and the long-term population growth in southwestern Colorado. American Antiquity 53:773-793.

Schmitt A. 2001. Validité de la sénescence du squelette humain, réflexions sur les indicateurs de l'âge au décès: à la recherche d'un outil performant [Thèse de Doctorat]. Bordeaux, France: Université de Bordeaux 1.

Schmitt A. 2005. Une nouvelle méthode pour estimer l'âge au décès des adultes à partir de la surface sacro-pelvienne iliaque. Bulletins et Mémoires de la Société d’Anthropologie de Paris 17:1-13.

Schmitt A, and Broqua C. 2000. Approche probabilistique pour estimer l'âge au décès à partir de la surface auriculaire de l'ilium. Bulletins et Mémoires de la Société d'Anthropologie de Paris 12(3-4):279-301.

Schollmeyer K. 2005. Prehispanic environmental impact in the Mimbres region, southwestern New Mexico. Kiva 70(4):375-398.

Schollmeyer K. 2010. Mimbres hunting and the importance of deer. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 91-98.

Schollmeyer K. 2011. Large game, agricultural land, and settlement pattern change in the eastern Mimbres area, southwest New Mexico. Journal of Anthropological Research in press.

Scott C. 1983. The evolution of Mimbres pottery. In: Brody JJ, editor. Mimbres pottery: ancient art of the American Southwest. New York: Hudson Hills Press. p 39-68.

Shafer HJ. 1982. Classic Mimbres phase households and room use patterns. Kiva 48:158-166.

Shafer HJ. 1985. A Mimbres potter's grave: an example of Mimbres craft specialization? Bulletin of the Texas Archaeological Society 56:185-200.

Shafer HJ. 1990a. Archaeology of the NAN Ranch Ruin: 1984 interim report. The Artifact 28(4):5-27.

Shafer HJ. 1990b. Ten years of Mimbres archaeology. The Artifact 28(4):1-4.

Shafer HJ. 1991a. Archaeology of the NAN Ruin (LA 15049) : 1985 interim report. The Artifact 29(1):1-29.

Shafer HJ. 1991b. Archaeology of the NAN Ruin: 1986 interim report. The Artifact 29(2):1-42.

Shafer HJ. 1991c. Archaeology of the NAN Ruin: 1987 interim report. The Artifact 29(3):1-43.

Shafer HJ. 1992. Archaeology of the NAN Ruin: 1989 season. The Artifact 29(4):23-47.

Shafer HJ. 1995. Architecture and symbolism in transitional pueblo development in the Mimbres Valley, SW, New Mexico. Journal of Field Archaeology 22(1):23-47.

Shafer HJ. 1999. The Mimbres classic and postclassic. In: Schaafsma CF, and Riley CL, editors. The Casas Grandes world. Salt Lake City: University of Utah Press. p 121-133.

Shafer HJ. 2003. Mimbres archaeology at the NAN Ranch Ruin. Albuquerque: University of New Mexico Press.

Shafer HJ. 2006. Extended families to corporate groups: pithouse to pueblo transformation of Mimbres society. In: Powell-Marti V, and Gilman P, editors. Mimbres society. Tucson: The University of Arizona Press. p 15-31.

Shafer HJ. 2010. Mimbres rituals and worldview. In: Nelson M, and Hegmon M, editors. Mimbres lives and landscapes. Santa Fe, New Mexico: School for Advanced Research Press. p 47-56.

Shafer HJ, and Brewington R. 1995. Microstylistic changes in Mimbres black-on-white pottery: examples from the NAN Ruin, Grant County, New Mexico. Kiva 61:5-30.

Shafer HJ, and Murry RE. 1978. A summary of the 1978 archaeological investigations at the Hinton Ruin, Grant County, New Mexico. College Station, TX Anthropology Laboratory, Texas A&M University.

Shafer HJ, and Taylor A. 1986. Mimbres Mogollon pueblo dynamics and ceramic style change. Journal of Field Archaeology 13(1):43-68.

Shafer HJ, Taylor AJ, and Usrey SJ. 1979. Archaeological investigations at the NAN (Hinton) Ranch Ruin, Grant County, New Mexico. College Station: Special Series No. 3, Anthropology Laboratory, Texas A&M University.

Shaffer B. 1990. The modified rabbit pelvis of the Mimbres: a preliminary description of a new tool type. The Artifact 28(2):7-14.

Shaffer B. 1991. The economic importance of vertebrae faunal remains from the NAN Ruin (LA15049), a classic Mimbres site, Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Shaffer B, Gardner K, and Powell J. 1996. Sexual division of labor in the prehistoric puebloan Southwest as portrayed by Mimbres potters. In: Whittlesey S, editor. Sixty years of Mogollon archaeology, papers from the 9th Mogollon conference Silver City, New Mexico. Tucson, Arizona: SRI Press.

Shaffer B, Gardner K, and Shafer HJ. 1997. An unusual birth depicted in Mimbres pottery: not cracked up to what it is supposed to be. American Antiquity 62(4):727-732.

Siler W. 1979. A competing-risk model for animal mortality. Ecology 60:750-757.

Siler W. 1983. Parameters of mortality in human populations with widely varying life spans. Statistics in Medicine 2:373-380.

Singer R. 1953. Estimation of age from cranial suture closure. Journal of Forensic Medicine 1:52-59.

Spielmann K. 1995. Glimpses of gender in prehistoric Southwest. Journal of Anthropological Research 51(2):91-104.

Spreen M. 1983. The social implications of mortuary remains at two Mimbres Mogollon sites in Grant County, New Mexico [M.A. thesis]. College Station: Texas A&M University.

Steckel R, and Rose J, editors. 2002. The backbone of history: health and nutrition in the western hemisphere. Cambridge: Cambridge University Press.

Steele G. 1976. The estimation of sex on the basis of the talus and calcaneus. American Journal of Physical Anthropology 45:581-588.

Steele G, and Bramblett C. 1988. The anatomy and biology of the human skeleton. College Station: Texas A&M University Press.

Stewart T. 1958. The rate of development of vertebral osteoarthritis in American whites and its significance in skeletal age identification. The Leech 28:144-151.

Stewart T. 1968. Identification by the skeletal structures. In: Camps F, editor. Gadwohl's legal medicine. Bristol, U.K.: John Wright and Sons, Ltd. p 123-154.

Stewart TD. 1979. Essentials of forensic anthropology. Springfield, Illinois: Charles C. Thomas.

Stodder A, Martin D, Goodman A, and Reff D. 2002. Cultural longevity and biological stress in the American Southwest. In: Steckel R, and Rose J, editors. The backbone of history. Cambridge: Cambridge University Press. p 481-505.

Stokes R, and Roth B. 1999. Mobility, sedentism, and settlement patterns in transition: the late pithouse period in the Sapillo Valley, New Mexico. Journal of Field Archaeology 26(4):423-434.

Stone T. 2003. Social identity and ethnic interaction in the western Pueblos of the American Southwest. Journal of Archaeological Method and Theory 10(1):31-67.

Stone T, and Lipe W. 2011. Standing out versus blending in. In: Nelson M, and Strawhacker C, editors. Movement, connectivity and landscape change in the ancient Southwest. Boulder: University of Colorado Press. p 275-296.

Storey R. 2007. An elusive paleodemography? a comparison of two methods for estimating the adult age distribution of deaths at Late Classic Copan, Honduras. American Journal of Physical Anthropology 132:40-47.

Stout S. 1992. Methods of determining age at death using bone microstructure. In: Saunders S, and Katzenberg A, editors. Skeletal biology of past peoples: research methods. New York: John Wiley and Sons Inc. p 21-35

Suchey JM, Brooks ST, and Rawson RD. 1982. Aging the female os pubis. 34th Annual Meeting of American Academy of Forensic Sciences. Orlando Florida.

Suchey JM, Wiseley DV, Green RF, and Nogushi TT. 1979. Analysis of dorsal pitting on the os pubis in an extensive sample of modern american females. American Journal of Physical Anthropology 51(4):517-540.

Sutherland LD, and Suchey JM. 1991. Use of ventral arc in pubis sex determination. Journal of Forensic Sciences 36:501-511.

Sutton M, Malik M, and Ogram A. 1996. Experiments on the determination of gender from coprolites by DNA analysis. Journal of Archaeological Science 23:263-267.

Tagg MD. 1996. Early cultigens from Fresnal Shelter, southeastern New Mexico. American Antiquity 61(20):311-324.

Thompson M. 1994. The evolution and dissemination of Mimbres iconography. In: Schaafsma P, editor. Kachinas in the Pueblo world. Albuquerque: University of New Mexico Press. p 93-105.

Thompson M. 2006. Pre-columbian venus: celestial twin and icon of duality. In: VanPool C, VanPool T, and Phillips D, editors. Religion in the prehispanic Southwest. Lanham, Maryland: Altamira Press. p 165-184.

Thurnbow C. 2000. Early agricultural settlements in the Big Burrow mountains, New Mexico. Mogollon Conference. Las Cruces, New Mexico.

Todd TW. 1920. Age changes in the pubic bone I. American Journal of Physical Anthropology 3(3):285-334.

Todd TW. 1921a. Age changes in the pubic bone II, III, IV. American Journal of Physical Anthropology 4(1):1-76.

Todd TW. 1921b. Age changes of the pubic bones V. American Journal of Physical Anthropology 4:333-406.

Todd TW. 1930. Age changes in the pubic bone VIII. American Journal of Physical Anthropology 14(2):255-271.

Todd TW, and Lyon DWJ. 1924. Endocranial suture closure, its progress and age relationship. part I. adult males of white stock. American Journal of Physical Anthropology 7:325-384.

Todd TW, and Lyon DWJ. 1925a. Cranial suture closure, its progress and age relationship. part II. ectocranial closure in adult males of white stock. American Journal of Physical Anthropology 8:23-45.

Todd TW, and Lyon DWJ. 1925b. Cranial suture closure: its progress and age relationship part IV. ectocranial closure in adult males of negro stock. American Journal of Physical Anthropology 8:149-168.

Todd TW, and Lyon DWJ. 1925c. Cranial suture closure: its progress and age relationship. part III. endocranial closure in adult males of negro stock. American Journal of Physical Anthropology 8:47-71.

Ubelaker DH. 1974. Reconstruction of demographic profiles from ossuary skeletal samples. Washington, D.C.: Smithsonian Institution Press.

Ubelaker DH. 1978. Human skeletal remains: excavation, analysis, interpretation. Chicago, Illinois: Aldine Publishing Company.

Upham S. 1984. Adaptive diversity and southwestern abandonment. Journal of Anthropological Research 40(2):235-256.

Upham S, MacNeish RS, and Stevenson CM. 1988. The age and evolutionary significance of southwestern maiz de ocho. American Anthropologist 90:683-684.

Usher B. 2002. Reference samples: the first step in linking biology and age in the human skeleton. In: Hoppa R, and Vaupel J, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge University Press. p 29-49.

Van Gerven D, and Armelagos GJ. 1983. "Farewell to paleodemography?" Rumors of its death have been greatly exaggerated. Journal of Human Evolution 12:353-360.

VanPool C, VanPool T, and Phillips D, editors. 2006. Religion in the prehispanic Southwest. Lanham, Maryland: Altamira Press.

Vierra B. 2011. Foraging societies in an arid environment. In: Nelson M, and Strawhacker C, editors. Movement, connectivity, and landscape change in the ancient Southwest. Boulder: University Press of Colorado. p 25-44.

Waldron T. 1987. The relative survival of the human skeleton: implications for palaeopathology In: Boddington A, Garland A, and Janaway R, editors. Death, decay and reconstruction: approaches for palaeopathology and forensic science. Manchester, U.K.: Manchester University Press. p 55-64.

Walker P. 2005. Greater schiatic notch morphology: sex, age, and population differences. American Journal of Physical Anthropology 127:385-391.

Walker P, Johnson J, and Lambert P. 1988. Age and sex biases in the preservation of human skeletal remains. American Journal of Physical Anthropology 76:183-188.

Waters MR, and Ravesloot JC. 2001. Landscape change and the cultural evolution of the Hohokam along the middle Gila River and other river valleys in South-Central Arizona. American Antiquity 66:285-299.

Weiss K. 1972. On the systematic bias in skeletal sexing. American Journal of Physical Anthropology 37(2):239-250.

Weiss K. 1973. Demographic models for anthropology. Memoirs of the Society for American Archaeology 27.

Weiss K, and Smoose PE. 1976. The demographic stability of small human population. In: Ward RH, and Weiss KM, editors. The demographic evolution of human populations. New York: Academic Press. p 59-74.

White C. 1996. Sutural effects of fronto-occipital cranial deformation. American Journal of Physical Anthropology 100:397-410.

Wilczak C, and Ousley S. 2009. Test of the relationship between sutural ossicles and cultural cranial deformation: results from Hawikuh, New Mexico. American Journal of Physical Anthropology 139:483-493.

Wills WH. 1989. Early prehistoric agriculture in the American Southwest. Santa Fe, New Mexico: School of American Research Press.

Wills WH. 1992. Plantcultivation and the evolution of risk-prone economies in the prehistoric American Southwest. In: Gebauer AB, and Price D, editors. Transitions to agriculture in prehistory. Madison, Wisconsin: Prehistory Press.

Wills WH. 1996. The transition from the preceramic to ceramic period in the Mogollon highlands of western New Mexico. Journal of Field Archaeology 23(3):335-359.

Wills WH, and Huckell B. 1994. Economic implications of changing land-use patterns in the late-archaic. In: Gumerman G, editor. Themes in Southwest prehistory. Santa Fe, New Mexico: School of American Research. p 33-52.

Wilmoth J. 1995. The earliest centenarians: a statistical analysis. In: Jeune B, and Vaupel J, editors. Exceptional longevity: from prehistory to the present. Odense, Denmark: Odense University Press. p 125-156.

Wittwer-Backofen U, and Buba H. 2002. Age estimation by tooth cementum annulation: perspectives of a new validation study. In: Hoppa R, and Vaupel J, editors. Paleodemography: age structure from skeletal samples. Cambridge: Cambridge University Press. p 107-128.

Woosley AI, and McIntyre AJ. 1996. Mimbres Mogollon archaeology: Charles C. Di Peso's excavations at Wind Mountain. Albuquerque: University of New Mexico Press.

Wright L, and Yoder C. 2003. Recent progress in bioarchaeology: approaches to the osteological paradox. Journal of Archaeological Research 11(1):43-70.

Young Holliday D. 1993. Occipital lesions: a possible cost of cradleboards. American Journal of Physical Anthropology 90:283-290.

Young Holliday D. 1996. Were some more equal?: diet and health at the NAN Ranch Pueblo, Mimbres Valley, New Mexico [PhD Dissertation]. Madison: University of Wisconsin-Madison.

APPENDIX A

LOCATION OF SKELETAL COMPONENTS USED IN TRANSITION ANALYSIS

(BOLDSEN et al. 2002; MILNER AND BOLDSEN 2007)

Cranium	
Coronal Pterica	The most lateral and inferior section of the coronal suture, a relatively straight part without a meandering appearance.
Sagittal Obelica	The relatively straight part of the posterior sagittal suture near the parietal foramina.
Lambdoidal Asterica	The most lateral and inferior segment of the lambdoidal suture is scored – it is the part adjacent to asterion that extends one-quarter to as much as one-third of the way up to lambda.
Zycomatico-maxillary	The facial, or anterior, part of the zygomaticomaxillary suture is scored.
Interpalatine (Median Palatine, Posterior Portion)	The suture between the two opposing palatine bones is scored. The Open and Juxtaposed distinction of the other suture segments is not scored because it is difficult to impossible to distinguish the two categories consistently. In addition, care should be taken when examining the interpalatine suture because a small bony crest that often forms along the midline of the palate can make it difficult to score the degree of suture closure properly.

Pubis Symphysis	
Symphyseal Relief	The entire face is of interest, although the features distinguished here, especially the billowing, is most clearly seen in the dorsal half of the symphyseal face. In fact, the low ridges of bone identified as billows can be entirely absent from the ventral part of the symphyseal face when there is ventral beveling, following McKern and Stewart's (1957) use of these terms.
Symphyseal Texture	The surface of the dorsal demiface is scored. The ventral part of the bone, when ventral beveling is present, is often pitted, giving it the appearance of microporosity. The porosity of the ventral demiface in such specimens should not be confused with whatever was happening on the dorsal demiface.
Superior Apex	A distinct knob of bone or, later, an elevated area can be seen on the superior part of some symphyseal faces; otherwise, this part of the symphyseal face resembles the rest of it.
Ventral Symphyseal Margin	The ventral part of the pubic symphysis is scored separately from the remainder of the bone.
Dorsal Symphyseal Margin	The dorsal part of the pubic symphysis is scored separately from the ventral part of the bone. In females, the dorsal margin characteristics can be obscured by large postpartum, or parity, pits – occasionally, such specimens cannot be scored properly.

Iliac Auricular Surface	
Superior Demiface Topography	The superior demiface is scored. The superior and inferior demifaces are divided by a line extending posteriorly from the most anterior point of the apex to the posterior border of the joint surface.
Inferior Demiface Topography	The inferior demiface is scored. The superior and inferior demifaces are divided by a line extending posteriorly from the most anterior point of the apex to the posterior border of the joint surface.
Superior Surface Morphology	The superior part of the face is scored. The joint surface is divided into the superior, apical (middle), and inferior segments.
Apical (Middle) Surface Morphology	The apical (Middle) part of the face is scored. The joint surface is divided into the superior, apical (middle), and inferior segments.
Inferior Surface Morphology	The inferior part of the face is scored. The joint surface is divided into the superior, apical (middle), and inferior segments.
Inferior Surface Texture	Only one part of the auricular surface – the inferior area – is scored for texture. This part of the joint surface is 1 cm long, as measured in a superior to inferior direction. Its lowermost point is a line defined by the margin of the greater sciatic notch on either side of the joint surface. Do not score the part of a joint surface that extends well beyond the margin of the notch as defined above. These elongated sacroiliac joints commonly occur in females, and they are often characterized by macroporosity and marginal lipping. This pitting and lipping frequently differs markedly from the appearance of the rest of the sacroiliac joint surface.
Superior Posterior Iliac Exostoses	Score the superior posterior iliac exostoses. This area refers to the superior part of the medial surface of the posterior ilium where ligaments attach during life. It is located superior to the sacroiliac joint surface; that is, to a line that passes from the anterior superior iliac spine, to the most superior point of the joint surface (the superior angle), and on through the posterior part of the ilium.

Iliac Auricular Surface	
Inferior Posterior Iliac Exostoses	Score the inferior posterior iliac exostoses. This area refers to the inferior part of the medial surface of the posterior ilium where ligaments attach during life. It is located inferior to a line that passes from the anterior superior iliac spine, to the most superior point of the sacroiliac joint surface (the superior angle), and on through the posterior part of the ilium. This area is located immediately posterior to the middle of the sacroiliac joint; that is, it lies behind the most anteriorly projecting part of the posterior margin of the joint.
Posterior Iliac Exostoses	The posterior iliac area between the Superior and Inferior Posterior Iliac Exostoses, as defined above, are scored. The area where the exostoses occur is on the medial side of the ilium bordered posteriorly by the iliac crest, anteriorly by the sacroiliac auricular surface, superiorly by a slightly raised area often surmounted by bony exostoses (Superior Posterior Iliac Exostoses), and inferiorly by an area typically covered by exostoses (Inferior Posterior Iliac Exostoses).

APPENDIX B

SCORES USED IN TRANSITION ANALYSIS (BOLDSEN et al. 2002:97-104)

Cranial Suture Closure

Components	Characteristics	Description
Coronal pterica, sagittal obelica, lambdoidal asterica, zygomaticomaxillary, interpalatine	1. Open	The suture is visible along its entire length, and there is a noticeable gap between the bones.
	2. Juxtaposed	The suture is visible along its entire length, but the suture is narrow because the bones are tightly juxtaposed. If there are any bony bridges they are rare and small, sometimes with a trace of the original suture still evident.
	3. Partially obliterated	The suture is partially obscured. There is no trace of the original suture in the bony bridges.
	4. Punctuated	Only remnants of the suture are present. These remnants appear as scattered small points or grooves each no more than two millimeters long.
	5. Obliterated	There is no evidence of a suture.

SCORES USED IN TRANSITION ANALYSIS (BOLDSEN et al. 2002:97-104)

Pubic Symphysis

Components	Characteristics	Description
Symphyseal Relief	1. Sharp billows	Sharply crested billows cover at least half of the surface. Deep furrows that extend completely across the symphyseal face separate the distinct ridges. The deepest furrows cut into the ventral and dorsal margins of the symphyseal face, interrupting the edge of the bone to give it a jagged appearance. The distance between the high and low points of adjacent ridges and furrows can often be 3 mm or more. Occasionally, round instead of sharp crests on billows occur in specimens that otherwise have deep furrows exceeding 3 mm. Such specimens are coded as Sharp Billowing. Sharp Billowing has only been noted in teenagers.
	2. Soft, deep billows	Softly crested to low billows separated by deep furrows extend over at least half of the surface, typically the dorsal demiface. The furrows do not appear as if they have been filled in with bone. The distance between the high and low points of adjacent ridges and furrows is 3 mm and less.
	3. Soft, shallow billows	Low but clearly visible and discrete billows separated by shallow Low but clearly visible and discrete billows separated by shallow furrows are present on at least half of the dorsal demiface. The remnants of an earlier ridge and furrow system dominate the dorsal demiface, and the furrows look as if they were partially filled with bone. Billows extend most or all of the way across the dorsal demiface, and in some specimens they can reach the ventral margin.
	4. Residual billows	Billows are barely elevated above the symphyseal face and blend into one another, forming low and indistinct raised areas lacking clearly defined furrows between them. The billows, however, are still an important element

Components	Characteristics	Description
		of the surface, and they almost invariably occur on the inferior one-half of the face, often in the dorsal demiface. Individual billows usually cross only part of the symphyseal face, typically less than one-half its width. There must be two or more adjacent raised areas corresponding to billows. A single isolated bony elevation is not sufficient to be classified as residual billowing; instead, such specimens would be considered flat.
	5. Flat	More than one-half of the symphyseal face within well-defined margins is flat or slightly recessed, especially if surrounded by a well-developed rim (see below). Occasionally small, flat, pillows of bone give the surface a pebbly appearance. The remainder of the symphyseal face does not conform to Residual Billowing (i.e., there is no more than one discrete low raised area). Sometimes there is a gap where the ventral rampart has failed to extend along the entire ventral edge of the pubis; in these specimens, the recessed surface of the bone is not coded.
	6. Irregular	Pitting, which can be deep, covers more than one-half of the symphyseal face, giving it an irregular appearance. The pits are often accompanied by small, sharp exostoses scattered across the face. Occasionally, an otherwise flat face is covered by sharp exostoses of bone. Similar to the Flat category, the scored part of the face is located within well-defined margins; the surface in the ventral gap described above is not coded. In Irregular specimens, the margins of the symphyseal face are typically defined by the Rim and Breakdown stages of the Ventral and Dorsal Margin components.
Symphyseal Texture	1. Smooth (fine grained)	Smooth to fine-grained bone extends across most, or all, of the dorsal demiface.
	2. Coarse grained	Coarse-textured bone covers over one-third of the dorsal demiface. The surface looks like fine, packed sand, similar to the appearance of common fine-grained sandpaper.
	3. Microporosity	Bone that appears porous covers over one-third of the dorsal demiface. It looks as if the bone was pierced by closely packed pin pricks.

Components	Characteristics	Description
	4. Macroporosity	Deep pits cover over one-third of the dorsal demiface, giving it an irregular, porous appearance. These pits are at least 0.5 mm in diameter, and are generally spaced close together.
Superior Apex	1. No protuberance	Deep to shallow billowing is visible in the superior part of the symphyseal face. There are no signs of a bony protuberance. This part of the symphyseal face can be poorly differentiated from the non-articular portion of the pubis immediately lateral to the joint.
	2. Early protuberance	A distinct bony knob of variable dimensions with a well-defined inferior margin is visible in the superior part of the symphyseal face. This structure projects above the plane(s) defined by the immediately adjacent symphyseal face (i.e., the superior portions of the dorsal and ventral demifaces, where the latter can be characterized by ventral beveling). The surface of the bony protuberance is typically smooth to fine- grained.
	3. Late protuberance	The superior part of the symphyseal face is raised somewhat above the rest of the articulation surface. This elevated area is typically located on the ventral side of the midline. The margins of the slightly raised area tend to be poorly defined. Thus the Late Protuberance is more completely integrated with the rest of the symphyseal face than the distinctly knob-like Early Protuberance. The integration as part of the face is, in part, a result of the formation of the ventral rampart. The Late Protuberance should not be confused with a narrow raised rim that can border the cranial end of the symphyseal face. The protuberance extends onto the symphyseal face; that is, it is not restricted to the margin where a pronounced rim can be found. Occasionally, the superior part of the symphyseal face can be isolated by marked pitting of the symphyseal surface, but these specimens should not be considered as being in the Late Protuberance stage. For Late Protuberance to be present, the slightly raised area must be visible on a rather smooth symphyseal face.

Components	Characteristics	Description
	4. Integrated	The superior end of the symphyseal face displays no evidence of a low bony elevation. The area where the protuberance was formerly present is fully integrated with the rest of the symphyseal face. That is, the smooth to pitted surface of the symphyseal face is essentially flat.
Ventral symphyseal margin	1. Serrated	Ridges and furrows typical of Sharp or Soft, Deep Billowing extend uninterrupted across the ventral part of the symphyseal face, producing a serrated or jagged ventral margin.
	2. Beveled	Billows are flattened in the ventral demiface, a process that generally starts at the superior end. The flattening, or beveling, must extend along at least one-third of the ventral margin to be scored as present. There is generally a well-defined margin where the ventral surface of the pubis (the beveled part of it) meets the articular surface.
	3. Rampart formation	The ventral rampart, which follows McKern and Stewart's (1957) use of the term, refers to a distinct outgrowth of bone that ultimately forms the ventral part of the symphyseal face. The rampart in this stage extends from one or both ends of the ventral demiface, and it often resembles a roll of chewed gum lying on the ventral edge of the symphyseal face. The rampart does not extend along the entire ventral edge, and often some of the elements of the youthful symphyseal surface can be followed uninterrupted to the ventral edge of the symphysis. In the superior part of the ventral margin, the rampart forms on a Beveled surface. In the inferior part of the margin, remnants of the original irregular surface can often be seen dipping below a partially formed rampart, which looks as if it was lying on a shallowly furrowed surface. An incomplete rampart frequently extends inferiorly from the bony protuberance defining the cranial end of the face; sometimes forming a bony elevation that somewhat resembles a comma. The rampart can also extend superiorly from the opposite, or inferior, end of the symphysis. In this stage, bony extensions from both the superior and inferior ends of the symphysis typically leave a gap in the middle one third of the ventral margin. The early

Components	Characteristics	Description
		Rampart Incomplete stage can consist of one or more bony knobs, which are commonly located in the middle one-third of the ventral margin. The knobs can occur with, or without, the formation of a bony rampart that extends from the superior and inferior ends of the symphysis. If the rampart is more than two-thirds complete but there is a gap in the superior part of it, you should consider the possibility that the specimen is in the Rampart Complete I or II stages. Occasionally a rampart never completely forms along the ventral margin.
	4. Rampart completion I	Here the ventral rampart is complete, but there remains a shallow sulcus extending along much of the length of the ventral pubis surface immediately lateral to the symphysis (typically in the inferior end). The groove is a residual feature related to rampart formation along the ventral margin. A reasonably flat symphyseal surface extends interrupted from its dorsal to ventral margins, so the face is unlike the somewhat furrowed appearance of many Rampart Incomplete specimens where there is a shallow groove just dorsal to an incomplete ventral rampart. Occasionally a gap exists in the superior one-half of the ventral margin; the ventral rampart is otherwise completely formed.
	5. Rampart completion II	Here the ventral rampart is complete, and there is no shallow sulcus described in Rampart Complete I. A reasonably flat symphyseal surface extends uninterrupted from its dorsal to ventral margins, so the face is unlike the somewhat furrowed appearance of many Rampart Incomplete specimens where there is a shallow groove just dorsal to an incomplete ventral rampart. Occasionally a gap exists in the superior one-half of the ventral margin; the ventral rampart is otherwise completely formed.

Components	Characteristics	Description
	6. Rim	A narrow, bony rim defining the ventral margin of the symphysis, which forms on the ventral rampart, demarcates a usually flat or irregular face. This rim does not have to be complete, but it must be at least 1 cm long and readily visible as a raised ridge adjacent to a slightly recessed symphyseal face. A ventral rim is always formed on top of a ventral rampart. Rim-like bone formations on gaps in a rampart or formed with no rampart at all are not scored as a ventral rim.
	7. Breakdown	The ventral margin of the symphyseal face has begun to break down, as indicated by pitting and an erosion of a Rim. The breakdown of the ventral margin must exceed 1 cm (either in one spot, or when two or more areas of erosion are combined) to be scored as present. Care must be taken to distinguish ante mortem degeneration of this bony feature from postmortem damage. The latter, of course, is not scored because it is of no interest when estimating age.
Dorsal symphyseal margin	1. Serrated	The dorsal margin of the symphyseal face is irregular because ridges and furrows typical of pronounced billowing extend uninterrupted to the edge of the bone.
	2. Flattening incomplete	A well-defined flattened area at least 1 cm long is present where the symphyseal face meets the dorsal margin of the pubis. Flattening usually starts in the superior part of the dorsal demiface. Billowing, typically Soft, Shallow, or Residual, is also present on the dorsal demiface, and it typically produces an undulating edge to the pubic symphysis, although it is not as extreme as that found in Serrated specimens. This undulating edge usually occurs in the inferior part of the symphyseal face.
	3. Flattening complete	There is a rather obvious area of flattening that completely (or virtually completely) covers the symphyseal face where it meets the dorsal surface of the pubis. Completion of the marginal flattening seemingly occurs through a coalescence of billows. A small area at the inferior end of the dorsal margin occasionally has retained an undulating appearance.

Components	Characteristics	Description
	4. Rim	A narrow bony rim demarcates a usually flat or irregular face, and the rim typically projects slightly above the symphyseal face. The rim does not have to extend along the entire dorsal margin to be scored as present, but it must be at least 1 cm long. The rim typically first develops along the superior part of the margin. It can, however, occur anywhere along the dorsal margin. The elevated margin is scored as a rim when one or more segments together extend over at least 1 centimeter.
	5. Breakdown	The dorsal margin where the Rim is located shows signs of breakdown that involves pitting and an erosion of the edge of the symphysis. The breakdown must exceed 1 cm in length (either in one spot or when two or more areas of erosion are combined) to be scored as present. Care must be taken to differentiate antemortem degeneration of the margin from postmortem damage, which is of no concern here. In addition, antemortem destruction attributable to large parity pits that undercut the dorsal margin can occur in females, but it is not considered breakdown in the sense of the term as used here.

SCORES USED IN TRANSITION ANALYSIS (BOLDSEN et al. 2002:97-104)

Iliac Portion of the Sacroiliac Joint

Components	Characteristics	Description
Superior and inferior demiface topography	1. Undulating	The surface is undulating, particularly in a superior to inferior direction. There is no centrally located area of elevated bone (i.e., the median elevation). The joint surface is slightly wavy occasionally giving it a somewhat hummocky appearance.
	2. Median elevation	In the middle to posterior part of the demiface there is a broad raised area where the part of the joint is elevated above the rest of the surface. The elevation is flanked anteriorly or anteriorly and posteriorly by one or two long low areas. The elevated area takes the form of an elongated ridge, particularly in the inferior demiface, with the long axis paralleling the main orientation of the demiface. This ridge will occupy as much as one-third of the joint surface.
	3. Flat to irregular	The surface is essentially flat or recessed, a result of marginal lipping, or it is irregular, a result of a degeneration of the joint or the formation of low pillow-like exostoses.
Superior, apical and inferior surface morphology	1. Billows cover >2/3 of the surface	Low rounded ridges separated by furrows, which have distinctly rounded bases, are clearly identifiable. The ridge surfaces are curved from the depths of the furrows completely across their crests. Most or all of the billowing is oriented roughly anterior to posterior, and individual furrows generally run across much, or all, of the face. The billowing covers most (>2/3) of the auricular surface (i.e., it is a dominant element of the surface).
	2. Billows cover 1/3-2/3 of the surface	About one-half of the surface is covered by billows.
	3. Billows cover <1/3 of the surface	Billows are a noticeable, but minor, component of the joint surface. The rest of the surface is flat or bumpy.
	4. Flat (no billows)	The auricular surface is flat.

Components	Characteristics	Description
	5. Bumps	Most, or all, of the auricular surface is covered by low, rounded bony exostoses, much like little irregular pillows. Part of the surface may be flat, but over one-half of it is bumpy.
Inferior surface texture	1. Smooth	Most or all of the bone comprising the auricular surface exhibits a smooth to slightly granular appearance.
	2 Microporosity	At least one-half of the surface has a porous appearance with apertures being less than 0.5 mm in diameter. The surface appears to be covered with numerous closely spaced pinpricks.
	3. Macroporosity	At least one-half of the surface is porous, and most or all of the apertures exceed 0.5 mm in diameter.
Superior and inferior posterior iliac exostoses	1. Smooth	The surface is undulating in this area, but shows no evidence of discrete bony elevations. At most there are a few isolated small exostoses that project up from the bone surface.
	2. Rounded bony elevations	Definite raised areas of bone with rounded crests dominate the scoring area.
	3. Pointed exostoses	Over one-half of the rough area where ligaments attach is dominated by sharply pointed elevations of bone.
	4. Jagged exostoses	The raised areas of bone have a jagged appearance, and round or sharp exostoses dominate the rough area where ligaments attach in life.
	5. Touching exostoses	There is a pronounced growth of bone with a relatively flat top, which is usually roughly oval, where the exostoses met their counterparts on the sacrum.
	6. Fusion	The ilium and sacrum are fused by excessive exostoses in this area.
Posterior iliac exostoses	1. Smooth	The area posterior to the sacroiliac joint is smooth, except for the two areas coded as the Superior and Inferior Posterior Iliac Exostoses.

Components	Characteristics	Description
	2. Rounded exostoses	Low, rounded exostoses (or spicules) cover the entire bone surface posterior to the sacroiliac joint, except for a ca. 0.5 cm band of smooth bone immediately adjacent to the posterior edge of the joint. The exostoses are normally lower than the Superior and Inferior Posterior Iliac Exostoses. The low exostoses give the normally smooth iliac surface a rough appearance.
	3. Pointed exostoses	Low, pointed exostoses (or spicules) cover the entire bone surface posterior to the sacroiliac joint, except for a ca. 0.5 cm band of smooth bone immediately adjacent to the posterior edge of the joint. The exostoses are normally lower than the Superior and Inferior Posterior Iliac Exostoses. The sharp exostoses give the normally smooth iliac surface a rough appearance.

APPENDIX C

TRANSITION.ANALYSIS.FORM

Project: ______________________________

Site or Collection: ____________________ **Skeleton:** __________________________

: __________ : ____/____/____ : __________ : ____/____/____

Cranial Sutures	**Left**	**Right**
Coronal Pterica	- 1 2 3 4 5	- 1 2 3 4 5
Sagittal Obelica (midline)	- 1 2 3 4 5	
Lambdoidal Asterica	- 1 2 3 4 5	- 1 2 3 4 5
Interpalatine (midline)	- 1 3 4 5	
Zygomaticomaxillary	- 1 2 3 4 5	- 1 2 3 4 5

Pubic Symphysis	**Left**	**Right**
Symphyseal Relief	- 1 2 3 4 5 6	- 1 2 3 4 5 6
Symphyseal Texture	- 1 2 3 4	- 1 2 3 4
Superior Apex	- 1 2 3 4	- 1 2 3 4
Ventral Symphyseal Margin	- 1 2 3 4 5 6 7	- 1 2 3 4 5 6 7
Dorsal Symphyseal Margin	- 1 2 3 4 5	- 1 2 3 4 5

Iliac Auricular Surface	**Left**	**Right**
Superior Demiface Topography	- 1 2 3	- 1 2 3
Inferior Demiface Topography	- 1 2 3	- 1 2 3
Superior Surface Morphology	- 1 2 3 4 5	- 1 2 3 4 5
Middle Surface Morphology	- 1 2 3 4 5	- 1 2 3 4 5
Inferior Surface Morphology	- 1 2 3 4 5	- 1 2 3 4 5
Inferior Surface Texture	- 1 2 3	- 1 2 3
Superior Posterior Iliac Exostoses	- 1 2 3 4 5 6	- 1 2 3 4 5 6
Inferior Posterior Iliac Exostoses	- 1 2 3 4 5 6	- 1 2 3 4 5 6
Posterior Exostoses	- 1 2 3	- 1 2 3

Codes: - (Missing or Not Observable), 1-7 (defined in Transition Analysis manual)

TA Form; Milner; 5/3/2007 Page _____ of _____

APPENDIX D

RAW SCORES FOR EACH SKELETAL FEATURE BY SKELETON

		Cranium								Pubis Symphysis										Auricular Surface of the Ilium																	
Burial #	Sex	Coronal Pterica		Sagittal Obelica	Lambdoidal Asterica		Interpalatine	Zygomaticomaxillary		Symphyseal Relief		Symphyseal Texture		Superior Apex		Ventral Symphyseal Margin		Dorsal Symphyseal		Superior Demiface Topography		Inferior Demiface Topography		Superior Surface Morphology		Middle Surface Morphology		Inferior Surface Morphology		Inferior Surface Texture		Superior Posterior Iliac Exostoses		Inferior Posterior Iliac Exostoses		Posterior Exostoses	
		L	R		L	R		L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
1	M	4.5		3.5	1	1	4	3													3		2		4		3		3.5		1.5		2		4		2
4	F		4.5					2																													
12	M	2	2	1	1	2	1	2	2		3		3		1		2		2	3	2	2	2	4	4	5		3	2	1	1	2	2	1	3	1	1
13	M	2		1	1	1	5	2	1.5	5		4		4		7		3		1	1.5	2	2	2	3	2	3	5	5	3	3	2	3		2		2
15	F	2	2	2	1	1	1	2	2											1	1	2	1	3	2	3	2	4	4	1	1	2	3				
20	M			1.5						5	4	3	2	4			3.5	4			3				4	4.5	4.5						2				
25	M						3																														
27	M			1.5		1		1	2																												
36	M	2.5	3.5	4.5	2.5	3	1	2	2	5.5	5.5	3.5	4	4	4	6.5	7	4	4	3	3			3.5	3	3	2					1.5	1.5	4	2.5	1	2
41	M		2	2	1	1	1	2.5	2.5											1	1	2	2	3	2		3	2	2	1	1	2	3	2.5	4	1	1.5
42	M									4	4.5	3	3	4	4	5	6.5	3.5	4																		
43	F		2	2		1				5	6	3.5	4		4		6.5	4	3.5			2		3		3		3.5		2.5							
46	F	5		2	2	2		3	3		6		4		4		7		4.5		2.5		3		4		3		5		2.5		4		4		1
52	M			2			1		2																												
56	F										4.5		3		4				3.5																		
57	F									3.5	4.5	4	4		3	4	7	2	2.5	3	3	2		4	3.5	2.5	3	3		2		3		2		2	
58	F	2			2.5			2.5	2.5	6	6	3.5	4	3	4			4			3		2.5		4		5		5		2.5		2				
62	M						2	3.5		5	5	3.5	4	3.5	3.5	5	5	3.5	3	3	1.5	2.5	2.5	4	3	3	3	5	3	2.5	2		2.5		4		2
64	M	1	1					1.5	1.5	6	5.5	4	3	4	4	7	7	3	3	1	2	1.5	2	2	3.5	1	3	3	3	1	1.5	2	2	2	2	1.5	2
68	M	2			2					4	3	2	2.5	1	1	1	1	3	2	2.5	2.5	2		3.5	4	3	3	3.5		1			2.5			3	2
73	F																			1	1		2	4	3.5	3	2						2.5				
76	F										6		4		4		7		2	3				2.5		2.5						3		4		1	
77	M?		2	1.5	1	1.5	3	2.5	2.5	6	6	3	4	4	4	7	7	5	5	2.5	2	2	2	5	2	3	3	3.5	3	2.5	2.5	3	4	4.5		3	3
82	M	5	5				3.5	3			6		4		4		5		4	3	2	2	2	4	4	4	4.5	5	4	1	1	2	3				2
83	F?						1		2																												
87	F?		3	3.5				2.5	2.5											2	3	2	2	3	4.5	3	3	4	5	2	2.5	4	5			2	2
88	M			1	1.5	1	2	2	2	4	4	3.5	3.5	3		2.5	2.5	2.5	2	3	2	1.5	3	3	2	2	2	2	3.5	1.5	2	2	2	1	2	1	1

92	M	5		4	3						5		2		4		5		3	2		2	2	3		2	3	3	4	1	1	5	5	2		1.5	1.5
95	M	4		5	2.5	2	5																														
100	M						4	4			5.5		3.5		4				3		3		2.5		5		4		5		2						
103	M									4	4	1	1		4		4	3.5	5	2				4													
109	M									4	5	2	3	4	4	6.5	6.5	4	4	3	1	2	2	4	2	3	2.5	3	4	1.5	1	4	4	4	2	1	1
111	F										3.5		3		1-4		3.5		3.5	1.5		2		3		2		3		1		1		1		2	
115	M							3.5			5		3		4		5		4	2.5	2	3	2.5	5	5	4	4	4	4.5	2.5	2.5		3.5	2	2		2
119	F										5.5		3		4		7		4	3	2	3		5	4	4		5		3				3			
123	F										4		3						4	3	2	3	3	2	3	2	2	3	3	1	1						
125	M																																				
130	F										4		2.5		3.5		5		4		2	2	3		3.5		3	3	3	2.5	1.5						
131	M	4.5		4.5			4			5	5	3	2.5	3.5	4	4	5	3	3.5	2	3			3	4	4	4	5		2.5		2					
132	F									5.5	5	3	3	4	4	6.5	6	4	4	3		3		5		5		4		3.5							
138	M	5		2	1	2															3	2	2		3.5	5	3	4	3.5	1.5	2	3.5	2	2	2	1	1
139	M							2.5	3													3						4		2							
140	F	2	2.5					2		5	5	1	1	4	4	5	5	3.5	3.5	2	2.5	2.5	3	4	4		3	5		2		4	3.5				3
144	F			4.5						4.5		2.5		4		4		4		2	1.5	2	2	3.5	3.5	3	3.5	4	4	2	2	3				2	
146	M						3	3	2																												
147	M	2	2	2.5	1	1	3	3	2	5		4	4	4	4	3	3	3	4	1.5	2			3	3	2	2					2	2			1	1
150	M	1	1		3.5		1	2	2.5	5	5	3.5	3.5	4	4	6	5	4	4	2	2	1.5	1.5	2	3	3	3					2	2			1	1
151	F	3.5	3	2	2	3	1	3	3	5.5	5.5	3	3	4	4	7	5	5	5			1.5	3			2			4		1						
153	F						3	2	2																				3		2						
154	M				2		1	2.5												3		2		4		3	4	4		2.5		2				1	
155	M		4	4		2.5				5		3		3.5		7		3		2		2	2	3		2	2	3.5	3	1.5	1.5	2		2		2	
156	F			3	1	2	1		4												3		1		3		2		3		2.5		4				
157	M			4	1.5	1.5	1		3											2		2		3		3		3		2.5		3.5				1	
160	?			1	1	1		1		5.5	5.5	4	4	4	4	5.5	7	4	4		2	2			3.5		3	3.5		2		3	3				
161	F			3					2														2			3	3		4		2.5						
165	F	1		2.5	2			2	1	5		2.5		4		4.5		3		2	2			3	3	2	3		3		1.5		2				1
169	F			2.5						5.5	6	2.5	4	4	4	3.5	4	4	4.5	3	3	2	2	4	4		3	4	4	1.5	1.5	2	3	3	3.5	2	2
170	F	4	4	2	2.5	2.5	3	2.3	2.3	3	2	1	1	1	1	1	1	2	2	3	3	2		3	3.5	2				2		1	1.5	2	2	2	2
173	F			3.5			3		2	4.5	5.5	3	3				7		4.5	1.5	3	2	2	2.5	5	2	3	2	3	1.5	1		2				
175	M									6	5	4	2					4	4																		
178	M			4	3	3				5	5	3	3			5.5	5	3	3.5		3		2		5		3		3		2		3.5				
179	F							2	2	4	4	2.5	2	3	3	3	3	2	2	1	1	2	2	3	2	2	3	4	3	1.5	1.5	2	2	5	4		1
184	M	4.5	5	4		4			3	5	5	3	2	4		4	5	4	4	2	2	2	2	4	4	4	3	4	4	1	1	4	4		2	2	1
185	F				2			2		5		3		4				3.5														6		6			
188	M	2						2.5	3		4.5		2		2.5		5		4	3	3	3	3	3	4	4	4	4	5	2	2		2				2
189	M		2	3	2.5																2.5		2.5		4		3.5		3.5		1.5		4				

198	F			1	2	2				5	6	3	4	4	4	6	7	4	4	2	2	2	2	3		3	4	3	4	1	2	4					
203	F			2	2	2															3				4		4										
204	F	4		3					2	6	6	4	4	4	4	7	7	4.5	4.5		2				3.5								2				
205	M		2.5				3	3.5		1	2	1	1	1		2	3	1	1	2	2	2	2	4	4	3	2	3	3	1	1	2		1			
207	F		4	4	5	3	3	2	2	4		3		4		3.5		3.5		3	3	2	3	4	3	3	3	3.5	4	2.5	2						
210	F		3		1	1		2.5		4		4		3.5				4			3		2.5		4		3		4		1.5		2		2		1.5
211	F																			3		2		5		2		3.5		1.5							
219	?			4		3		2.5																													
222	?								2.5		5				4																						
223	M								2	4		3		3		2		2																			

APPENDIX E

ADDITIONAL LIFE TABLES

NAN Ruin abridged composite life table (Classic burials from the East Room Block)

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.9	26	26.00	26.80	100	0.268004	86.60	2097.79	20.98
1-4.9	17	17.33	17.87	73.20	0.244086	257.06	2011.19	27.48
5-9.9	9	8.67	8.93	55.33	0.161451	254.33	1754.12	31.70
10-14.9	0	4.00	4.12	46.40	0.088863	221.69	1499.79	32.32
15-19.5	3	2.52	2.60	42.28	0.061443	204.89	1278.11	30.23
20-24.9	4.56	4.04	4.16	39.68	0.104953	187.98	1073.22	27.05
25-29.9	4.56	5.07	5.22	35.51	0.147059	164.51	885.24	24.93
30-34.9	6.08	5.07	5.22	30.29	0.172414	138.40	720.73	23.79
35-39.9	4.56	5.07	5.22	25.07	0.208333	112.29	582.33	23.23
40-44.9	4.56	3.55	3.66	19.85	0.184211	90.09	470.04	23.68
45-49.5	1.52	2.03	2.09	16.19	0.129032	75.73	379.95	23.47
50-54.9	0.00	1.01	1.04	14.10	0.074074	67.89	304.22	21.57
55-59.9	1.52	0.51	0.52	13.06	0.04	63.98	236.32	18.10
60-64.9	0.00	1.52	1.57	12.53	0.125	58.75	172.35	13.75
65-69.9	3.04	2.53	2.61	10.97	0.238095	48.31	113.59	10.36
70-74.9	4.56	2.53	2.61	8.36	0.3125	35.25	65.28	7.81
75-79.9	0.00	2.53	2.61	5.74	0.454545	22.20	30.03	5.23
80+	3.04	3.04	3.13	3.13	1	7.83	7.83	2.50

NAN Ruin abridged composite life table (Classic burials from the South Room Block)

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.9	28	28.00	35.22	100	0.352157	82.39	1927.17	19.27
1-4.9	11	14.33	18.03	64.78	0.278263	223.08	1844.78	28.48
5-9.9	4	6.00	7.55	46.76	0.161392	214.92	1621.69	34.68
10-14.9	3	2.67	3.35	39.21	0.085534	187.67	1406.77	35.88
15-19.5	1	2.05	2.58	35.86	0.071905	172.84	1219.10	34.00
20-24.9	2.15	1.41	1.77	33.28	0.053162	161.97	1046.26	31.44
25-29.9	1.07	2.51	3.15	31.51	0.100053	149.67	884.29	28.06
30-34.9	4.30	3.58	4.50	28.36	0.158782	130.53	734.62	25.91
35-39.9	5.37	3.22	4.05	23.85	0.169947	109.14	604.10	25.32
40-44.9	0.00	2.51	3.15	19.80	0.159221	91.12	494.96	25.00
45-49.5	2.15	0.72	0.90	16.65	0.054143	80.99	403.84	24.26
50-54.9	0.00	1.07	1.35	15.75	0.085729	75.36	322.85	20.50
55-59.9	1.07	0.36	0.45	14.40	0.031159	70.86	247.50	17.19
60-64.9	0.00	0.71	0.90	13.95	0.064322	67.50	176.63	12.66
65-69.9	1.07	2.15	2.70	13.05	0.206874	58.50	109.14	8.36
70-74.9	5.37	4.29	5.40	10.35	0.521669	38.26	50.63	4.89
75-79.9	6.44	3.94	4.95	4.95	1	12.38	12.38	2.50
80+	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00

NAN Ruin abridged composite life table (All Classic burials using same age intervals than Patrick (1988).

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.9	55	55.00	27.75	100	0.27746	86.13	2044.67	20.45
1-4.9	29	33.00	16.65	72.25	0.230404	319.65	1958.54	27.11
5-9.9	15	15.67	7.90	55.61	0.142131	258.27	1638.89	29.47
10-14.9	3	7.67	3.87	47.70	0.081077	228.85	1380.62	28.94
15-19.5	5	4.82	2.43	43.84	0.055432	213.10	1151.77	26.27
20-24.9	6.45	5.54	2.79	41.41	0.067457	200.04	938.67	22.67
25-29.9	5.16	7.74	3.90	38.61	0.101124	183.30	738.62	19.13
30-34.9	11.61	9.03	4.56	34.71	0.13125	162.15	555.32	16.00
35-39.9	10.32	9.03	4.56	30.15	0.151079	139.37	393.17	13.04
40-44.9	5.16	6.45	3.25	25.60	0.127119	119.85	253.80	9.92
45-49.5	3.87	13.33	6.72	22.34	0.300971	94.90	133.95	6.00
50-54.9	30.96	30.96	15.62	15.62	1	39.05	39.05	2.50

NAN Ruin abridged composite life table (Transitional Period).

Years	NAN Dx	Dx Smoothed	dx	lx	qx	Lx	Tx	ex
0-0.9	3	3.00	9.14	100	0.091389	95.43	2491.25	24.91
1-4.9	5	5.00	15.23	90.86	0.167635	332.98	2395.82	26.37
5-9.9	7	5.00	15.23	75.63	0.201396	340.07	2062.84	27.28
10-14.9	3	4.00	12.19	60.40	0.201748	271.53	1722.77	28.52
15-19.5	2	1.67	5.08	48.21	0.105307	228.37	1451.25	30.10
20-24.9	0	1.29	3.92	43.14	0.090866	205.88	1222.87	28.35
25-29.9	1.86	1.24	3.78	39.22	0.096323	186.64	1017.00	25.93
30-34.9	1.86	1.86	5.67	35.44	0.159885	163.03	830.36	23.43
35-39.9	1.86	1.24	3.78	29.77	0.126876	139.42	667.33	22.41
40-44.9	0	1.24	3.78	26.00	0.145313	120.53	527.91	20.31
45-49.5	1.86	1.24	3.78	22.22	0.170018	101.65	407.38	18.34
50-54.9	1.86	1.24	3.78	18.44	0.204846	82.76	305.73	16.58
55-59.9	0	1.24	3.78	14.66	0.257618	63.87	222.98	15.21
60-64.9	1.86	0.62	1.89	10.89	0.173507	49.71	159.11	14.62
65-69.9	0	0.62	1.89	9.00	0.209932	40.26	109.40	12.16
70-74.9	0	0.00	0.00	7.11	0	35.54	69.14	9.73
75-79.9	0	0.58	1.78	7.11	0.25	20.27	33.60	4.73
80+	1.86	1.75	5.33	5.33	1	13.33	13.33	2.50

VITA

Aline A. Lovings is a native of France, where she graduated from high school in 2001. She came to the United States to pursue her higher education, first attending Blinn College in Brenham then transferring to Texas A&M University. She received her Bachelor of Arts degree in anthropology in May 2006 and entered the physical anthropology graduate program at Texas A&M the following fall. She received her Master of Arts degree in December 2011.

As an undergraduate student she volunteered at the Center for the Study of the First Americans, working on material from the Vernor Site in Clute, TX and on the Gault Site in Salado, TX. She also worked on a variety of projects on three continents: at the Pointe du Hoc in Normandy, France in 2005, at the Buttermilk Creek Site in Salado, TX in 2006, at the Meloding Railroad Cutting Site in Meloding, Free State, Republic of South Africa in 2007 and at the Place de la République Site in Luxeuil, France, her native grounds, in 2009. Her research interests include paleodemography, migration, diet and health in prehistoric societies and paleopathology.

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