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A COMPARISON OF MISSISSIPPIAN PERIOD SUBADULTS FROM THE MIDDLE CUMBERLAND AND EASTERN REGIONS OF TENNESSEE TO ASSESS HEALTH AND PAST POPULATION INTERACTIONS

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To the Graduate Council:

I am submitting herewith a dissertation written by Rebecca Scopa Kelso entitled "A COMPARISON OF MISSISSIPPIAN PERIOD SUBADULTS FROM THE MIDDLE CUMBERLAND AND EASTERN REGIONS OF TENNESSEE TO ASSESS HEALTH AND PAST POPULATION INTERACTIONS." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

Benjamin M. Auerbach, Major Professor

We have read this dissertation and recommend its acceptance:

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(Original signatures are on file with official student records.)

A COMPARISON OF MISSISSIPPIAN PERIOD SUBADULTS FROM THE MIDDLE CUMBERLAND AND EASTERN REGIONS OF TENNESSEE TO ASSESS HEALTH AND PAST POPULATION INTERACTIONS

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ABSTRACT

Human subadult skeletal remains can provide a unique perspective into biosocial aspects of past populations. However, for a variety of reasons, they are often overlooked in the skeletal record. This is especially true for the Mississippian period (ca. 1000 years before present to ca. 400 years before present) populations that inhabited the Middle Cumberland region (MCR) and Eastern Tennessee Region (ETR). Most of the previous studies of these areas focused on adult skeletal remains, leaving out a large and extremely important population segment. To further expand current knowledge on the prehistory of the MCR and ETR, skeletal indicators of disease, growth, body proportions, and metabolic stress were investigated among the subadult remains from four archaeological sites. Crucial to overcoming limitations associated with the osteological paradox, the biological results were placed into an archaeological context based on prior studies as well as paleoclimatological data.

Results demonstrate a high degree of homogeneity both within and between regions for most skeletal indicators investigated. Within the ETR, there is no evidence for biological differences between the Early Dallas and the later Late Dallas and Mouse Creek cultural phases; this finding is consistent with previous studies of adult skeletons. Despite the presumed signs of increased conflict at the Dallas site, rates and types of skeletal pathology and growth disruptions are comparable to other sites in the region. These findings suggest there was no large-scale incursion of an outside population into

the ETR during the Late Mississippian Period, or if one occurred, it is biologically invisible.

Cultural differences between the ETR and MCR have been clearly demonstrated in previous studies. Although the skeletal data for the two regions are similar in many respects, there are several noteworthy differences. Namely, the subadults from the ETR display a higher frequency of pathology than those from MCR, while stature is significantly lower in younger subadults from the MCR. These results, combined with climatic and archaeobotanical data, suggests that the MCR subadults were under increased stress, especially during their earlier years. This may have been associated with increased interpersonal violence and dependence on few food sources occurring with greater scarcity.

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CHAPTER 1: INTRODUCTION

Despite what human subadult skeletons may reveal about past populations, researchers have generally overlooked subadults in their assessments of the effects of subsistence, evidence for group affinities, or aspects of health among Mississippian period (ca. 1000 years before present to ca. 400 years before present) peoples (Gottlieb, 2000; Kamp, 2001; Schwartzman, 2005; Chapeskie, 2006). Instead, researchers have focused on adult dental and skeletal data to document the instances of disease processes, trauma, and signs of subsistence differences (Berryman, 1981; Auerbach, 2011). The only exception is Ghalib (1999), who analyzed the health of a subadult population from a single site in northeastern Arkansas from the Middle Mississippian period.

Subadult health and nutritional status are powerful indicators of overall population responses to environmental stressors. Health can be considered to be a dynamic state in which a person is able to function well physically, mentally, socially, and spiritually in the absence of disease. Health maintenance requires constant modifications to thrive within the environment in which one is living. In the words of René Dubos, "[t]he states of health or disease are the expressions of the success or failure experienced by the organism in its efforts to respond adaptively to environmental challenges" (Dubos, 1959). Nutritional status is commonly considered to be the extent to which nutrients are available to meet the metabolic needs of an individual. Subadults comprise that portion of a population considered to be immature adults. "Subadult" has many different connotations, which will be discussed in detail in Chapter 3, but for use

in this dissertation, subadult will refer to a *biologically/skeletally* immature individual. These skeletally immature individuals require higher amounts of nutrients and resources to grow and mature properly, therefore when a population is experiencing biological stressors, subadults will often be the first ones affected.

This dissertation investigates indicators of disease, growth, skeletal proportions, and metabolic stress in subadults of the Mississippian period who lived in the Middle Cumberland and western Appalachian regions of central and eastern Tennessee, respectively (highlighted in Figure 1.1). Previous studies have compared these indicators among adults from these regions (Boyd, 1984; Schroedl, et al., 1990b; Boyd and Boyd, 1991). Despite the existing research, though, the interactions and influences of central Tennessee Mississippian period peoples with those from eastern Tennessee are ambiguous. By combining the results of this dissertation with conclusions and evidence drawn from prior studies, this research seeks to further illuminate differences and possibly establish evidence for interactions among Mississippian groups from these two different regions. To accomplish this, much of the evidence obtained from skeletal remains may be assessed against known changes that occurred in climate and culture (Anderson, et al., 1995; Schurr and Schoeninger, 1995; Cobb and King, 2005). From the results, this study will expand the knowledge of variation in lifeways among Mississippians, as well as refine the understandings of differences and potential interactions between groups of the two Tennessee regions.

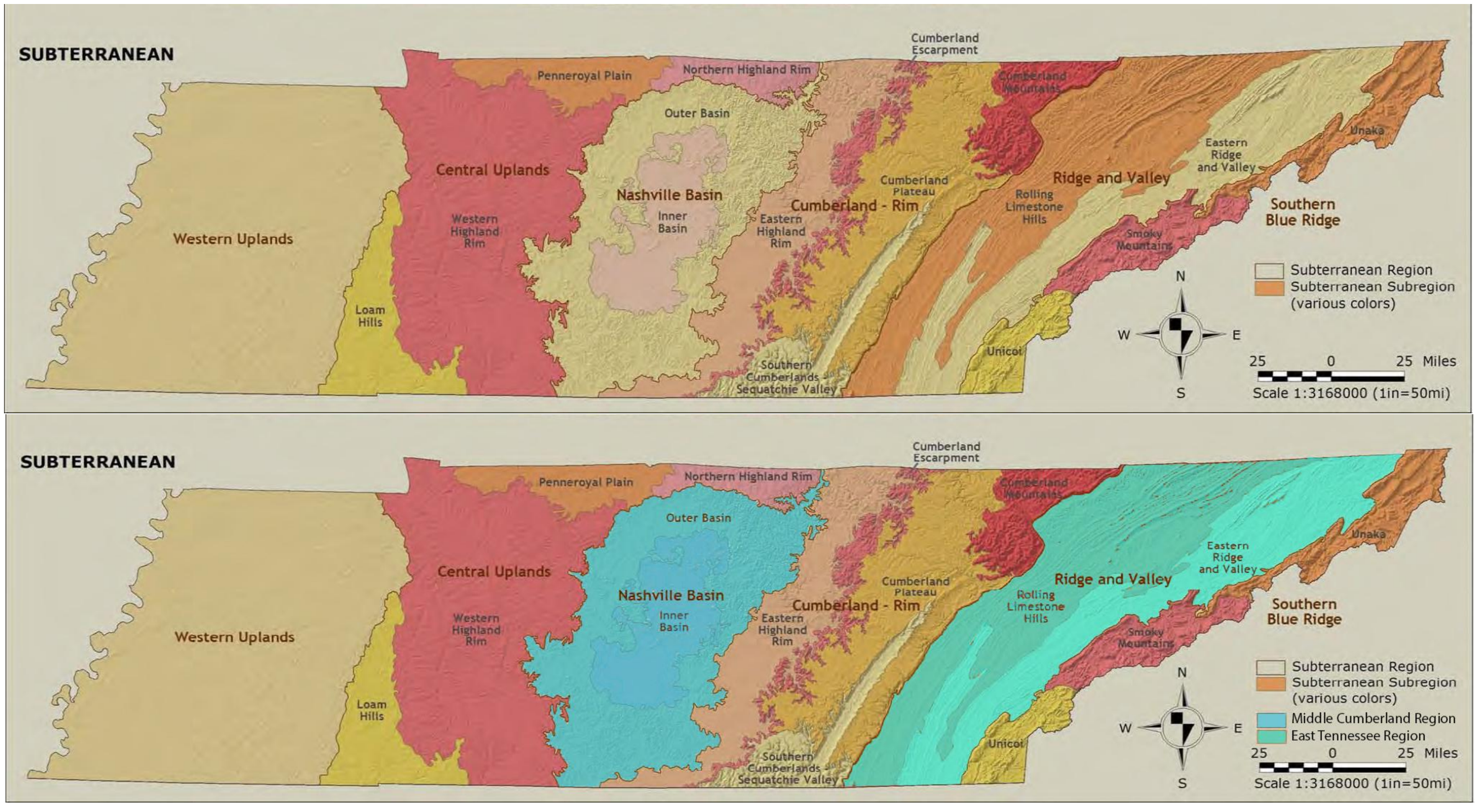

Figure 1.1 Geologic Map of Tennessee from the Department of Environment & Conservation, State of Tennessee

The comparison of the Middle Cumberland and East Tennessee Regions is of special interest given the archaeological and paleoclimatological contexts for these regions. As will be discussed in more detail in Chapter 2, climatological and archaeological data both strongly indicate that Mississippian Period peoples (henceforth, "Mississippians") depopulated the Middle Cumberland region (as well as parts of the Mississippi Valley) toward the end of the fifteenth century, which coincided with extended droughts that marked the end of the Middle Mississippian period (Cook et al, 2007; see Chapter 2). Sites like the Middle Mississippian period village and cemetery at the Averbuch site in Davidson County were abandoned. Also during the middle fifteenth century, among Mississippians in the western Appalachian region of eastern Tennessee, the Mouse Creek cultural phase appeared alongside the Dallas cultural phase, the latter being an archaeological tradition that started during the previous century. Cultural changes in eastern Tennessee occurred around the same time period as the apparent depopulation event that occurred in the Middle Cumberland, including changes in at least a portion of the region (Sullivan, 1986), as well as the scorching and abandonment of the Dallas site (Sullivan, 2007, 2009). The factors that contributed to these changes, and whether or not they were related between the two regions, even causally, remains unresolved. However, documented differences between and within these regions, especially just before and after the climatic anomalies in the Middle Cumberland, provide tantalizing evidence that elicits further study.

Throughout the Mississippian period, communities generally experienced a rapid increase in population throughout the Southeast. Demographic expansions without concomitant increases in food production, or increased reliance on less diverse food sources, would have likely caused biological stress on communities as a whole (Schurr and Schoeninger, 1995). The stresses associated with larger, more densely populated communities, coupled with the drought conditions that occurred in the Middle Cumberland region, could have created a hostile environment both culturally as well as biologically (Anderson, et al., 1995; Cobb and Butler, 2002; Cook, et al., 2007; Benson, et al., 2009; Hsiang and Burke, 2013; Hsiang, et al., 2013). Thus, one hypothesis assessed by this study is that central groups from the Middle Cumberland Region, facing drought and climatic variability, moved south and then northeast (around the Cumberland Plateau) to more suitable environments (see Figure 1.1). This population displacement may have then affected social structure and group interactions in the eastern Tennessee region, leading to increased violence (as evidenced, possibly, by the construction of palisade walls and the burning of the village at the Dallas site), as well as increased sources of individual metabolic stress.

To document potential evidence for change in populations in both regions, it is important to observe the biological indicators of poor health—e.g., markers left by disease or other metabolic stressors—reported in prior research on the adult skeletal remains. In the Middle Cumberland, skeletal research has primarily utilized remains recovered from the Averbuch site. Early studies by Berryman (1975, 1981) documented

signs of disease and metabolic stress in that sample. This was followed up by a number of studies that examined adult dental variation and dental health at Averbuch (e.g.,(Jablonski, 1981; Muendel, 1997; Hamilton, 1999), as well as more recent research among multiple Middle Cumberland sites examining evidence for trauma and warfare among the Averbuch site skeletons (Worne, 2011; Vidoli, 2012).

This knowledge concerning the biological indicators of individual health, and thus population resilience to the climatic changes occurring in the Middle Cumberland region during the Late Mississippian Period, is especially interesting when contrasted against various Middle to Late Mississippian sites in eastern Tennessee. Importantly, McCarthy (2011) demonstrated that the frequencies of indicators of individual adult health varied among Mississippian groups living in eastern Tennessee; some sites had more evidence for poor health than others. Harle (2010) and McCarthy (2011) showed biological and cultural differences between adult Mississippian groups living in northern Georgia and eastern Tennessee, but also significant outliers (namely, the Hixon site) within eastern Tennessee, as well as some evidence for population consolidation during the Late Mississippian in eastern Tennessee. The role that central (Middle Cumberland Region) Tennessee groups might have played in these population dynamics, however, has not been established.

By comparing skeletons and their proportions from the sites in the two regions, evidence for biological differences may be established, which in turn provide evidence for two essential topics (Auerbach, 2011; Auerbach and Sylvester, 2011; Auerbach,

2012): relative health and biological affinity. First, were growth, metabolic stress, and the presence of disease different between the central and eastern Tennessee Mississippians? If the indicators for these were dissimilar between the regions, or even within eastern Tennessee, this could indicate a number of discrepancies in cultural practices (e.g., weaning age, weaning foods, childhood activities, etc.). Were samples from the Early Dallas Phase in eastern Tennessee different from the Late Dallas and Mouse Creek Phases in east Tennessee or Dallas Phase sites different from Mouse Creek Phase sites, then this could indicate changes in cultural or subsistence practices within eastern Tennessee, which in turn might have resulted from local changes or as a consequence of an incursion of Middle Cumberland (or associated) groups.

Second, do subadult skeletal proportions provide insight into whether Middle Cumberland peoples were biologically distinct (that is, unrelated) from later Mississippian sites in eastern Tennessee, especially during and after the depopulation event? Even if no differences in disease and growth indicators were observed between the Middle Cumberland and eastern Tennessee samples, the results cannot reject easterly population movement because growth patterns and health indicators are culturally and nutritionally dependent; cultural malleability could cause changes, for example, in weaning practices, which would cause convergences in the biological evidence based on skeletal health indicators. Some skeletal morphologies, as explored in Chapter 3, are less changeable by these kinds of environmental shifts (such as limb proportions; Auerbach,

2010), and thus distinctions in those would suggest Middle Cumberland peoples would be evident among eastern Tennessee Mississippians, or vice versa.

The results of this study are not intended to suggest all-or-nothing models for biological and cultural interactions between the regions under examination. Evidence from multiple sources, including the analysis of archaeological materials, site construction, mortuary practices, and demography, among others, would be necessary to construct a model for Middle to Late Mississippian interaction networks in central and eastern Tennessee. While some of these previous data are taken into consideration, as introduced in the following background chapters, a full reconstruction of group interactions and dynamics in this Mississippian region is beyond the scope of this dissertation. Rather, the data and analyses presented in the following pages reflect the contribution of subadult data toward better understanding and interpreting the factors causing variation among Mississippians in this region, especially as informed by climatic and cultural differences.

To assess these topics and their associated questions, subadult skeletons from five sites were measured and evaluated for a number of biological markers. All sites are Middle to Late Mississippian in age (Figure 1.2). The eastern Tennessee sites include Mouse Creek Phase (A.D. 1400-1600) Ledford Island, and Late Dallas Phase (A.D. 1400-1600) Fain's Island and Cox Village sites, as well as the Dallas Phase (A.D. 1300-1400) type site, Dallas mound and village. The Thruston Phase (A.D. 1250-1450) Middle Cumberland

Region Averbuch site was used as a central Tennessee comparison. More information about these sites is provided in Chapter 4.

Figure 1.2 Location of the sites used in the present study

Analyses of biological data in this study focus on three areas of investigation. Linear growth via comparisons of limb bone development relative to dental development as a standard is evaluated among the four eastern Tennessee sites, as well as between central and eastern Tennessee regions. Likewise, body size (i.e., body mass and stature) and proportions are compared between the regions, as these have been used in other studies (e.g., Auerbach, 2010, 2012) as evidence for population movement between regions, or differences in diet and/or metabolic stress. Finally, the patterns and presence of health indicators of disease and stress are examined, especially those related to dietary stress, such as enamel hypoplasias. These data and their analyses are discussed within the context of the archaeological and prior biological evidence presented for these regions.

Organization of Chapters

The first two chapters provide the archaeological and biological anthropological background and theory for this study. Chapter 2 compiles the published information about the cultures of populations living in the Middle Cumberland and eastern Tennessee regions during the Mississippian Period. Most of these published analyses have based their interpretations of adult human data, whether biological or archaeological (in that the artifacts and sites are most likely reflective of adult behaviors). The goals and hypotheses of this dissertation are then presented. In Chapter 3, current knowledge about normal biological growth and health of children is detailed, as are the biological indicators of metabolic stress and growth stunting that may be found in archaeological populations when children are growing under less than optimal conditions. These are especially considered within the context of the osteological paradox, which dictates how we

interpret the presence of disease indicators in the skeleton. In this light, Chapter 3 discusses the role that evaluation of skeletal growth and health indicators has in the behavioral interpretation of past populations.

Analyses of the five sites depicted in Figure 1.2 follow this background. Site descriptions and summaries of adult mortuary practice trends for each are provided in Chapter 4. Chapter 5 describes the skeletal samples used in this study and, following the theoretical background provided in Chapter 3, this chapter provides the methodology implemented in data collection and analysis. Statistical results and a summary interpretation of their implications are presented in Chapter 6. Chapter 7 discusses of how these findings can be interpreted in light of the goals and hypotheses summarized above and in Chapter 2, which further broadens the understanding of these population groups and how they interacted during the Mississippian Period. A theme that emerges from this study is that the potential information to be gleaned from the study of subadult remains highlights the need for further research in the bioarchaeology of Mississippian subadults; they provide subtleties in the interpretation of cultural and environmental effects not available by examining adult human remains alone.

CHAPTER 2: ARCHAEOLOGICAL BACKGROUND

The Mississippian Period (A.D. 1000-1600) provides a complex archaeological record. The recency of the period, its conspicuous sites (due to locations in floodplains and the construction of earthen mounds), and good taphonomic preservation at those sites provide a thorough archaeological record and highly visible study populations. This allows for the study of variation in the activities, culture, and health of the people who lived during this time.

During the Mississippian Period, in what is currently the state of Tennessee, there were a number of cultural groups present. Their cultural differences may have, in part, been influenced by different uses of local resources; viable access to water and available arable land, as well as cultural choices. For example, archaeobotanical evidence from both the eastern and central regions of Tennessee shows increasing dependence on maize throughout the Mississippian Period, but that there was regional variation in its prevalence, as well as the presence of additional local crops (e.g., sumpweed, goosefoot, and sunflower) (Smith, 1992; Crites, 1993; Harle and Meeks, 2013). To this point, as explored briefly below, the Middle Cumberland Averbuch site has been interpreted to show increased reliance on maize to the exclusion of the local cultivars. This crop monoculture focus would have led to poor nutrition and increased dietary stress, especially during times of drought (Crites, 1984a). In contrast, geographic conditions in some areas of eastern Tennessee, including narrow floodplains and limited agricultural soils, may have limited the amount of maize that could be grown (Harle and Meeks 2013), and thus reliance on wild foods was greater than in the Middle Cumberland.

The high level of dependence on maize agriculture at the Averbuch and other Middle Cumberland sites is especially important in light of a major climatic shift that occurred in the Southeast late in the Mississippian Period, but that only directly affected the Central and western portions of Tennessee; there is no evidence for a major effect on the subsistence and demographics of groups living in the eastern Tennessee region (Meeks, 2009). Such disparity in the effects of the Late Mississippian climatic anomaly caused unfavorable conditions for agriculture in the Middle Cumberland, leaving the inhabitants of that region without the food and resources that continued to be sufficiently abundant toward the east. It is hypothesized that during this time of climatic changes in the western and central parts of the state, there was a nearly complete migration of the people out of the affected region (the "Vacant Quarter" hypothesis), which coincides with documented cultural changes taking place in the eastern region (Williams, 1980, 1990; Cobb and Butler, 2002). It is this regional pattern that forms the archaeological context under which the analysis of subadult skeletons from the Mississippian Period is undertaken in this dissertation.

Definition of Mississippian Period

Before exploring the distinctions between the Mississippians who lived in the Middle Cumberland and eastern Tennessee regions, a tailored discussion of the Mississippian Period and culture is in order. Radiocarbon dates have temporally placed the Mississippian culture starting around A.D. 1000 and ending by A.D. 1600, at the time of European contact in the Southeast (Cobb, 2003). Holmes (1903) originally defined archaeological sites Mississippian based on association with shell-tempered pottery, but

this narrow definition was eventually expanded to include a suite of characteristics associated with large settlements (i.e., towns) containing platform mounds and plazas, shared iconography, elaborate mortuary practices, and agricultural intensification (Muller, 1989; Cobb, 2003). Dependence upon agriculture was a critical aspect in the shift from the preceding Late Woodland to the Early Mississippian cultures (Steponaitis, 1986).

Beginning in the Early Mississippian Period (approximately A.D. 1000 to A.D. 1200) in eastern Tennessee, native people began to construct earthen platform mounds in addition to the conical burial mounds already in use (Lewis and Kneberg, 1946; Schroedl, et al., 1990a). Similar platform mounds also were constructed in the Middle Cumberland region about the same time (Moore and Smith, 2009). These earthen mounds usually had an associated ceremonial structure built atop them and in some areas were sometimes associated with charnel houses, elite residences, elite burials, or a public ceremonial center (Griffin, 1967; Steponaitis, 1986; Vogel, 2007). These mounds are physical evidence of widespread cultural changes that may have had their beginnings in the Central Mississippi Valley at the Cahokia site (Pauketat and Emerson, 1997; Pauketat, 2004, 2009) through a process archaeologists refer to as “Mississippianization.” Mississippian villages often had residential areas surrounding the platform mound and a plaza, which served as the focus for community ceremonial activities.

In some areas, population growth may have created competition between neighbors for resources, and factionalism and violence became more common later in the Mississippian Period, though this varied among regions (Smith, 1992; Bridges, 2000; Worne, 2011). Violence may have escalated especially in the drought-stricken areas as

people dealt with the problem of decreased food supplies. This situation illuminates a possible reason behind the Mississippian characteristic of defensive structures such as palisades around villages and their public spaces (Griffin, 1967; Milner, et al., 1991; Moore, et al., 2006).

A problem with this description of Mississippian Period settlement patterns, subsistence, and their effects on group interactions is that it ignores the regional variation that occurred as Mississippian culture formed and proliferated (Muller and Stephens, 1991). Local traditions and subsistence pattern variants were the norm among Mississippian groups. The two Mississippian regions under study herein—Middle Cumberland and East Tennessee—are two examples of these patterns of diversity.

Defining the Geographic and Temporal Boundaries of the Study Regions

As noted above and in Chapter 1, the sites examined in this dissertation are located in two regions located within present-day Tennessee. The Middle Cumberland region is defined as encompassing the area labeled as the Inner and Outer Central Basin and surrounded by the Eastern, Western, and Northern Highland Rim regions (Figure 1.1) (Smith, 1992; Moore, et al., 2006). This region surrounds present-day Nashville, Tennessee, and is bordered on the east by the Caney Fork and Cumberland Rivers and on the west by the Cumberland and Red Rivers. The East Tennessee region, which borders the western foothills, ridges, and ranges of the Appalachian Mountains in the region (i.e., the Western

Table 2.1: Mississippian Period Cultural Phases of the Middle Cumberland and Upper Tennessee Valley Regions

<table>
<tr><td colspan="4">Mississippian Phases</td></tr>
<tr><td>Century</td><td>Middle Cumberland Region[1]</td><td colspan="2">Upper Tennessee Valley East Tennessee Region[2]</td></tr>
<tr><td>A.D. 1800</td><td rowspan="2">Shawnee</td><td colspan="2" rowspan="2">Overhill Cherokee</td></tr>
<tr><td>A.D. 1700</td></tr>
<tr><td>A.D. 1600</td><td>Vacant</td><td rowspan="2">Dallas</td><td rowspan="2">Mouse Creek[3]</td></tr>
<tr><td>A.D. 1500</td><td>Period V</td></tr>
<tr><td>A.D. 1400</td><td>Period IV</td><td colspan="2">Dallas</td></tr>
<tr><td>A.D. 1300</td><td>Period III</td><td colspan="2" rowspan="2">Hiwassee Island</td></tr>
<tr><td>A.D. 1200</td><td>Period II</td></tr>
<tr><td>A.D. 1000</td><td>Period I</td><td colspan="2" rowspan="2">Martin Farm</td></tr>
<tr><td>A.D. 900</td><td></td></tr>
</table>

[1]after Moore and Smith, 2009
[2]after Schroedl, 1998
[3]after Sullivan 1986, In Press; Sullivan and Harle, 2010

Blue Ridge Mountains), is defined as encompassing the area labeled as the Ridge and Valley on Figure 1.1. This region is bordered to the east by the Southern Blue Ridge (Unaka Mountains and Unicoi Mountains) and to the west by the Cumberland Plateau and Mountains.

Mississippian Period Chronology in the Middle Cumberland Region

The "Middle Cumberland" or "Stone Box" culture was first defined by Ferguson (1972). Within the Middle Cumberland region, Mississippian culture flourished between the thirteenth and fifteenth centuries, but began around A.D. 1000 with small hamlet style communities (Berryman, 1981; Smith, 1992; Smith and Moore, 1996). People within this region were generally buried in stone-lined boxes, unlike the mostly unlined flexed or extended burials found in at the East Tennessee Regional sites (Smith, 1992; Smith and Moore, 1996).

After a close examination of over 3000 artifacts from over a substantial portion of the Middle Cumberland Region, Moore and Smith (2009) redefined the phases for the Mississippian Period in the region by expanding the original two phases into five periods (Table 2.1), all referred to as Regional Periods. Regional Period I (A.D. 1000-A.D. 1100) is defined by small dispersed mound sites in the western portion of the Middle Cumberland Region and farms and hamlets to the east. Few residential burials were preserved from this time, which undermines attempts to establish any mortuary pattern. Regional Period II (A.D. 1100- A.D. 1200) experienced an increase in population, coupled with evidence for the rise of chiefdoms throughout the region. During this period, there was also an increase in use of stone box graves near residential areas.

During Regional Period III (A.D. 1200-A.D. 1325), the population continued to increase, and Moore and Smith (2009) argued that there is evidence for a hierarchy of mounds and increased social complexity in the region. During Regional Period III, within residential areas, the use of stone box graves became more common, at times being incorporated into platform burial mounds. Thus, the first three Regional Periods embody increasing population sizes along with increasing social complexity in the form of chiefdoms. However, Moore and Smith (2009) describe Regional Period IV (A.D. 1325-A.D. 1425) as a period of fission where the political focus was pulled away from a centralized authority and concentrated within villages; the previously larger mound centers begin to devolve into smaller, more dispersed villages. Many of these smaller villages were fortified with palisades and did not contain a ceremonial mound. The mortuary patterns during this period consisted of large residential cemeteries with the infants being buried within the village homes; this is typified at sites like Averbuch, the Middle Cumberland site examined in this study. The final period, Regional Period V (A.D. 1425-A.D. 1475), is differentiated by a precipitous decrease in population. By the end of Period V, the population was at such low numbers that Moore and Smith (2009) characterized it as archaeologically invisible.

Mississippian Period Chronology in the East Tennessee Region

In contrast with the Middle Cumberland region, the Mississippian culture in East Tennessee was characterized by multiple traditions, some of which were concurrent and/or related, while others had ambiguous relationships. Burial mound construction was already present in the region during the Late Woodland Period, and continued into the

early Mississippian period when construction of platform mounds began (Schroedl, et al., 1990a). Unlike the Middle Cumberland, the region was populated through European contact, with a visible archaeological record extending after the end of the Mississippian Period (Sullivan, in press).

In the Upper Tennessee River Valley of East Tennessee, the Mississippian Period is divided into four phases: Martin Farm Phase, Hiwassee Island Phase, Dallas Phase, and Mouse Creek Phase (Table 2.1). The Dallas Phase and the Mouse Creek Phases occur simultaneously except along the lower Hiwassee River and nearby sections of the Tennessee River where these four phases are successive, with the Mouse Creek Phase following the Dallas Phase (Sullivan, 2009; Sullivan and Harle, 2010; Sullivan, in press). The possibility of migrations into eastern Tennessee has long been suggested by archaeologists (Schroedl, 1998). From the 1930s well into the 1960s, researchers argued that an influx of Creek ancestors into the region spurred the transition from Woodland culture to Mississippian culture in East Tennessee and that the Mouse Creek Phase represented an intrusion of people from Middle Tennessee (Lewis and Kneberg, 1946; Lewis, et al., 1995). After thorough analysis of the type-site Martin Farm (40MR20), as well as, analysis of other Early Mississippian sites, researchers (Schroedl, et al., 1990a) determined that Mississippian culture developed in situ in East Tennessee without replacement of the local population by an outside population (Chapman, 1994; Sullivan, 1995; Schroedl, 1998).

The first phase of Mississippian Culture in the East Tennessee Region, the Martin Farm Phase, spans from approximately from A.D. 1000 to 1100 (Schroedl, et al., 1990a; Sullivan and Koerner, 2010). This phase was first defined by Salo in 1969 and represents

the transition from Late Woodland culture to a true Mississippian cultural horizon. The suite of traits that encapsulates the Martin Farm phase is a mixture of plain and cord-marked limestone-tempered pottery, but there are also instances of loop handles and jar forms. Shell-tempered pottery, which became the standard pottery manufacture method during the Mississippian Period, was explored in a few cases (Kimball and Baden, 1985; Schroedl, et al., 1990a; Sullivan and Koerner, 2010). Other than a higher reliance on agriculture—namely increased corn production—and the slight changes in pottery noted above, the culture, as preserved in the archaeological record, remains mainly the same as the Late Woodland. Occasionally, small platform mounds were built as ceremonial centers, but during the Martin Farm Phase people continue to live in dispersed, semi-permanent settlements as they did during the Late Woodland (Sullivan and Koerner, 2010; Sullivan, in press). Mortuary practices also remained fairly constant: deceased individuals continued to be buried in Hamilton Mounds, which are conical shaped burial mounds set away from the habitation sites (Lewis and Kneberg, 1946; Schroedl, et al., 1990a).

Shortly after the slight cultural changes associated with the Martin Farm Phase, cultural and archaeological distinctions associated with the Hiwassee Island Phase occurred; this phase spanned approximately from A.D. 1100 to A.D. 1300. Lewis and Kneberg (1946) first defined this phase based on their excavations of Hiwassee Island site (40MG31) and the surrounding area. This phase is defined by shell-tempered pottery, loop handled and flared rim jars, as well as some wall-trenched buildings. Schroedl (1998) noted that more formalized villages were formed during this phase, with a centralized plaza surrounded by community buildings. In contrast with Late Woodland

(i.e., Hamilton) sites and Martin Farm Phase settlements, there are platform mounds either within the village or nearby. For most of the Hiwassee Island Phase, the mortuary practices remained mostly unchanged from the Late Woodland Period; individuals continued to bury the dead in Hamilton mounds. However, in the last century of the phase (A.D. 1200-A.D. 1300) there was a significant shift in mortuary practices, especially in the southern part of the region. Burials became more elaborate, were located within the platform mounds, and contained many more associated goods. Some researchers regard this shift as resulting from influence by and alliance with culture groups to the south in northern Georgia (Sullivan and Humpf, 2001; Cobb and King, 2005; Sullivan, 2007, 2009, in press).

Lewis and Kneberg (1946) proposed the subsequent Dallas Phase (A.D. 1300-A.D. 1650) based on continuing changes in mortuary practices (mentioned above), as well as alterations in architecture style in village sites. The characteristic small post and wall-trench buildings of the Martin Farm and Hiwassee Phases were replaced by single-set, large log structures. Villages became consolidated and the population during this phase increased (Schroedl, 1998). Another distinguishing characteristic of the Dallas Phase, in contrast with the Hiwassee Island Phase, was the location of burials. The dead were regularly placed in a flexed position and interred in public platform mounds, as well as in house floors and adjacent residential cemeteries. Continuing a trend that began in the Late Hiwassee Island phase, burials became more elaborate, containing more associated mortuary artifacts, such as marine shell gorgets, beads, and earpins, pottery vessels, triangular projectile points, clay or groundstone pipes, and a variety of bone and groundstone tools (Lewis and Kneberg, 1946; Lewis, et al., 1995).

The final phase of the Mississippian Period in the southern part of the East Tennessee region was the Mouse Creek Phase (A.D. 1400 until circa A.D. 1600). Lewis and Kneberg (1946) noted differences between the Dallas Phase pottery and that of the Mouse Creek Phase, which was one basis for the designation of their distinctions; while both were still shell-tempered, Dallas Phase pottery more typically was cordmarked while Mouse Creek Phase pottery was plain. In the settlements, the most striking difference between Dallas Phase sites and Mouse Creek Phase sites was the lack of mound building during the latter phase. Although villages continued to be arranged in a formal layout with a central plaza, they were no longer associated with a mound, platform or otherwise. Additionally, burials continued to be interred in village and residential cemeteries, but were laid out in an extended position at Mouse Creek Phase sites. Infants and subadults were commonly buried within the houses to the exclusion of adults. The Mouse Creek Phase is geographically limited to the lower Hiwassee River and the section of the Tennessee River near the mouth of the Hiwassee. Radiocarbon dates only recently have shown that it succeeds the Dallas Phase in Chickamauga and is concurrent with the Dallas Phase elsewhere (Sullivan and Harle, 2010; Sullivan, in press). Protohistoric sites, dating to the early parts of European contact (especially the Spanish entradas) follow the Mouse Creek and Dallas sites in many parts of eastern Tennessee (Dalton-Carriger and Blair, 2013; Sullivan, in press).

Mississippian Mortuary Practices and Social Organization

As noted in the chronologies above, distinctions in mortuary practices are archaeological indicators for cultural phases within the Mississippian Period, as well as differences between regions. In the Middle Cumberland region, an increased use of

limestone-lined (stone-box) graves marked the Mississippian Period, with a decline of their presence only as the region faced depopulation. In contrast, multiple burial practices were found in the East Tennessee region. All ages and both sexes were buried in conical mounds early in the Mississippian Period (carrying on a Late Woodland practice), only with later cultural changes to be interred within platform mounds with elaborate burial goods, or interred within village cemeteries. Subadults were sometimes interred within house structures in both regions, but in eastern Tennessee they were also often interred in cemeteries adjacent to the houses and in the Middle Cumberland region they were interred in stone box cemeteries in areas separate from the houses.

Although archaeologists previously used mortuary practices as a basis for characterizing Mississippian societies as highly ranked chiefdoms similar to those in Polynesia (e,g., Peebles and Kus, 1977) more recently, researchers (Cobb, 2003; Pauketat, 2009; Sullivan and Mainsfort, 2010) have found fault with the interpretation that Mississippian society was typified by the presence of chiefdom model. There is much debate surrounding the notion of regional centralization as a defining feature of Mississippian culture. The archaeological record has been interpreted as providing evidence that certain groups of people accumulated the symbolic and material goods that would have given them some form of authority over the other people of the community (Cobb 2003). The massive building projects—earthen mounds, palisade walls, and other large-scale constructions—are presumed to be material indicators of this influence. It would have required many hours of people working under difficult conditions to construct these structures, but just how much chiefly influence would have been required for populations to organize and build the structures is unclear. Furthermore, differences in

burial artifact types and quantities may not have reflected social rank of the individual buried, but instead could be related to other social or ritual functions (Brown, 2006).

Thus, the nature of social organization among the Mississippians of the Middle Cumberland and East Tennessee regions remains unresolved. What is certain, however, is that social organization did change in both regions over the Mississippian Period. If some centralized authority that controlled resource surpluses were present, the societies may have been more resilient to social stressors—warfare, crop failure, and drought—which would have more quickly decimated self-reliant, smaller groups.

Environment, Climate, and Subsistence

Aside from differences in temporal cultural sequences, settlement organization, and mortuary practices, local environment and subsistence practices were distinctive between the Middle Cumberland and the East Tennessee regions. This section summarizes the differences in crop use and the environments of these two regions. Emphasis is placed on the evidence available for subsistence at the five archaeological sites under study—the Dallas site, Ledford Island, Fain's Island, and the Cox site in East Tennessee, along with Averbuch in the Middle Cumberland. Finally, the climatological factors that potentially contributed to depopulation of the Middle Cumberland region are discussed.

The variation in the quantity of dietary and related resources that each of the sites mentioned below had available was largely dependent upon a combination of environmental factors. Average temperatures, annual rainfall, available farmland, topography, as well as accessibility to water worked together to either promote or inhibit

the growth and health of a site's population. Combinations of these factors also heavily affected the mode of subsistence that was successful at these sites.

East Tennessee Region Subsistence

As noted above, the Mississippian culture of East Tennessee developed, at least in part, as a gradual change from Late Woodland culture. Thus, along with the retention of some site formation and artifacts, the peoples of East Tennessee continued to consume locally domesticated foods, such as sunflower, maygrass, and goosefoot (Jefferson and Crites, 1987; Scarry, 1993). The prevalence of maize in the diet was variable and largely a product of the amount of arable land (though conscious cultural choices about plant use cannot be dismissed).

According to Harle and Meeks (2013), the percentage of arable land was statistically higher in the Chickamauga Basin than in the Douglas and Norris basins. Within a two-kilometer zone, the Dallas and Ledford Island sites in the Chickamauga Basin were surrounded by over 65,000 acres of prime farmland. Fain's Island, in the Douglas Basin, would have had access to around 20,000 acres of farmable land. The Cox site, within the Norris Basin, would have had a mere availability of less than 5,000 acres of farmland. There is also a disproportionate amount of rainfall between these basins due to elevation changes in East Tennessee, inherent to the topography of the region.

The East Tennessee sites in this study are all located in an area called the Ridge and Valley. To the west the of this area the elevation is higher along the Cumberland Plateau, particularly in the area west of the more northern sites, Cox and Fain's Island, which are situated geographically below an area of higher elevation called the Dissected

Plateau (Figure 2.1). This topographic uprising creates a rain shadow to the east, leaving the Norris and Douglas Basins with less precipitation (Figure 2.2). The Chickamauga Basin, containing the Dallas and Ledford Island sites, receives 56-58 inches of rain per year (Harle and Meeks 2013). The region of the Norris Basin—where the Cox site is located—receives between 52-54 inches of rain annually. However, the Douglas Basin, which is in the vicinity of the Fain's Island site, receives only 46-48 inches of rain annually. These differences, therefore, would have contributed to crop use distinctions among the four East Tennessee sites. The Dallas site and the Ledford Island site, both in the Chickamauga Basin, would have received the most rain of the study sites and had access to the highest amount of arable farmland. The Cox site in the Norris basin had slightly less rain than the Chickamauga Basin sites, but had by far the least amount of available farmland. The Fain's Island site in the Douglas Basin received the least amount of rain of the study sites and had considerably less available farmland than the Chickamauga Basin sites, but much more than that of the Cox site.

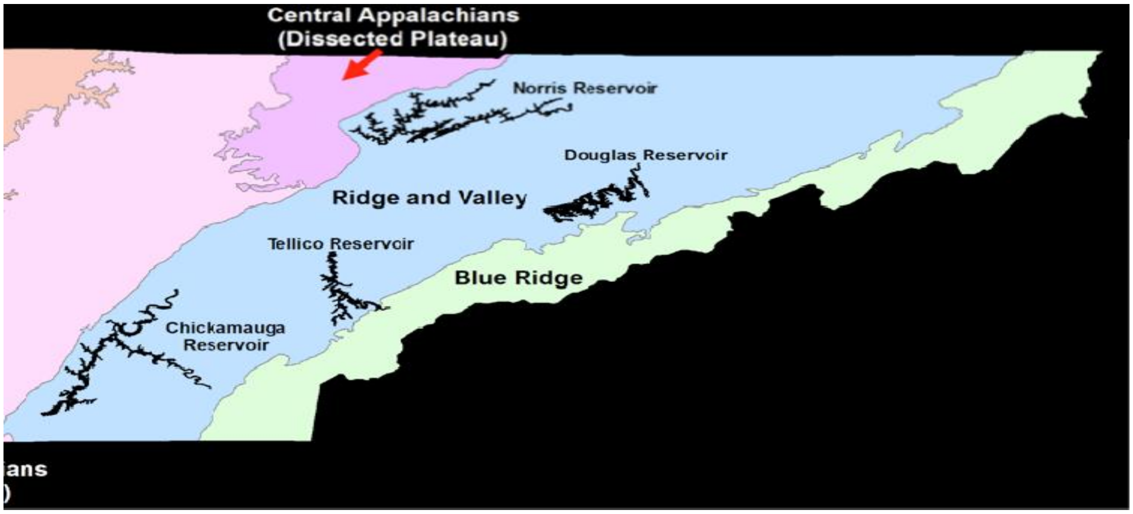

Figure 2.1: Ridge and Valley and the Rain Shadow Effect [reprinted from Harle and Meeks 2013)]

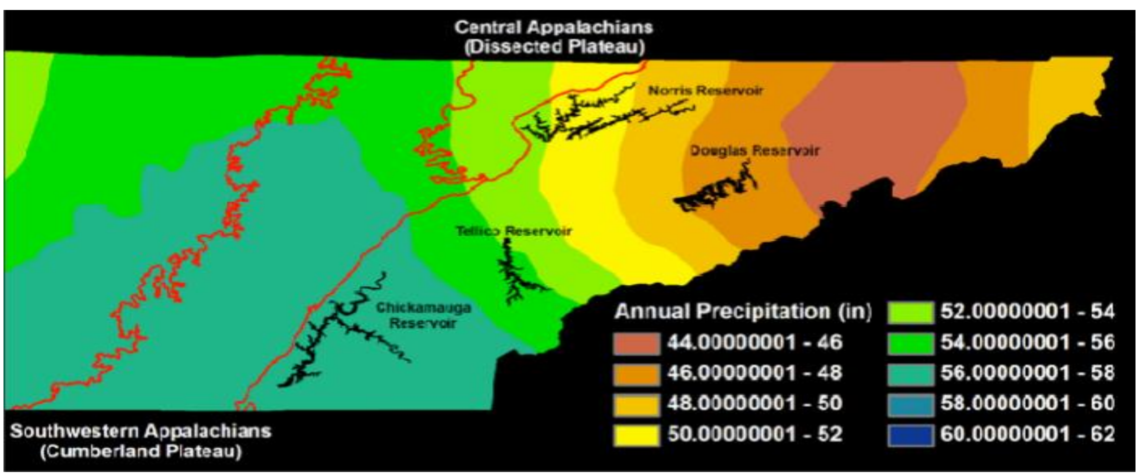

Figure 2.2: Annual Precipitation for the Four Reservoirs [reprinted from Harle and Meeks (2013)]

Based on this geographic situation, conclusions could be made that the people of the Dallas and Ledford Island sites in the Chickamauga Basin relied heavily on agriculture to support their populations and, more specifically, they were more likely to have grown maize as staple crop. The people of the Cox and Fain's Island sites on the other hand, with little or less arable land and rain, were probably much less likely to have been as dependent upon maize as a staple crop, depending on the size of the populations at these sites.

Harle and Meeks (2013) took their analysis of this assumption a step further by comparing instances of dental caries, linear enamel hypoplasias, and severity of calculus accumulation in adults among these sites. Higher prevalence of dental caries and greater accumulation of dental calculus are commonly-used markers of high starch, maize-based diets (Larsen, et al., 1991). Those with a more varied diet tend to have lower incidence rates. Harle and Meeks (2013) found that individuals from Dallas site had a higher percentage of caries that those of individuals from the Cox and Fain's Island sites. Dallas had a higher instance of caries located on anterior teeth rather than on posterior teeth, while in contrast caries were more prevalent on posterior teeth among individuals from the Cox and Fain's Island sites. Calculus was also found in a higher degree on the teeth of adult individuals from the Dallas site than on those from the Cox and Fain's Island sites. Between the Cox site and Fain's Island site, Cox adults had a lower rate of calculus, but a higher rate of caries than Fain's Island adults (Harle and Meeks, 2013). These findings indicate that the people of the Dallas site were relying more heavily on the agriculture of starchy foods, such as maize, for their subsistence and the Cox and Fain's Island sites relied less on such starchy crops, and perhaps were less reliant on agriculture overall.

Middle Cumberland Region Subsistence

Relative to other research involving the Middle Cumberland Region, there have been few studies on the subsistence economies in the region. Overall, the subsistence economy for the Middle Cumberland Region was diverse and included horticulture, hunting, and gathering. However, at the Averbuch site specifically, the subsistence economy relied much more heavily on maize than other sites in the region, as well as sites from the East Tennessee Region (Benthall, 1983; Crites, 1984a, b; Smith, 1992). Averbuch's exact geographical location, which will be discussed further in Chapter 4, limited the access of its residents to resources. These people were far from a major body of water, the Cumberland River, which reduced their access to many food sources. To supplement their diet, Averbuch residents heavily relied on deer as the most exploited faunal resource, while also utilizing rodents, turtles, birds, and fish as additional food supplies (Romanowski, 1984a, b; Smith, 1992). Unlike other Mississippian groups, the residents of the Middle Cumberland seem to have increased their dependency on maize much more quickly to the exclusion of other resources (Buikstra et al. 1988), a trend that is readily apparent at sites like Averbuch; this dependence on maize occurred to the exclusion of the presence of other regional cultivars like goosefoot and sunflowers.

Regional Climatic Shifts

During the Late Mississippian Period (i.e., after A.D. 1300), there were four severe droughts in the American South that lasted nearly a decade each (Cook, et al., 2007) (see Figure 2.3). However, due to elevation changes across the state of Tennessee, some of which

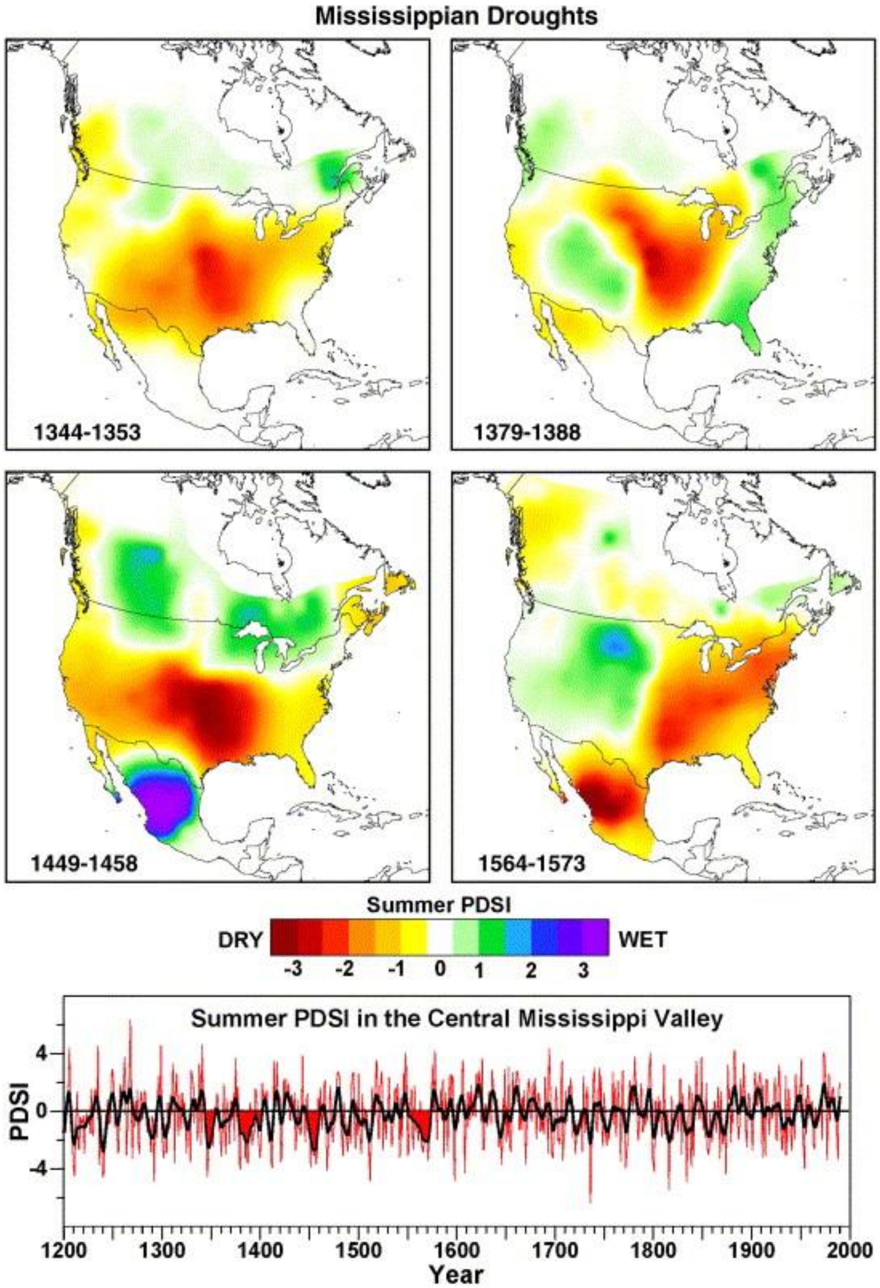

Figure 2.3: The PDSI reconstructions for the central Mississippi Valley (time series for 37.5 N–90.0°W) indicate that the Mississippian droughts of the 14th, 15th and 16th centuries (red shading) may have been the most severe and sustained in 700 yr period (reproduced from Cook et al. 2007).

are noted above, the effect of the droughts was highly variable between the Middle Cumberland Region and the East Tennessee Region. Each of the successive droughts occurring in the Middle Cumberland Region increased in intensity, peaking during the late fifteenth century. The rise of the Cumberland Plateau created a shadow effect, reducing the amount of rain the Middle Cumberland Region received to its west and increasing the amount of rain the Tennessee River Valley received to its east (Harle and Meeks, 2013). The Cumberland Plateau also made travel between the two regions difficult, isolating the western Middle Cumberland from the eastern Tennessee River Valley.

These periods of drought would have created a strain on the resources available in the Middle Cumberland Region. A global study by Hsiang and Burke (2013) showed a pattern of increased interpersonal violence, which would have resulted from the breakdown of social organization that coincided with periods of increased temperatures. Food shortages and increased violence may have resulted in increased illness and death throughout the Middle Cumberland Region's populations, as well as a decline of the overall Mississippian culture in the region.

Similar drought conditions were likely a major factor in the depopulation that occurred in the American Southwest during the twelfth century (Axtell, et al., 2002) (see Figure 2.4). Studies have shown that the severe drought would have greatly impacted water resource access, crop yields, and social structure in the region of Long Valley, Arizona (Gumerman and Dean, 2000). Although the drought would have led to a significant decrease

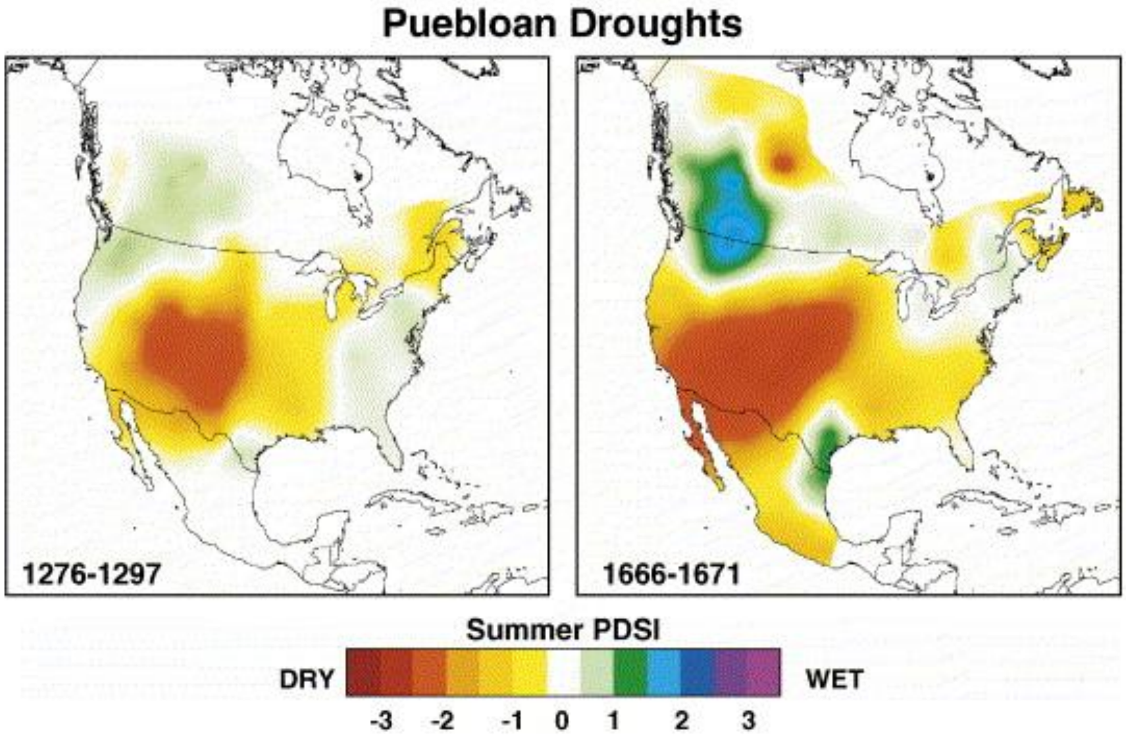

Figure 2.4: Tree-ring reconstructed summer PDSI during two multi-year droughts centered over the Puebloan cultural area.
Similar to the Middle Cumberland, depopulation occurred in the American Southwest during drought periods (reproduced from Cook et al. 2007).

in the available natural and cultivated resources for the area, climate models show that these shortages should not have completely depleted the area beyond the carrying capacity needed to sustain the population. Thus, there must have been cultural factors that combined with the environmental strain imposed by the drought to induce an abandonment of that region (Anderson, et al., 1995; Axtell, et al., 2002; Cobb and Butler, 2002).

Hypotheses and Aims of This Study

Within the archaeological context presented above, this dissertation proposes several questions regarding the populations of the Middle Cumberland and East Tennessee regions. Even before the climatic shifts that led to depopulation events in the central Tennessee region, Middle Cumberland Mississippians at the Averbuch site were already more dependent on maize as a staple crop than residents at East Tennessee sites. This situation would have made the inhabitants of Averbuch more susceptible to the effects of the droughts that began in the mid-fourteenth century and continued into the sixteenth century. It is therefore possible that people from the Middle Cumberland Region, facing drought and climatic variability when the people of the East Tennessee Region were not, moved south and then followed the Tennessee River and Valley northeast into the East Tennessee Region. This population displacement may have affected social structure and group interactions in the Eastern Tennessee Region, leading to increased violence (as possibly evidenced by the burning of villages, namely at the Dallas site). This hypothesized population movement out of the Middle Cumberland

Region into the Eastern Tennessee Region would have then led to increased population sizes and individual biological stress on the people already living in the area.

Analyzing the skeletal remains of subadults is the most effective way to assess a past population's overall health, as subadults are more susceptible than adults to environmental stressors. They therefore function as an early indicator of overall population stress. This pattern is discussed more fully in the next chapter. Moreover, any differences in the effects of subsistence between the sites within East Tennessee, or between that region and the Middle Cumberland, will be evident through differences in growth patterns and pathological conditions. Thus, this study focuses on subadult remains to ascertain regional differences and the possible signs of population movement during the later Mississippian Period.

Of course, any temporal changes in growth and paleopathology patterns within East Tennessee subadult samples does not necessarily correlate with the depopulation event in the Middle Cumberland. No direct evidence has yet been presented to suggest an incursion of Middle Cumberland peoples into Eastern Tennessee. Rather, the presence of artifacts such as gorget styles typically associated with the Nashville area (but which also could be trade goods) (Hally, 2007; Sullivan, 2007), the razing of villages, increases in the prevalence of palisade walls, and other changes among sites, as well as evidence for population aggregation (Meeks, 2009), collectively indicate that there was a demographic and possible cultural change that began in the early Dallas Phase, which coincided with the mid-fourteenth century droughts. Thus, the analyses of this dissertation seek to add to this growing body of evidence for late Mississippian Period changes among groups in Tennessee.

The first hypothesis assessed in this study is that the subadult population from East Tennessee represents a single biological population. Previous biological distance studies comparing both Dallas and Mouse Creek Phase sites from within the East Tennessee Region have found no biological differences between the adults of the East Tennessee (Boyd, 1984, 1986; Boyd and Boyd, 1989; Boyd and Boyd, 1991; Harle, 2010; McCarthy, 2011). Therefore the subadult populations from the East Tennessee Early Dallas Phase and the temporally later Late Dallas and Mouse Creek Phases should be biologically comparable. Additionally, the subadult populations from the East Tennessee Dallas Phase culture group should be biologically equivalent to those of the East Tennessee Mouse Creek Phase culture group. In order to accept the premise of the hypothesis, a comparative skeletal analysis should show that the subadults from the Early Dallas Phase site of Dallas, the Late Dallas sites, Fains Island and Cox, and the Mouse Creek Phase Ledford Island site in the East Tennessee Region had similar body sizes and proportions. Their health should have been very similar as well, evidenced by an equivalent occurrence of dental enamel hypoplasias and trauma. There should also be a similar occurrence of pathology, such as cribra orbitalia and porotic hyperostosis among the Eastern Tennessee Region subadults. If this were not the case then it may be possible evidence for population stress that resulted from demographic shifts, and in turn may be a consequence of regional population dynamics occurring after the central Tennessee region was depopulated.

The second hypothesis tested in this study, then, is that the subadults from the East Tennessee Region had lower morbidity (and therefore were more “healthy”) than the contemporaneous subadults from the Middle Cumberland Region during the Late

Mississippian Period. In order to accept this premise, a comparative skeletal analysis should show that the subadults from the East Tennessee region had a lower occurrence of dental enamel hypoplasias and trauma than those from the Averbuch site in the Middle Cumberland Region. There should also be a lower occurrence of pathology, such as cribra orbitalia, porotic hyperostosis, and infection among the East Tennessee region children than those from the Middle Cumberland region. If biological stressors were severe enough, an overall pattern of stunted growth should be evident within the Middle Cumberland region and not evident within the Eastern Tennessee region. Recognizing that preservation and frailty factors greatly affect the skeletal record the issue of the Osteological Paradox will be address in detail in Chapters 3 and 7.

CHAPTER 3: BACKGROUND TO SKELETAL BIOLOGY AND DEVELOPMENT

To assess the evidence for variation in indicators of biological stress among the central and eastern Tennessee Mississippian subadults, a thorough understanding of these indicators is necessary. Biological stress can be defined in this study as any biological pressure causing an individual to diverge from the state of good health. As noted in Chapter 1, subadults are especially sensitive to dietary deficiencies, pathogens, and social stressors, and therefore will better present evidence of the occurrence of these than adults (Goodman and Armelagos, 1989; Blakey, 1994; Kamp, 2001; Perry, 2005; Chapeskie, 2006; Lewis, 2007; Lewis and Gowland, 2007). Severe or chronic effects from these factors will affect normal growth and development, as well as manifest as lesions on the skeleton. This chapter reviews these influences, and discusses them in light of the analysis of subadult skeletal remains. One must be careful with terminology. “Subadult” could be interpreted as literally any individual who is not an adult, which, skeletally, could extend between ages zero and twenty-four. This study is primarily interested in individuals who were undergoing primary growth, defined as those whose long bones were not entirely fused (excluding the clavicle). Therefore, the term “subadult” is used herein to refer to individuals generally chronologically younger than seventeen or eighteen.

The Culture of Childhood

"Subadult" is often used as a biological category synonymous with children (Lewis, 2007). However, "child" can have many cultural meanings and can include individuals of a wide variety of biological and chronological ages, but generally refers to an individual who is less mature than an adult (Lewis, 2007). It is important to determine "childhood" categories that are appropriate for the population in question before making any assumptions about the health and stress of the non-adults in that population. When the goal of a research project is to study subadults, those who are younger than adults, one must decide which definition is being used. If the definitions are used interchangeably it may be unclear what specific age groups are being included. The sample could include individuals with a variety of ages, from zero to twenty-four years of age. The questions become: does a researcher want to study individuals who would be considered children by their own culture's standards, or do they want to study those who would have been considered children in the society and time in which the sample population comes from? Both definitions are viable choices depending upon the research question being asked. If the question relates to the social treatment of children then perhaps it is important to classify them as their own culture would have, but if the research question is contrasting individuals of today to those from the past, defining individuals by the researcher's own criteria would be more fitting. In this study, to reduce the temptation of imposing the western cultural view of childhood (and due to the biologically based research questions) the most appropriate method is to use a biologically-based definition of skeletal maturity.

Subadults in Archaeology

Archaeologists, biological anthropologists, cultural anthropologists, and historians have often overlooked subadults when analyzing past and even current populations (Gottlieb, 2000; Kamp, 2001; Perry, 2005; Schwartzman, 2005; Chapeskie, 2006; Halcrow and Tayles, 2008a). On a practical scale, in archaeological studies it is often difficult to locate the physical remains of subadults of past populations. Juvenile bones are much more porous and less robust than those of adults and, therefore, tend to decompose more easily (Chamberlain, 2000; Perry, 2005; Chapeskie, 2006; Lewis, 2007). This leaves a significant portion of past populations underrepresented in the bioarchaeological record, and thus skews interpretations of past cultures.

Most important to this point, the preservation of infant and juvenile bones is dependent upon where and how they were buried (Lewis, 2007). Burial location is mostly contingent upon the cultural norms of the time, and thus the very cultural practices that would be illuminated by subadult burials may inherently be absent in the archaeological record. In some past cultures, such as Mississippian culture, infants were not yet considered full members of society, and so they were not buried formally in cemeteries but within settlements (Berryman, 1984; Sullivan, 1986, 1987; Lewis, 2007). Oftentimes, infants and children were interred under floors or walls of the houses (Berryman, 1984). Graves were usually shallow and unlined, reducing the chances of good skeletal perseveration (Berryman, 1984; Perry, 2005; Lewis, 2007). Biased archaeological sampling and excavation of sites may then conspire with increased chances of decay to reduce the presence of subadults from the archaeological record.

In light of the current study, this is especially unfortunate, as individuals under the age of five in both modern day and past contexts are the most susceptible to environmental and physiological insults (Lewis, 2007). Based on ethnographic and dietary analysis, individuals from birth to one year of age have the highest risk of death. Infantile infection and diarrheal diseases were among the top killers of children and infants in these age categories during the Mississippian Period (Cook, 1979; Wright and Yoder, 2003b; Lewis, 2007). Although group demography is dependent upon a population's size and whether or not it is growing, typically children make up a large portion of the total population. Dependent upon whether the child mortality rate is high or low, the total percentage of the population under fifteen years of age could be 36% to 19%, respectively (Chamberlain, 2000).

Aside from preservation and excavation bias, it is uncertain whether the portion of the living population that was comprised of subadults is proportionally represented in the mortuary record. After all, subadults in the archaeological record died due to a specific cause, which makes using them to discuss the overall health of the *living population* questionable (Lewis 2007). Thus, the archaeological record is mostly made up of individuals who were at increased risk of a poor health outcome for one reason or another, which does not offer a complete picture of the entire population at one moment in time. This "hidden heterogeneity" in morbidity and mortality forms the basis of the osteological paradox argument (Wood, et al., 1992), which will be discussed in more detail below.

In addition to these concerns, archaeologists and bioarchaeologists have overlooked subadult remains due to analytical limitations. Estimating age, sex, and

ancestry to juvenile skeletal remains continues to prove difficult (Lampl and Johnston, 1996; Lewis and Roberts, 1997; Humphrey, 2000; Perry, 2005; Chapeskie, 2006; Lewis, 2007). Estimating biologically meaningful dimensions like stature, body mass, and limb robusticity have also been limited and not even a possibility until recently (e.g., Ruff, 2007). Some of these ambiguities and methodological limitations are discussed in more detail below, but because of those limitations, even basic analyses of subadult biology are rare (Lampl and Johnston, 1996; Lewis and Roberts, 1997; Humphrey, 2000; Perry, 2005; Chapeskie, 2006; Lewis, 2007). Biological anthropology researchers instead chose to focus on topics that yielded results more readily, namely, focusing on adults.

Defining the Sample

Before discussing these topics in more detail, including growth and measures of stress, it should be realized that while subadults are defined biologically as individuals still undergoing primary growth, these individuals engaged in adult behaviors long before their skeletons fully matured. There is a categorical problem in distinguishing sociocultural age from individual biological age (Bucbli and Lucas, 2000; Perry, 2005; Lewis, 2007; Halcrow and Tayles, 2008b), especially as the former varies across cultures and time periods. In many past cultures, individuals engaged in adult tasks as early as six or seven years old, and may have been married around the age of twelve; conversely, many subadults were not considered members of a society until they reached around the age of three and had a better chance of survival (Bucbli and Lucas, 2000). Thus, while these maturing individuals may not yet have been considered able to fully care for or

provide for themselves, and thus were socially “children”, they were often given many privileges and rights of a full member of society.

This distinction is important when assessing behaviors and risks that will affect the skeleton. Although the cultural and sociological age and status can be inferred to some degree from clues in the archaeological and historical records, there are also bioarchaeological indicators that can inform to age categories as well. Individuals would have engaged in more manual labor at earlier ages in the past, and therefore their skeletons will show signs of increased mechanical loading at early ages, especially compared with postindustrial children (Ruff, et al., 1994; Trinkaus, et al., 1994; Cowgill, 2008, 2010; Garofalo, 2013; Ruff, et al., 2013). Moreover, the activities that these past children engaged in would have potentially exposed them to environmental stressors (e.g., infection, physical demands, social stress), and so one must be aware of the cultural context in which they lived to assess whether the presence of skeletal pathologies and lesions were exceptional.

Aging Subadults: Biological Versus Social Age

In examining past populations, especially those without written historical documentation, there are few resources available to determine a culturally accurate view of what “childhood” was for those people (Kamp, 2001; Halcrow and Tayles, 2008b). This lack of documentation forces bioarchaeologists to use the skeletal record to try to estimate biological ages approximating chronological ages for young individuals. They then combine those skeletal ages with archaeological evidence to place the subadults back into the cultural context of their society, and thus determine a sociocultural age and

possible social roles at that age (Kamp, 2001; Perry, 2005). Estimating the chronological age of an individual from skeletal remains depends on the use of biological markers, but how those markers respond to environmental influence should be considered. Skeletal maturity can be measured by the fusion of epiphyses, the longitudinal growth of long bones, and the appearance of some ossified elements, such as carpal bones (Scheuer and Black, 2000).

In populations with poor nutrition and high occurrence of disease, subadults may endure periods of growth stunting (Bogin, 1999b, a; Ortner, 2003). Subadults who experience repeated or prolonged periods of biological stress over the majority of their primary growth period will then become more growth stunted adults. In other words, they will not reach their full growth potential (Tanner, 1986; Eveleth and Tanner, 1990b; Eveleth and Tanner, 1990a; Bogin, 1999b, a; Keep and Bogin, 1999; Mays, 1999; Pinhasi, et al., 2006). However, depending upon when the biological insults occurred, there may be the potential for "catch-up" growth. If the biological insults occurred earlier in primary growth and for short durations, the individual may be able to attain their full growth, assuming the insults ceased (Eveleth and Tanner, 1990b; Eveleth and Tanner, 1990a; Bogin, 1999b, a; Bogin, et al., 2002). Therefore, subadult long bone length and overall growth is considered to be sensitive to environmental influences (Jantz and Owsley, 1984b, a; Tanner, 1986; Johnston and Zimmer, 1989; Lovejoy, et al., 1990; Hoppa, 1992; Saunders and Hoppa, 1993; Mays, 1999; Stinson, 2000; Lewis, 2002; Pinhasi, et al., 2005; Pinhasi, et al., 2006). In contrast, dental development, which is explored further below, is considered to be the most resistant to the effects of malnutrition, disease, or other sources of individual metabolic stress (Delgado, 1975;

Demirjian, 1978a; Ubelaker, 1989; Saunders, 1992; Huda and Bowman, 1995; Herring, et al., 1998; Lewis, 2007; Saunders, 2008; Conceição and Cardoso, 2011).

None of these techniques, however, come without criticism regarding incongruities between skeletal and chronological age, their applicability to comparisons between populations, and the ability to be used equally throughout the past (Lampl and Johnston, 1996; Lewis and Roberts, 1997; Humphrey, 2000; Perry, 2005; Chapeskie, 2006; Lewis, 2007; Heuzé and Cardoso, 2008). For example, the widely used dental development aging chart by Moorrees et al. (1963b) has received criticism by many bioarchaeologists and paleodemographers because it is based upon certain assumptions of growth and development. The charts assume that all people at all locations from all time periods, no matter their nutritional or health status, will develop dentally at the same rate. Studies have shown that this is not the case for many populations (Delgado, 1975; Demirjian and Levesque, 1980; Saunders and Hoppa, 1993). Undernutrition or malnutrition, chronic illness, as well as many environmental and genetic factors can delay dental development. This has caused an underestimation of the age at death of many children and infants, which would greatly alter the mortality profile of previously studied archaeological sites (Delgado, 1975; Duray, 1996). A more thorough discussion of dental development and aging methods is addressed later in this chapter. Awareness of the issues with matching skeletal ages to chronological ages is important, but these limitations should not be read as undermining age estimations altogether.

The greatest difficulty is in using chronological age estimates to understand cultural roles of subadults. This “social age” varies, but some of the differences among societies remain invisible when all that is available to determine the cultural standing of

children within a population are skeletal remains and associated material culture (Perry, 2005; Lewis, 2007; Halcrow and Tayles, 2008b). However, this multidisciplinary approach, combining the biological anthropology and archaeology, is the best approach to obtaining a complete picture of individual identity, as well as the roles of subadults in a society (Perry, 2005; Schwartzman, 2005; Perry, 2007). Without sensitivity to the influence cultural has on subadults, there is no frame of reference for understanding mortuary treatment, and, most relevant to this study, the individual risk of death, as well as social roles in helping individuals recover from disease. (This is important, as recovery from disease may be necessary for the formation of skeletal lesions; see the discussion about the osteological paradox below.)

Consequences of Social Age for Understanding Social Status

As noted above, estimating social age is important when ascertaining the cultural roles of individuals in past societies. This dissertation does not examine the social roles of subadults in Mississippian cultures, and neither are mortuary treatment data used. However, it is important to understand these contexts, both to appreciate factors that affect the sample available in the archaeological record, as well as to relate the health status of individuals back to the cultures to which they belonged; a high prevalence of unhealthy subadults may have implications for social treatment as well as nutrition, disease and stress. Only within an archaeological context is the researcher able to decide the relative importance of these factors, but that context is often ambiguous.

It is up to a society (e.g., caregivers) as to how subadults are treated, fed, cared for when ill, and where, how, and with whom they are buried if they do not survive. When an

individual dies, what is done with their remains is up to the living. This is true for all individuals, but especially subadults, who generally lack agency in both death and in life. This final act of burial determines how these subadults will be preserved, but also reflects back on the society to which they belonged. If a younger subadult was treated as an adult, then it would most likely have been buried similarly to adults; for instance, in the Middle Cumberland culture, that subadult would most likely be buried in a stone lined grave within the setting of a community cemetery. This type of burial treatment would help to preserve the more porous bone of subadults from taphonomic processes. In turn, this could indicate that the individual would have been more likely cared for through illness than an individual buried in a setting alternative to formal cemeteries. This is exemplified by infants and children who were interred under the floors or walls of the houses, or in separate areas of the communities (Berryman, 1984; Sullivan, 1987; Sullivan and Mainsfort, 2010). As noted above, the alternative placement and burial treatments of subadults potentially decreases the level of preservation and can make it harder to find and recover the skeletal remains (Berryman, 1984; Sullivan, 1986; Scott and Polhemus, 1987; Sullivan, 1987; Gottlieb, 2000; Wiley, 2000; Kamp, 2001; Wright and Yoder, 2003a; Baxter, 2005; Perry, 2005; Chapeskie, 2006; Wadley, 2006; Lewis, 2007; Perry, 2007; Halcrow and Tayles, 2008b). This argument is not meant to imply that subadults recovered from archaeological sites, and especially formal cemeteries within those sites, were inherently the subjects of better care; rather, it adds some caution to direct assumptions that a subadult sample from a site are a proportional representation of the subadult population from which they were drawn. Simple burial choices may reflect social biases that extended to general cultural roles and treatment.

Using grave goods to address this uncertainty by assigning cultural standing to a buried individual has been a long-standing practice among archaeologists (Perry, 2005; Chapeskie, 2006; Lewis, 2007). This practice is made more complicated for subadults because they are often not, as described above, formally buried in cemeteries. Subadult burials are regularly hard to find or are located in an area where the community was unable (or unwilling) to leave goods, such as within house structures. When burial goods are present in subadult burials, these goods are most often interpreted as inherited wealth, but it cannot be ruled out that perhaps these burial goods should be considered markers of ascribed status (Wilkie, 2000; Halcrow and Tayles, 2008b). The message or image that is portrayed by these objects is also important. Toys are made by, traded for, and bought by adults for children enforcing or suggesting stereotypes, norms of behavior or aspirations based on gender and age (Janik, 2000; Wilkie, 2000). These imposed items of cultural importance, can greatly cloud the interpretation of *actual* non-adult status (as experienced by the subadult itself) within a society.

Thus, the material culture of subadults is often difficult to decipher. Recognition of "play" items is very difficult because these objects were usually made crudely, or were not made specifically for play at all, but were objects manufactured and discarded by adults (Park, 1998; Wilkie, 2000; Politis, 2005). Miniature household items were often made for "mimic play" but were also used by shamans or as adult grave goods, confusing their purpose and meaning (Park, 1998; Wilkie, 2000; Politis, 2005). In ethnographic studies, modern children have been recorded collecting, altering, and dispersing items discarded by adults (Hammond and Hammond, 1981; Politis, 2005). This secondary movement of everyday items can greatly alter the interpretation of artifacts found at an

archaeological site. For instance, a child's small hidden stash of "play" items could be interpreted as a ritual cache (Perry, 2005; Lewis, 2007; Halcrow and Tayles, 2008b).

Thus, while the examination of burial practices and grave goods informs the researcher about the social status of subadults, these may be opaque indicators, especially concerning their levels of independence and cultural practices for their care. The social status of subadults does matter when considering their health, and in turn their growth, but, as explained above, ascertaining their status is overlain by many cultural practices. Despite some difficulties in estimating chronological ages from skeletal data, then, this is a more objective (and less ambiguous) criterion for examining subadults than trying to determine social status or social age. The most appropriate and repeatable method is to use a biologically based definition of maturity, and to account for the assumptions of using this method as an estimator of chronological maturity, namely by comparing dental and long bone age estimates for parity. Moreover, it is important not to mistake the chronological age estimate with the individual's actual social age.

The Osteological Paradox, and Age Group Representation

Regardless of the potential for mismatching chronological age estimates with social age, as well as uncertainty in ascertaining social roles or treatment of subadults, there is a more important problem associated with mortality (rate of death) and morbidity (rate of disease) assessments of the full population from the population subsample recovered from sites: the osteological paradox (Wood, et al., 1992). Wood et al. (1992) cautioned against making the assumption that the skeletal sample found at most archaeological is representative of what was once a living population. This paradox has

multiple components that concern this study. First, the skeletal sample recovered from a cemetery may inherently present a demographic misrepresentation of the living population(s) from which it was derived. Second, and relatedly, there is typically an overrepresentation of individuals in the mortuary record that were at greater risk of death at each age category, relative to the living population. At the same time, however, frailty in these individuals —which is physiological vulnerability to stressors associated with adverse health outcomes and mortality— is heterogeneous with respect to age, sex, and socioeconomic factors. Knowing that frailty affects age, sex, and socioeconomic groups differently, it is essential to keep in mind that this affects the skeletal archaeological record. Although heterogeneous frailty was ultimately termed a “nuisance” by Milner et al. (2008), it is of potentially great importance when interpreting past health and demography from skeletal remains within an archaeological context.

A third issue—and one central to this dissertation—arises from this “hidden heterogeneity” in frailty: the problematic interpretation of pathology and biological stress markers, especially in subadults. These markers are the result of disease or a metabolic insult, yet their presence may inherently require individuals to recover from insults before biological markers are evident, leading to paradoxes in their interpretation. Before Wood et al.’s study, the presence of skeletal lesions resulting from disease was traditionally regarded as indicative of disadvantage and lower social status (e.g., Saunders and Hoppa, 1993; (Cohen, et al., 1994; Bennike, et al., 2005); Wood and colleagues, following Ortner’s (1991) arguments, suggested an opposing interpretation. In either case, the presence of a pathological lesion means that an individual is experiencing illness or

disease for a duration of time long enough to form a skeletal lesion. The presence of a lesion, though, can be interpreted in two ways:

1) On one hand, the formation of a lesion could be a sign of a sickly or frail individual who succumbed to a disease or illness. Compared to an individual who does not have any lesions, this individual is not as healthy and is under increased biological stress. This is an argument especially made by researchers such as Goodman (1993) and Cohen (1994), and, to a lesser degree, in direct tests of the paradox by authors like Storey (1997).

2) Alternatively, it is possible to interpret the same presence of a pathological lesion as a sign of resilience and health; this was the main premise of Ortner's 1991 paper, and was argued by Wood et al. (1992), and was reinforced by their 1994 response to Cohen (1994). If a lesion is formed, then the individual must have lived long enough to form the lesion, and if the lesion shows signs of healing, then the individual must have at least begun to recover.

Wood et al. (1992) also suggested that individuals who are shorter in stature may not actually be more frail, as is traditionally interpreted. They suggest that reducing stature, i.e. reduced overall growth, could be a sign of biological buffering. This buffering would reduce the biological needs—namely nutritional—of that individual and therefore avoided additional biologic stress incurred by the "healthier" taller individuals. Individuals who have average or increased stature comparatively may have normal

growth, but in doing so unable to buffer themselves from increased biologic stress and therefore increasing their frailty.

Therefore, there are two perspectives that may be taken in this dissertation with regard to interpreting the biological consequences of skeletal lesions and short statures, if they are apparent. Either the presence of these indicates that subadults had greater resilience to disease and other insults, or that the subadults had greater frailty in concert with their greater morbidity. As advocated by Wood et al. (1992), as well as subsequent authors (e.g., Wright and Yoder, 2003; Bennike et al., 2005), archaeological context ultimately will play a decisive role in the interpretation of the presence or absence of skeletal signs of disease and stress.

Archaeological context is also essential in reconstructing past population demography. Past populations, barring a catastrophe or an epidemic, should have a normal mortality curve manifest in their skeletal record, but most do not. A normal mortality curve for age-at-death in a prehistoric population should be double peaked, with higher percentages of skeletons representing the very young and very old, because these are the most frail segments of the overall population. However, the archaeological record usually contains the complete opposite, which is a higher percentage of middle-aged adults. This could simply be due to underestimations of elderly ages because of problems inherent in regression-based age estimations from the skeleton (Boldsen, et al., 2002). Assuming, though, that elderly individuals are underrepresented in the archaeological record, one explanation could be that, on average, individuals died at an earlier age than what we now consider elderly. However, if this were the case, children and infants should still be evident in greater numbers in the archaeological record (Chamberlain, 2000). The

other possibility for both the elderly and the very young is a cultural matter of burial location—they may not undergo the same treatment as middle-aged adults—as well as poor preservation due to porous or brittle bones. The former scenario can only be determined by the thorough investigation of mortuary practices in archaeological sites across a cultural area, which is beyond the scope of this study.

Nevertheless, subadults should make up a large number of individuals buried within archaeological sites because of the higher morbidity and risk of death among their age group. Children and infants under the age of five are the most susceptible to environmental and physiological insults (Lewis, 2007); infants up to one year of age are at the highest risk within this category. Infantile infection and diarrheal diseases are among the top killers of children and infants (Katzenberg, 1996; Lewis and Roberts, 1997; Walter and Olivares, 1997; Ulijaszek, 1998; Lewis, 2007). Thus, any subadults who fall into this age group (birth to around five years) may artificially bias estimates of pathologies within the population (Perry, 2005), when what we are really observing are the population's individuals who were at and succumbed to the greater health risks.

Disease and Stress in Archaeological Subadults

Factors Contributing to Subadult Skeletal Pathology and Growth Reduction

A number of factors may affect normal growth and increase morbidity in subadults. Some are related to dietary deficiencies, including reduced caloric intake (undernutrition) and missing essential nutrients in the diet (malnutrition). Others are the product of pathogen exposure, which increases with weaning. During weaning there is also an increased psychosocial stress, which can make subadults even more susceptible to

succumbing to illness. This subsection briefly reviews some of the factors that most likely affected the Mississippians examined in this study, especially those exposed to less diverse, maize-centric subsistence.

To evaluate the overall health and well being of archaeological populations it is important to keep in mind the particular effects diets can have on an individual's health. An overabundance of nutrients, or deficiencies of certain nutrients, can put individuals at an increased risk for a variety of illnesses. Because we already know that children and infants require higher levels of certain nutrients due to their rapid rate of growth, and are therefore more susceptible to dietary and environmental insults, children are likely to succumb to deficits more quickly than adults. This age-dependant variable sensitivity within past societies has long-term impacts on those communities; if the subadults of a society mature with nutrient deficiencies and the resulting illnesses, they may ultimately become adults with illness. If these adults were still burdened with their childhood illnesses, they would have a higher susceptibility for new illnesses, which, in turn, results in a weakened workforce, greatly affecting the long-term survival of the community. For example, deficient adult females who continue to eat a nutrient poor diet may not be able to provide the necessary nutrients for their children during pregnancy and nursing, perpetuating the problem and creating a whole new nutrient deficient generation. Therefore, consideration of maternal effects, as well as direct effects on subadult morbidity and mortality should be considered when examining factors that influence growth and pathology. While this study does not examine adult females (as this would assume they are the maternal population), ascribing poor nutrition to direct effects on

subadults, rather than a combination with maternal effects, would be oversimplifying the etiology of inadequate nutrition.

Subsistence & Weaning: Anemia & Pathogens

The diets of the Mississippian groups, as reviewed in Chapter 2, were heterogeneous; some groups relied more heavily on a few crops (e.g., maize), while others continued to consume the more varied diets of Woodland Period forbearers. In all cases, the sufficient intake of certain elements remained crucial to normal growth and development, both in utero and in the first years of life. In addition, weaning often placed high stress on individuals, as the content of food changed from breast milk to solid foods, many of which would have been derived from cultivated plants, and which would have introduced parasites from which subadults would have previously been protected (Gordon, et al., 1963; Sazawal, et al., 1995a; 1995b; Blom, et al., 2005). In addition, many weaning gruels were also high in phytates, which would sequester the available minerals, such as zinc, calcium, and magnesium (Shils, et al., 2006). Vitamin B_{12}, iron and calcium were among those nutrients that were essential for adequate maintenance of health and normal growth. Deficiencies in vitamin B_{12} and iron would have been especially impactful, and could have been caused by reduced access to varied diets or, more likely, to increased parasitic and infectious loads (Reinhard, 1992; Blom, et al., 2005). The reductions in these nutrients would have led to anemia.

It is evident that there are at least some long-term effects of chronic iron deficiency anemia from analysis of skeletal remains of infants and children from areas with a low iron diet (Lallo, 1977; Cook, 1979; Stuart-Macadam, 1985; Walker, 1986;

Stuart-Macadam, 1992; Wright and Chew, 1998; Lewis, 2002; Wapler, et al., 2004; Blom, et al., 2005; Walker, et al., 2009). Added bone growth, typically in the crania, and hypertrophy of the medullary cavities to increase red blood cell production are physical signs of severe iron deficiency anemia, as well as megaloblastic anemia arising from a B_{12} or folate deficiency. These deficiencies, if left unchecked, can continue to cause health problems throughout an individual's life.

During pregnancy, a female has a twenty percent increase in red blood cells in order to provide substantial iron deposits to the fetus and the placenta (Allen, 1997). The maximum expansion in maternal red blood cells occurs during the twentieth to twenty-fifth weeks gestation, while most fetal iron uptake does not occur until after thirty weeks gestation. The increased iron needs are presumably met by the increased maternal ability to metabolize iron during the last ten weeks of pregnancy. However, when these increased demands are not met, females run the risk of becoming anemic. This would be expressed physically by reduced energy levels, dyspnea, and possibly low maternal weight gain (Allen, 1997).

Although the mechanism behind the association between anemia and maternal mortality is largely unknown, it is thought that an inability to handle blood loss, higher risk of cardiac arrest, greater risk of infection, and increased recovery time may play a role (Allen, 1997). Because iron is essential for the immune system to function properly, iron deficiency anemia especially affects the ability to appropriately ward off infection at a time when the mother is potentially very vulnerable to infectious diseases. However, some studies have shown a reverse scenario where an increased risk of infection is associated with high levels of iron and decreased infection with low levels of iron (Walter

and Olivares, 1997). These studies assert that the reduced blood oxygen levels associated with iron deficiency inhibit the survival and reproduction of bacteria responsible for infection. More research into this area needs to be completed with larger and more complete research designs in place before formal conclusions can be made.

There are many potential hazards associated with maternal iron deficiency anemia that affect the newborn infant as well. Scholl et al. (1992) and Lindsay (1997) found that anemia doubled the risk of preterm labor and was also associated with a tripled risk of low birth weight. Preterm birth, in association with inadequate weight gain may be inferred as a possible cause of the low birth weight in the newborns (Scholl et al. 1992), in addition to reduced growth rates. There is also an increased risk of mortality for preterm newborns due to the multitude of complications that can occur with early delivery.

Poor maternal nutrition and overall health play a significant part in the increased risk of maternal iron deficiency anemia. Mothers who have continued iron deficiency anemia tend to have a decreased level of interaction with their newborns (Lindsay 1997). The reduced interaction can result in less care and attention given to the newborns, which can then result in a poor long-term outcome for the infants.

Modern Correlates

Modern correlates allow for insight into the behavior and the quality of life that individuals afflicted with deficiencies may have experienced. Research has shown that iron deficiency anemia during fetal and/or early infancy can have long-term effects. Infants and young children with this condition tend to score lower on both mental and

motor developmental achievement tests (de Andraca and Castillo, 1997; Pollitt, 1997; Grantham-McGregor and Ani, 2001). Most studies have been conducted with study groups consisting of infants and children from geographical and/or environmental areas that are known to have problems with iron deficiency anemia. Other studies show that iron deficiency anemic infants have immature respiratory patterns during sleep (Grantham-McGregor and Ani 2001). This condition can lead to neuromotor development delays, altered cardiac activity, and even central nervous system developmental problems. If dietary deficiencies can be corrected before children are two years of age and continue for an extended period of time (e.g., longer than three months), then there may be a chance that they can increase their cognitive and motor development scores (Pollitt 1997; Grantham-McGregor and Ani 2001). Other studies indicate that if an iron deficiency anemic infant has continued developmental delays past twelve months of age they will continue to exhibit long-term cognitive and motor developmental delays (Grantham-McGregor and Ani 2001).

Vitamin & Mineral Deficiencies

In addition to vitamin B_{12} and iron, calcium and vitamin D play integral roles in the formation and maintenance of bones and teeth. Calcium is reliant on vitamin D for adequate absorption (Gartner, et al., 2003; Pettifor, 2004; den Elzen, et al., 2008; Erkkola, 2009). Many of the body’s responses to these deficiencies are also interconnected. Bone diseases like rickets, osteomalacia, and osteoporosis seem to have etiologies that are actually associated with deficiencies of both calcium and vitamin D

(Marie, et al., 1982; Gartner, et al., 2003; Pettifor, 2004; den Elzen, et al., 2008; Erkkola, 2009).

Calcium is the fundamental element in the mineral content of teeth and bones. The body's ability to absorb calcium changes throughout different stages of life, as well as in response to various diseases. Life stages like pregnancy and post weaning in infants and young children increase calcium absorption, but menopause and estrogen deficiency decrease calcium absorption (Shils, et al., 2006). Moreover, diarrheal diseases that cause rapid intestinal transit time or diseases that decrease the mucosal permeability of the intestines also decrease the body's ability to absorb calcium.

There are several mainstay foods that have been essential in helping humans to get calcium in their diets where dairy products are either not available or where they are culturally avoided. Roots, tubers, nuts and beans all contain high amounts of calcium allowing for adequate intake in geographic areas that would otherwise lack sufficient sources of calcium. With the intensification of agriculture in the Southeast, Mississippians moved away from utilizing these resources and instead relied more on grains and cereals. These foods are not only low in calcium, but often contain phytic acid, which will actually inhibits calcium absorption from other foods (Shils et al. 2006).

Vitamin D is an essential player in the building and maintenance of bones, affecting calcium absorption in the small intestine. Adequate levels of vitamin D support neuromuscular function and bone ossification (Shils et al. 2006). Because it was nearly impossible to receive adequate amounts of vitamin D through dietary means before postindustrial supplementation, past populations would have had to rely on their exposure to sunlight to maintain sufficient levels. Cultural, religious, and climatic conditions (e.g.,

as a result of clothing choices) could restrict the amount of sunlight exposure both adults and children receive (Pettifor, 2004).

In infancy, vitamin D intake and maintenance depended on the content of breast milk and sunlight exposure. The vitamin D content of breast milk from a vitamin D sufficient mother is fairly low; if an infant were able to drink as much breast milk as it possibly could, it will still not receive adequate amounts of vitamin D (Gartner, et al., 2003; Pettifor, 2004). Infants born to mothers who have had sufficient vitamin D levels will have enough liver stores of their own after birth. These vitamin D stores are necessary to maintain proper blood levels through the first months of life if relying on breast milk alone, but after that time the infant needs sufficient sunlight exposure to manufacture vitamin D or supplementation (Gartner et al 2003; Pettifor 2004). Infants who are breastfeeding and have increased skin pigmentation or experience decreased sunlight exposure are at high risk for vitamin deficiency.

No matter the cause, vitamin D deficiency, along with low calcium levels, is a likely etiology of rickets (Gartner et al. 2003; Pettifor 2004). Rickets is a disease that is characterized by a softening of the bones in children during growth. This softening can cause bowing of the long bones in the arms and legs when pressure is applied during crawling and walking. Rickets is also known to enlarge the epiphyses of long bones and rib cage, as well as cause bending of the spine and muscle weakness. If circumstances change to allow for a recovery in vitamin D levels, the bones will harden and attempt to repair themselves with remodeling. But in most cases at least some of the osseous effects will last into adulthood. Individuals with rickets often have reduced mobility and muscle

pain. Rickets and osteomalacia—when vitamin D deficiency occurs in adults—are also associated with an increase in co-morbidities (Brickley, et al., 2007).

Individuals who have rickets or osteomalacia can develop misshapen pelvic outlets due to the forces placed on softened bones during crawling and walking. This deformity often goes unnoticed in women until complications arise during childbirth. In past populations, this was a major cause of maternal and neonatal death (Brickley et al. 2007). In general, the symptoms of rickets and osteomalacia together can cause an increased risk of falling, fractures, and ultimately an increased risk of mortality.

Assessing Growth and Morbidity in Subadult Skeletons

Based on the effects of the factors outlined above, subadult skeletons in this study are evaluated for a number of pathological indicators of dietary deficiency and disease. These are listed in Chapter 4 (the Materials and Methods), but the etiologies are explored below. Some disorders affect the outer tables of bones, while others are restricted to specific skeleton regions (e.g., the crania or dentition). An extensive volume of literature has been devoted to assessing these pathological indicators in the skeleton, and in many cases their etiologies are still the subjects of debate (for fuller discussion, see, for example, (Aufderheide and Rodriguez-Martin, 2011).

General Skeletal Indicators

A variety of skeletal lesions may be identified with both specific and general pathologies encountered by individuals in life. One limitation to relying on these indicators in skeletal remains is that individuals who have expressed them generally

suffered from the pathological condition for a sufficiently long period of time for it to manifest on bone, or the presence of the lesions may not be related to the cause of death; that is, an individual may recover from the disease leading to the pathology, but recovered only to die of a different cause. This is another aspect of the osteological paradox (Wood et al., 1992). In addition, individuals who succumbed quickly to a pathological condition may not have any skeletal indications of their diseased state. Thus, examining the presence of lesions alone in evaluating the health of subadults is not sufficient; identifying retardations in growth may provide another source for health information, and so these should also be considered when assessing the health of past populations.

Skeletal lesions located on the outer tables of bones have both causes arising from external and internal factors for the individual. Past studies have suggested that the porous pitting of bone occurring in the orbital roof (cribra orbitalia) or cranial vault (porotic hyperostosis) was a result of iron-deficient anemia (Ortner, 2003). However, more recent research has cited etiologies arising from parasite loads, weaning stress, and the resulting deficiencies in vitamin B_{12} (Walker et al., 2009). In either case, the presence of these conditions is indicative of systemic anemia, and may be an indicator of weaning stress or, later during primary growth, nutrient deficiencies due to dietary restriction and/or infectious diseases (especially parasites). Abnormally added bone to the periosteum could be the result of localized infection (Ortner, 2003), or it may reflect metabolic disorders (such as acromegaly). Therefore, attributing one cause to any pathology is reductionistic, though the presence of any of these indicates an individual suffering from an abnormal health state.

In all cases, the observation of these lesions depends on the maintenance of the lesion; that is, due to growth, modeling and remodeling of bone may remove the signs of the disease states that led to the formation of the osteological abnormalities earlier in life. Thus, other indicators of individual growth disruptions that are not subject to remodeling must be taken into consideration. Among the most useful of these are those obtained by analyzing teeth.

Dental Analysis

Unlike bone, teeth do not remodel, so they remain a permanent record of the health and diet of an individual during formation. Tooth enamel is such a durable material that in many archaeological settings, where the preservation of the skeletal material is very poor, the teeth are the only material left for analysis. In these cases, it is of the utmost importance to obtain as much information from the dental remains as possible. This has made dental studies a desirable commodity within cultural, sociological, archaeological, paleontological and forensics research.

More than indicators of general skeletal stress, or measurements of long bone growth, study of dental data has great potential to indicate individual development, reactions to metabolic stress, and the effects of diet and subsistence. To obtain a more complete picture of what past people were eating and changes in subsistence methods, microwear patterns, hypoplastic analysis, and isotopic analysis have become crucial analytical tools. These research methods help to shed light on weaning ages, in addition to signs of migration or dietary alterations necessitated by climatic or other influences on subsistence (Cook, 1979; Corruccini, et al., 1987; Blakey, 1994; Duray, 1996; Seow,

1997; Steckel, 2002b; Steckel, 2002a; Cucina and Tiesler, 2003; Tomczak and Powell, 2003; Littleton, 2005; Hutchinson, 2006).

Dental development rates have been used for many years to estimate the age of an individual at their time of death. Crown and root development stages from an individual in both forensic and archaeological contexts can be compared to the Moorrees et al. (1963) growth charts to determine the approximate age of the individual, as long as dental development is still ongoing. As stated earlier, the use of tooth crown and root development as methods for estimating chronological age is more reliable than alternatives; long bone linear growth and fusion, for example, is subject to multiple perturbations and growth insults to which teeth may be more resilient (Demirjian, 1978a; Ubelaker, 1989; Saunders, 1992; Huda and Bowman, 1995; Conceição and Cardoso, 2011).

A potentially more precise measure of individual metabolic insults, dental enamel hypoplasias have been used as stress indicators for decades (Kreshover, 1944; Cook, 1979; Goodman, et al., 1980; Goodman and Armelagos, 1985; Skinner, 1989; Hodges, 1990; McKee, 1990; Hillson, 1992; Danforth, 1993; Blakey, 1994; Berti, 1995; Ensor, 1995; Katzenberg, et al., 1996; Danforth, 1997; Hillson and Bond, 1997; Seow, 1997; Lukacs, 1999; Santos and Coimbra, 1999; Lukacs, 2001; Goodman, 2002; Lewis, 2002; Littleton, 2005; Danforth, et al., 2007; Martin, et al., 2008; Ritzman, et al., 2008). Enamel hypoplasias are formed by a complete disruption of the ameloblasts, which deposit tooth enamel during primary growth. As an illness or malnutrition episode becomes so severe that a subadult is forced to shunt energy away from growth processes in order to survive, enamel production by the ameloblasts is halted (Hillson and Bond, 1997). Hypoplasia

presence, therefore, may illustrate particular ages in which all individuals in a population encountered sources of metabolic stress (e.g., at weaning), or single out a weak and more susceptible segment of the population that was more sickly than the rest (Cook et al. 1979; Blakley et al. 1994; Duray 1996; Littleton 2005). Thus, the analysis of the frequencies and timings of enamel hypoplasia occurrences has the potential to yield important distinctions among individuals when examining the overall health of an archaeological population.

Although the factors that can initiate the formation of hypoplasias are known, the cause of any particular hypoplasia cannot be determined (Rose, et al., 1978; Cook, 1979; Duray, 1996; Hillson and Bond, 1997; FitzGerald, 2005). The inability to pinpoint an exact cause for the growth disruption is problematic when trying to establish the source of illness within a population. According to Fitzgerald et al. (2005), all stressors leave their mark within the tooth structure; it is just a matter of where, when, and to what severity. Yet, correlating enamel hypoplasia development to the duration or severity of a growth disruption is not possible at this time, and the correspondence of hypoplasia frequencies to other skeletal lesions is indeterminate. The varying widths, depths, and types of enamel hypoplasia may be caused by the susceptibility of the enamel on the tooth, the location of the defect on the tooth, and the age of the individual at the time of the growth disruption (Suckling and Thurley, 1984; Huda and Bowman, 1995; Hillson and Bond, 1997; FitzGerald, 2005). Thus, it is erroneous to associate hypoplasia dimensions with illness severity (Fitzgerald et al. 2005).

Dental development ends around twelve years of age, and so the study of dental enamel hypoplasias only allows for an assessment of morbidity during this

developmental period. However, the deciduous dentition gives a small glimpse into the health of the maternal population as well. Stresses that occur to the fetus are most often those experienced by the mother, which are severe enough to be passed on to the fetus despite placental buffering (Cook, 1979; Storey, 1986). In fact, Cook et al. (1979) found that individuals with deciduous or prenatal dental defects had a specifically higher rate of death during the weaning years. Also, individuals with deciduous enamel hypoplasia are more prone to growth disruptions and have a lower mean age at death; therefore stress experienced by the mother could have a long-term effect on their offspring (Cook et al. 1979; Littleton 2005).

The interpretation of enamel hypoplasias leads researchers to conclusions about health, diet, feeding practices, and vulnerability of a population. Individuals with numerous enamel hypoplasias are categorized as chronically ill, which further implicates repeated or continuous exposures to a high pathogen load, or excessive levels of stress, malnutrition, or undernutrition (Rose et al. 1978; Skinner et al. 1989; Steckel et al. 2002; Hutchinson et al. 2005; Littleton 2005). Even more importantly, enamel hypoplasia can be correlated to a specific age at which they formed (Goodman, et al., 1980; Saunders and Hoppa, 1993; Huda and Bowman, 1995; Reid and Dean, 2000; Littleton, 2005; Hutchinson, 2006). Goodman et al. (1980) pioneered the relationship of age of occurrence with the linear distance of hypoplastic defects to the cementum-enamel junction (CEJ) at the gum line, but subsequent studies have critiques and refined this method (Hodges and Wilkinson 1990; Hillson and Bond 1997; Reid and Dean 2006, 2008; Martin et al. 2008; Ritzman et al. 2008). In all cases, however, the examination of enamel hypoplasia distribution allows one to discern if insults came at regular intervals,

perhaps due to seasonal food shortages, or specifically at a stressful time in life, such as weaning (Cook et al. 1979; Blakley et al. 1994; Durary 1996; Steckel et al. 2002; Hutchinson et al. 2005; Littleton 2005).

Most of the studies cited above support weaning as a major and common source of hypoplastic defects, but this is not always the case. Many samples show high frequencies of hypoplasia around the ages thought to be associated with the time of weaning (Katzenburg et al. 1996; Herring et al. 1998). However, other studies found that the timing of growth disruptions did not match up with known historical data on weaning times (Blakley et al. 1994). Incidentally, some individuals have proposed that perhaps defects argued to result from weaning stress instead represent a developmental stage in which ameloblasts are more susceptible to disruption (Suckling and Thurley 1984). These and other studies show that weaning is a complex and population-specific issue, especially in its biological signature on dentition. However, it is likely that at least a portion of enamel hypoplastic defects arise because of metabolic stress induced by weaning, as it may be a precarious time for infants. Weaning, when done with appropriate nutrient and calorie rich foods, while slowly reducing a young subadult's access to breast milk, should not cause any adverse health effects. However, when weaning is initiated at too young an age, before the digestive and immune systems are mature, or when breast milk is substituted with nutrient and calorie poor foods, a negative outcome can occur. The practice of introducing a weaning gruel in an agricultural subsistence based economy usually entailed making a cereal mush that potentially exposed young subadults to the harmful bacteria and parasitic infections (see above, in Factors Contributing to Subadult Skeletal Pathology and Growth Reduction).

The infections from early or poor weaning practices can create long-term diarrhea, which then leads to the inability to absorb nutrients (Blom et al., 2005). This escalation in pathogen exposure during this period of development increases biological stress that may cause severe growth disruptions enough to cause dental enamel hypoplasias (Katzenburg et al. 1996; Herring et al. 1998; Littleton 2005).

Long Bone Growth and Development

As noted earlier in this chapter, patterns of long bone growth are used in this study as the determining criterion for assigning an individual as a subadult; specifically, individuals are included only if the long bone epiphyses are not fused. Complete epiphyseal fusion with the metaphyses of the limb long bones is regarded an osteological sign that primary growth is reaching an end for an individual (White and Folkens, 2005; White, et al., 2011). However, the chronological timing for this varies among populations, and even within populations (e.g., (McKern and Stewart, 1957; Scheuer and Black, 2000).

As discussed above when considering skeletal versus chronological age, the timing of closure for the long bones is dependent on a number of factors, which were reviewed above. Dental crown and root development, which is considered to be more resilient to these growth insults (despite the formation of enamel hypoplasias), may be a more accurate indicator for an individual's chronological age (Scheuer and Black, 2000; Kanbur, et al., 2006). Therefore, a comparison of the dental age estimate of an individual with the age estimate determined by examining long bone fusion could indicate hidden stress or growth perturbations that do not manifest in other ways in the skeleton. This is

especially useful if the conditions that led to an individual's growth stunting were unrelated to the nutrient deprivations and pathological loads discussed with respect to skeletal lesions, or their presence was not severe enough to produce the lesions.

Summary of Analytical Approaches Taken toward Assessing Growth and Health

As reviewed above, a number of factors influence normal growth and development, and, more importantly, departures from it. "Normal" growth patterns can be used as a starting point for determining age, but this estimate must then be adjusted by known disruption factors, such as, environmental, nutritional, and disease. As stated, there are challenges in interpreting basic biological information from subadult skeletal remains—owing to uncertainties associated with aging and with the osteological paradox—let alone relating the biological information to sociocultural aspects. Therefore, taking the information presented into consideration, this study will focus on the data described in the next chapter to assess differences in the growth and health of Middle Cumberland and East Tennessee Mississippians. Briefly, these consist of measurements of dental development and limb development to assess age-at-death, as well as observations of the presence and frequencies of dental and skeletal lesions. These data will be combined with measurements of body shape and size to assess evidence for differences in population stress and biological continuity between the two Mississippian regions under consideration.

Final Considerations: Body Shape and Size as Indicators of Population Continuity

In addition to the assessment of growth and health to assess cultural and biological distinctions between groups, the comparison of size and shape may be used to indicate continuity or discontinuity between human populations. Examining adults, various authors have demonstrated the utility of analyzing body mass, stature, and limb proportions to discern regional replacements of a human group by unrelated groups (Holliday, 1997; Temple, et al., 2008; Auerbach, 2010, 2012). These are characterized by differences in these morphologies that occur within short time periods, as body mass and limb proportions have been argued to evolve slowly (e.g., Ruff, 1994; Holliday, 1997). This concept has recently been reinforced, as Cowgill et al. (2012) showed that intralimb proportions (brachial and crural indices) and some body proportions are set early in development among subadults. Therefore, population differences between any two regions—in this case the Middle Cumberland and East Tennessee—may be reflected by distinctions in body shape and size. Were these differences evident between the regions, then, hypothetically, it would be possible to observe the movement of individuals from one population into the region occupied by the other.

In addition to these dimensions, other distinctions may exist within and among populations by comparing the robusticity of the limb long bones. A review of skeletal robusticity and biomechanics is beyond the scope of this dissertation (see Ruff, 2008, for a review). However, as bone functionally adapts to the mechanical loads it encounters (called bone functional adaptation; see Ruff et al., 2006), especially during primary growth (Ruff, 2003), differences in activity levels and types are discernable when comparing human long bone diaphyseal shape (e.g., Bridges et al., 2000; Stock and

Pfeiffer, 2004). For example, groups who engaged in activities using the upper limb more often (such as in rowing or throwing) than groups that were, relatively, inactive (like postindustrial Westerners) would exhibit wider diaphyses relative to the lengths of the upper limb bones (that is, more robust bones). Thus, distinctions in activity levels may be apparent when comparing the diaphyseal dimensions of long bones between groups. If the Mississippians compared in this study exhibited different robusticity in limb bones, though specific causes could not be ascribed, this would contribute to the general picture of health and stress evidenced by observations of growth and skeletal lesions among the subadults.

CHAPTER 4: INDIVIDUAL SITE DESCRIPTIONS, MORTUARY, AND ENVIRONMENTAL DATA

This chapter presents a description of the archaeological sites used in this study and their excavation history to provide context for the biological and archaeological data. This chapter will also discuss the similarities and differences of the East Tennessee sites, Ledford Island (40BY13; WPA #16BY13), Fains Island (40JE1), Cox (40AN16), and the Dallas site (40HA1) which encompasses the village (WPA #7HA1) and platform mound (WPA #8HA1). The chapter also sets up the rational for combining the East Tennessee sites as a comparative group for the Middle Cumberland, Averbuch site (40DV60), which is the basis of the first hypothesis tested. The summaries of age and sex counts for the skeletal series at these sites are based on inventories conducted in the 1980s by Maria O. Smith, Donna Boyd, and University of Tennessee students in biological anthropology. The inventories were supported by a grant from the National Science Foundation.

Site Descriptions

Ledford Island (40BY13)

Ledford Island is located in Bradley County, Tennessee, on the Hiwassee River twelve miles upriver from its conjunction with the Tennessee River. It was excavated by the Works Progress Administration and the Tennessee Valley Authority (WPA/TVA) in preparation for the damming of the Tennessee River by the Chickamauga Dam. The archaeological site is located on an elevated area on the southeastern portion of the approximately 234 acre island (Lewis, et al., 1995). Excavations began in May of 1938

and continued for seven months. Ledford Island was one of the sites used to define the Mouse Creek Phase site by Lewis and Kneberg (1946; Sullivan, 1986, 1987; Lewis, et al., 1995; Sullivan and Harle, 2010). A radiocarbon date based on a wood sample from the large public building at the site places its occupation in the mid-fifteenth century (A.D. 1414-1481, 450+/-50) and it may have been the most densely occupied site in the Chickamauga Basin during this time period (Sullivan, 1986; Sullivan and Harle, 2010; Sullivan, in press). The level island had its fertile soil replenished by the flood waters of the Hiwassee River, making it highly coveted land for farming in the 1930s; this was a trend that likely existed during its Mouse Creek Phase occupation (Lewis, et al., 1995).

The Ledford Island site had an arrangement similar to other sites of the same time period in the Southern Appalachians (Sullivan and Rodning, 2011). The Ledford Island site is organized around a large plaza, surrounded by buildings, and burial areas (Sullivan, 1987). There is a lack of mounds in association with ceremonial structures at the Ledford Island site and other Mouse Creek Phase sites, which is one of several distinguishing factors that separate the Mouse Creek and Dallas phases. Another is that Mouse Creek Phase burials typically are extended while those of the Dallas Phase are flexed (Lewis et al., 1995).

The site consists of a palisaded village with summer and winter dwellings, and public structures. A total of sixteen winter and public structures were excavated at the site; the WPA excavators did not recognize the summer structures (Sullivan 1987). The general population was typically buried in association with both summer and winter dwellings (n=382), while presumed community leaders and other individuals of special statuses are associated with cemeteries beside the plaza (Sullivan, 1986, 1987). Infants

and children were usually buried within the winter houses, while adolescents and adults within the general population were buried in the summer houses and in the household cemeteries (Sullivan, 1986, 1987). There was one (1) infant buried in the northeast corner of the large ceremonial structure, which is located in the northern part of the site. Within the public cemeteries, there was a total of eight-six (86) individuals, but only ten (10) subadults. None of these subadult burials contained burial artifacts (Sullivan, 1986, 1987).

According to Sullivan (1986, 1987), the public cemetery contained mostly male individuals, forty percent (40%) of whom had at least one (1) associated burial artifact. Only one (1) of the nine (9) women in the public cemetery had any associated burial artifacts. Within the household cemeteries, there were a much larger percentage of female individuals with burial artifacts (29 percent) and males had a nearly even 31 percent. Males are more likely to have been interred with burial artifacts that coincide with activities that are traditionally associated with males, such as blades, celts, projectile points, and pipes. Females, on the other hand, were more likely to have been buried with items made of shell and pottery. The occurrence of burial artifacts increases with the deceased individual’s age, which is a pattern similar to most Dallas phase sites (Sullivan 1986). It is interesting to note that occurrence of shell ornaments is slightly higher in females and subadults and seems to be one exception to the increasing age rule (Sullivan 1986).

Fains Island (40JE1)

Fains Island is located on the French Broad River in Jefferson County, Tennessee. The excavations at the site began in 1934 by T.M.N. Lewis and C.C. Wilder (Harle, 2003). The work was initiated to prepare for the construction of the Douglas Dam by the TVA, which flooded the area to form the Douglas Reservoir. The focus of the excavations was the mound and its burials, which were located at the south end of the island. The remainder of the site was left almost entirely unexcavated and is now under water. A radiocarbon date from the mound at the site places its occupation in the late-fifteenth century (A.D. 1454-1518, 370+/-30) (Harle, 2003; Sullivan and Harle, 2010).

Excavations of the mound and the immediate surrounding area revealed a mound built in two phases that had five successive floors. As illustrated by the presence of several large posts, there was a ceremonial structure built upon each of the levels. The dimensions of the buildings were 35 by 35 feet (Harle, 2003), the first of which was built directly on the unmodified ground surface. There were only five feet between the first and the final fifth floor, resulting in a relatively low total height of the mound.

The excavations by Lewis and Wilder resulted in the exhumation of 300 burials. The vast majority of burials (293), came directly from the mound itself. The sheer number of mound burials makes Fains Island unique within Dallas Phase sites (Harle, 2003; Sullivan and Harle, 2010). The other stand out mortuary pattern found at Fains Island is the fact that the distribution of age and sex within the mound burials is nearly representative of a normal population. With 75 individuals sexed as male, 84 sexed as female, and 98 identified as subadults within the mounds, the Fains Island mound is not a

male dominated burial location like most Dallas Phase site mounds (Sullivan, 2001; Harle, 2003; Sullivan and Harle, 2010).

Most of the burials were found under the fifth and final floor of the mound. Nearly all burials were pit burials with most individuals in a flexed or partially flexed position. The site records also described a few burials were oriented in a “horizontal position” and two individuals reported as being buried in the “seated” position. Most burials were primary internments in plain pits and many had covers constructed from bark-covered wooden cleats that were originally placed over the burials on a 8-12” shelf, but were sagging by the time of excavation. A few of the burial pits were completely lined with logs (Harle, 2003).

The funerary objects follow a slightly different pattern at Fains Island than the pattern discussed by Hatch (1974) in his study of Dallas mortuary practices. Harle (2003) also revisited the funerary object patterning in her study of the site and its skeletal series. The frequency of artifacts tends to increase with skeletal age estimates. In general, males have a greater chance of being buried with one or more artifacts and most of the time these artifacts are activity related: blades, celts, projectile points, and pipes. Interestingly, young males are more commonly buried with artifacts than older males. Only 30% of female burials were buried in association with any artifacts, but it is not possible to know if artifacts that did not preserve such as baskets, feathers, or textiles might have been placed in graves. Fains Island again shows a unique mortuary patterning in the use of shell ornaments as burial artifacts. Shell ornaments including pendants, hair and ear pins, beads, and gorgets are placed with all age and sex categories. Overall, 27% of males and 20% of females were accompanied by such items. Thirty-one percent of subadults at

Fains Island were buried with columella, small shell beads, columella ear bobs, or incised gorgets. Shell gorgets and shell masks are almost exclusively interned with subadults, with the exception of one adult male.

Cox (40AN19)

The Cox site is located on the east bank of the Clinch River in Anderson County, Tennessee. The site was first excavated in 1934 as a Civil Works Administration project, in conjunction with the TVA's construction of the Norris Dam (Webb, 1938; Sullivan, et al., 2011). Three Accelerator Mass Spectrometry (AMS) dates obtained by Bobby R. Braly for his dissertation project, at the University of Tennessee, on the archaeology of the Norris Basin place the Cox site squarely in the mid-sixteenth century.

Webb (1938) reported that the initial excavations found most of the 39 burials associated with the mound, which was the main focus of the excavations conducted at that time. The mound appears to have been built in three construction phases. The mound at its final stage stood approximately eight feet high. A single ceremonial structure was built on each of the three levels. The majority of the uppermost surface was destroyed by plowing. The second level contained the most number of burials and artifacts according to the site report. The primary level contained the outline of a nearly square structure that was approximately 37.5 feet by 36.5 feet, as were the two buildings in subsequent levels. There were an additional ten burials found surrounding the mound (Webb, 1938; Vogel, 2007). The field report was submitted to the Smithsonian Institution as a part of the Bureau of American Ethnology by Webb in 1938. Sites documentation and burial artifacts are curated at the Frank H. McClung Museum in Knoxville, Tennessee.

During the early 1960s, Charles McNutt conducted a second round of excavations on the Cox site before the area was flooded due to the construction of the Melton Hill Dam. The University of Tennessee's Department of Anthropology provided crews for the first year of excavations in the 1960 field season. The excavations focused on the residential area of the village and recovered 43 burials. Most of these burials were determined to be Woodland Period based on their depth and poor preservation (Vogel, 2007).

Excavations in the 1961 field season were completed by crews made up of amateur archaeologists from the Tennessee Archaeological Society Knoxville Chapter and again focused on the Cox Village site (McNutt and Fischer, 1960; Vogel, 2007). Problematic and incomplete record keeping of the nearly 200 burials found that year makes it difficult to determine whether the individuals are from the Woodland Period or later Mississippian Period. Several factors preclude the ability to directly assign burial artifacts to the individual with whom they were originally interred. First, the burial artifacts were not curated, but were kept in the personal collections of the excavators themselves. Second, the poorly-kept field records and missing burial forms resulted in a number system that does not match the system currently used to inventory the skeletal remains (Vogel, 2007).

The Late Mississippian Period subadult sample from the Cox site is comprised of eight individuals from the mound and 82 subadults that were positively identified as Late Mississippian Period from the Cox Village site (Vogel, 2007).

Dallas Site (40HA1)

The Dallas site is located on the east bank of the Tennessee River in Hamilton County, Tennessee. The site was excavated by chief investigators Charles H. Nash, Stuart Neitzel, Jesse D. Jennings, Charles H. Fairbanks, and Wendell Walker from November 1936 to March 1937 in preparation for flooding of the area due to the building of the Chickamauga Dam (Lewis, et al., 1995). The mound is located on the south end of the site with the village extending northward. As defined by Kneberg and Lewis (1946; Lewis, et al., 1995), the Dallas site is the type-site for the Dallas Phase. A palisade surrounded the site, enclosing an area approximately six-hundred (600) feet by two-hundred (200) feet. Twenty-three (23) quadrangular domestic dwellings were excavated within the palisade, some built consecutively on top of one another. The excavations yielded two-hundred and ninety-eight (298) burials across the site (Lewis, et al., 1995). There are two radiocarbon dates from the Dallas site placing the site in the late fourteenth and early fifteenth centuries. A burned house structure and scorched wooden grave cover , each at opposite ends of the village, provide radiocarbon dates for the village of A.D. 1410 and A.D. 1405 respectively (Sullivan, 2007, 2009, in press). These dates document the complete burning of the village which ended the occupation of the site (Sullivan, 2007, 2009, in press).

Four construction stages were identified at the Dallas Mound (8Ha1), but there were likely additional stages that were obscured by cultivation and plowing activity that occurred on the site during the late 1800s and early 1900's. The first of the presumed multiple consecutive public ceremonial structures was built on cleared natural ground. The outline of the second ceremonial structure was only partially visible due to plowing,

as were any remnants of the presumed structures built above that level (Lewis, et al., 1995).

Less than one-third of the burials were considered to be indeterminable in any or all categories (age, sex, deposition and/or orientation) due to the fact that the Dallas site had been used for “modern” cultivation, as well as disturbance from rodents, other burial intrusions, or general taphonomic processes. Relying on the remainder of the burial series (~2/3 of the total sample), the generalization can be made that nearly all of the individuals were primary burials, either fully or partially flexed (97.5%) (Lewis, et al., 1995). There were only a handful of exceptions to that rule from the Dallas Village site (7Ha1), namely a fully extended adult male, an extended infant burial, and one reburial of a child. From the Dallas Mound (8Ha1) area there were again very few exceptions: two extended infant burials, an extended older adolescent male burial, and an extended older adult male burial (Lewis, et al., 1995).

Burial artifacts interred with individuals from the Dallas village were fairly evenly distributed between age and sex groups: 12 adult males, 10 adult females, 18 infants and children, and four adolescents had associated burials artifacts with them (Lewis, et al., 1995). Within the Dallas mound area there is a very similar pattern of burial artifacts to that found in the village. Twenty males, 17 females, 39 infants and children, and four adolescents have associated burials artifacts with them. This makes for a rather high percentage of associated burial artifacts present at the Dallas site. The Dallas village (7Ha1) has 36% of interred individuals that have associated burial artifacts and a slightly higher occurrence present in the Dallas mound (8Ha1) at 51%. Much like the burial artifact patterns outlined in discussion of the other sites used in this study, and

of other Dallas phase sites in general, males are most often associated with burial artifacts related to activities traditionally associated with males such as projectile points, celts, awls, pipes, and very few with pottery. Also consistent with patterns previously discussed, females were often associated with pottery and shell. Infants and children were often interred with shell, pottery, and gorgets.

Averbuch (40DV60)

The Averbuch site is located on a hill in north Davidson County, Tennessee. It is approximately 450 meters east of the Drake Branch, a subsidiary of the White Creek, which leads to the Cumberland River, within the Bordeaux section of the county (Klippel and Bass 1984). Unlike the other sites included in this study, the Averbuch site is not directly located on a major waterway. It is two kilometers from the White Creek and approximately four kilometers from the Cumberland River. After the site's initial discovery a basic survey was initiated by Patricia Coats and Donald P. Rapp in 1975 while an addition to the Royal Hills subdivision was beginning. Drs. Walter E. Klippel and William M. Bass later supervised full excavations at Averbuch, which began in September of 1977 and ran until December of the same year and then picked back up and ran from March of 1978 to July of the same year (Berryman 1981). The objectives of the fall field season were to fully excavate the cemetery and habitation areas, establish the size of the site, and to compare Averbuch temporally and spatially to other sites in the area. Averbuch is thought to have been occupied in the fourteenth and fifteenth centuries, during the Late Mississippian Period (Boyd, 1984; Klippel and Bass, 1984). The site was estimated to have covered approximately 66,000 square meters (Reed,

1978). As defined by Ferguson (1972), Averbuch is considered a Mississippian Period site of the Middle Cumberland culture (see Chapter 2).

Due to the nearly complete excavation of the cemetery at Averbuch a total of 645 graves that includes 887 individuals were recovered. It was estimated that an additional 409 individuals were missed due to previous construction and the usual sampling biases that occur with most archaeological sample. Preservation issues, especially among sudabults, are still a complication. It has been estimated that approximately 30% of the site had been destroyed by road and home construction prior to site excavation (Berryman, 1981).

Although there are three cemeteries associated with the Averbuch site, the majority of subadults were buried in or near village structures (Boyd, 1984; Klippel and Bass, 1984). There are a total of 427 subadult (<20 years) (as reported) burials excavated from the three cemeteries and from within structures at the site (Berryman, 1984a). Cemeteries 1 & 2 are located on the western side of the village within 30 to 35 meters from each other and located within the village palisades. Cemetery 1 is actually built over the top of several domestic structures. Cemetery 3 is located in the northeastern portion of the site and the palisade cuts through its graves on the southwest corner. This implies that Cemetery 3 is older than Cemeteries 1 & 2.

The majority of the burials from all three cemeteries at the Averbuch site are of stone box construction, but there is considerable variation in quality of construction (Berryman 1981). Individuals buried within stone boxes, as well as the few pit style burials, were nearly all oriented in a supine extended position, in other words lying on their backs with their legs fully extended and their arms at their sides. A mortuary pattern

that makes Averbuch unique among centralTennessee sites is the reuse of burial locations. During use of the cemetery, graves were reopened and the original occupant was moved aside or discarded to make room for a new deceased individual. There was also a number burials containing the remains of multiple individuals. Existing graves were often obtrusively cut into by new graves. This occurrence implies a long period of use, assuming these relations reflect the fact that the previous grave location had been forgotten.

As fitting with other sites from the Middle Cumberland culture, there is a considerable lack of associated burial artifacts compared to the East Tennessee groups (Berryman 1981). Most adult individuals were not interred with any burial artifacts at all, and when they were, they were very utilitarian in nature (e.g., awls, blades, projectile points, etc.). There was also a regular occurrence of ornamental items such as earplugs and hair pins (Berryman 1981). There is a difference in this mortuary pattern for the subadults. Nearly half the subadults are buried with one or more artifacts and most of the highly elaborate burials are those of subadults. These burials contain items like effigy vessels, shell spoons, human effigy ceramic figurines, and shell gorgets (Klippel and Bass, 1984).

CHAPTER 5: MATERIALS AND METHODS

As stated in Chapter 1, this study uses subadult skeletal samples to assess biological distinctions and general health among the populations from the Middle Cumberland and East Tennessee regions. These samples are used to further assess the hypotheses detailed at the end of Chapter 2. This chapter provides a discussion of the skeletal samples, including information about the selection criteria. The *Materials* section details the site sample compositions, sizes, and general archaeological contexts. The skeletal measurements taken from each individual and health assessment techniques (i.e., paleopathological analysis) are presented in the *Methods* section. Specific archaeological contextual information about the sites sampled may be found in the next chapter, Chapter 5.

Materials

Biological Sample Selection Criteria

The sites selected for this study represent late occupation Mississippian sites from both the Middle Cumberland and East Tennessee regions. In the Middle Cumberland, the Averbuch site represents the largest cemetery in the region dating to the Mississippian Period, as well as good preservation of a large sample (more than 100 individuals) of subadults. The East Tennessee sites sampled were the Dallas site (both the village and the mound), Ledford Island, Cox Village, and Fain's Island; the latter three were Mouse Creek Phase sites, and both components of Dallas were of the Dallas Phase. These sites were chosen in part because previous researchers have analyzed adults from the sites for

overall health, social status, and mortuary practices, as well as to compare nutritional and health status among age groups. Sites were also selected based on the presence of a sufficient sample of subadult skeletal remains to allow for inclusion of the site in the study (that is, to avoid sampling sites with fewer than five subadults).

More than the preservation of subadults was necessary for inclusion of a site in this study. As noted in Chapter 2, the use of archaeological sites that have been previously excavated come with additional caveats. Namely, the use of these sites requires sole reliance on the record keeping done at the time of excavations and, when available, site reports. While recent research has been motivated to more fully document the archaeological sites of Tennessee, especially eastern Tennessee (e.g., Sullivan, 2009), some chronologies within sites still remain unresolved (e.g., for Hiwassee Island or for Toqua). Therefore, some East Tennessee sites were excluded from the study, despite their large cemeteries.

Mortuary treatment, and its analysis, was furthermore not used in ascertaining samples. This was mostly due to an inability to easily associate burial artifacts with skeletons, or to understand the cultural context even when present. For instance, at the Cox site, the eighty-year-old excavations were conducted by multiple agencies, which in turn caused confusion with the burial numbering system; this resulted in the duplication of burial numbers assigned to separate burials. Therefore, the burial records from the Cox site would not allow for accurate assignment of burial artifacts to individuals. While the burial contexts for subadults are crucial for ascertaining cultural cues about their individual status and possible social roles (e.g., the identification of social elites in the sample), and so would be important in the selection of the study sample, this information

was not used as a sampling criterion due to the unevenness of the available data among sites.

Despite these limitations, samples were identified. Only the skeletal remains of subadults were selected for inclusion in this study. Subadults in this study were classified as individual skeletons that did not have fully fused limb bone epiphyses. Individuals with fused limb bone epiphyses but unfused medial clavicles or iliac crests were not regarded as subadults, even though these individuals were still completing primary growth. Individuals must have had at least two complete and measureable long bones to be included in the dataset. Only individuals with very minimal erosion of metaphyses and epiphyses were included in the study.

Due to the fragile nature of archaeological subadult skeletal remains, especially in the youngest individuals, there are preservation issues that occur during even the best attempts at curation. The very thin layer of cortical bone that surrounds subadult bone can be easily cracked and subsequently chipped off. This opens up the inner trabecular bone to exposure. Without protection from the cortical bone, the more delicate trabecular bone can easily be worn off, especially along the epiphyseal ends of the long bones. Upon visual inspection, it is impossible to determine exactly how much bone has been removed. Therefore, individuals with long bone ends that had had wear, either before or after excavation, were excluded from this study.

Paleodemographic profiles are not available for all of the Mississippian sites (compare with Klippel, 1984 for example), and no attempt to ascertain the demographic profile of the sites was attempted as part of this study. It is uncertain whether the subadult samples taken are proportionally representative of the relative size of either the total

number of subadults at each site, or the distribution of age groups. Equal sampling between the regions was instead the guiding criterion.

The sample sizes for the individuals from the selected sites are listed in Table 5.1. Note that, while individual East Tennessee sites have small sample sizes, when aggregated, the total sample in East Tennessee is comparable to the sample obtained from the Averbuch site. A total of 96 subadult skeletons met the minimum criteria explained above and were assessed for this study. Age groups (the methodology is explained in the next section) are equally represented except for the youngest age group, the perinatal sample.

Table 5.1. Number of subadult skeletons measured for inclusion in samples.
The East Tennessee sites are listed separately, and are aggregated in a single subtotal.

Site	Age Category					Total
	Perinatal (0-1.0)	Early Child (1.5-3.0)	Late Child (3.5-7.0)	Early Adolescent (7.5-12.0)	Late Adolescent (12.5-17.0)	
Dallas						
Village	4	2	4	3	1	
Mound	1	0	4	2	4	
Ledford Island	4	1	6	5	2	
Cox Village	3	2	0	3	5	
Fain’s Island	2	2	1	2	0	
East Tennessee Subtotal	14	7	15	15	12	63
Middle Cumberland Averbuch site	11	18	12	3	7	51
Total sample	**25**	**25**	**27**	**18**	**19**	**114**

Aging Criteria

As discussed in Chapter 3, the age-at-death estimation of subadults based on skeletal indicators continues to be a topic of discussion and refinement within biological anthropology. At the root of these methods is the goal to use skeletal age indicators to reliably estimate the chronological age of the individual. For this study, individuals were aged based upon dental development, and if that was unavailable epiphyseal closure and femoral diaphyseal length was used, following Ubelaker (1989), Scheuer and Black (2000), and Baker et al. (2005).

Dental development was used preferentially because it has been shown that dental aging exhibits less variability than skeletal aging in response to nutritional and environmental stressors (Delgado, 1975; Demirjian, 1978b; Ubelaker, 1989; Saunders, 1992; Huda and Bowman, 1995; Conceição and Cardoso, 2011) (see also Chapter 3**)**. Toascertain dental ages, the Ubelaker (1978) dental development charts were used to determine probable age-at-death. Ubelaker's (1978) developmental chart is appropriate due to the fact that it was originally adapted for Native American populations. The method of evaluating tooth crown and root formation is a viable option for the sample used herein due to the fact that in most cases at least some, if not all, the roots were visible for both erupted an unerupted teeth. Teeth were visible in their entirety because, like many archaeological samples, the mandible and maxilla were fragmented or the teeth had fallen out of the sockets. All present tooth crowns and roots—both maxillary and mandibular as well as right and left—were recorded by level of formation following Moorrees et al. (1963b; 1963a). In the instance that a tooth was intact within the alveolar bone, its level of eruption was recorded. Distinctions were made if a tooth was

completely unerupted and therefore not visible, or if it was missing because it had not been recovered. Loose teeth were identified and evaluated for development consistent with the same individual in order to avoid perpetuating any excavation errors that may have occurred. When there were no diagnostic dental remains associated with a particular burial, age was estimated based on the appearance and fusion of primary ossification centers, long bone diaphyseal length (priority given to the femur), and epiphyseal fusion (Scheuer, et al., 1980; Scheuer and Black, 2000; Baker, et al., 2005). A total of 21 subadults had to be aged by bone size. Of these alternate methods of age estimation, preference was given to long bone length and the appearance of primary ossification centers.

In addition to dental development, the status of the fusion of limb epiphyses was also assessed. Stages of limb epiphyseal fusion were scored as described below in the *Methods* section. Limb epiphyseal closure was used to estimate chronological age, using the epiphyseal closure sequences (Scheuer and Black, 2000). These ages were assessed to contrast with the chronological age estimates derived from the dentition, in part to ascertain whether any subadult group exhibited signs of discrepancies in the growth of long bones versus teeth (e.g., delayed limb fusion due to metabolic stress) (see further explanation below in the *Methods*).

For both sets of age estimates, chronological ages were classified into five categories following Bogin's (1997) work on subadult growth: perinatal (0 to 1.0 years), early child (1.5 to 3.0 years), late child (3.5 to 7.0 years), early adolescent (7.5 to 12.0 years) and late adolescent (12.5- until approximately 18 years). Individuals over the age of 18 were not included in this study. These age categories were selected to provide a

summary and age distribution of the study sample, as well as to allow for inter-study comparison. However, given the small size within these age categories, statistical analysis could not be done on these categories separately (see Statistical Analysis below).

It should be noted that the age-at-death estimation methods used in this dissertation depend on least squares regressions, and may be inaccurate or biased estimators. As no reference population reliably exists for the Mississippian sample used in this study, any age estimation method will not be optimal in minimizing errors. Alternative aging methods exist to address some of these unintentional biases, namely Transition Analysis (Boldsen et al., 2002). This technique is more aimed at addressing the absence of recognition of older adults in the skeletal record, though it has been used with some success in subadults (Taylor, 2013). While this method has promise for obtaining more accurate age estimates for archaeological samples, its use is beyond the scope of this dissertation.

Sexing

Sex differences were not assessed between individuals in this study due to the unreliable nature of sex estimation from the skeletal remains of subadults (Stini, 1969; Meiklejohn, et al., 1984; Rathburn and Buikstra, 1984; Stinson, 1985, 2000). Skeletal differences have been shown to exist between adult males and females and become visible during and after puberty (Washburn, 1948; Brothwell, 1981; Ruff, 1987; Tague, 1989). The majority of the individuals used in the skeletal analysis are assumed prepubescent with an age estimation of 10 years of age or below. Therefore, while there were undoubtedly different behaviors and cultural roles for male and for female

subadults, which potentially would be reflected on their skeletons, the lack of diagnostic indicators of sex in the sample precludes its inclusion in this study.

Methods

The skeletal sample was assessed for both metric and nonmetric data. Metric data were mostly obtained from the long bones of the limbs, while the entire skeleton was assessed for nonmetric traits, namely indicators of pathology. This section details the methods used to obtain these data. The types of statistical analysis used to address the proposed research hypotheses are also discussed in this section.

Epiphyseal Closure Scoring

Initially, each skeleton was inventoried upon inclusion in the study sample. Every skeletal element and all epiphyses were noted as completely present, fragmented, or absent. The stage of epiphyseal fusion was recorded for all epiphyses. If the epiphyseal joint was completely unfused with no indication of any closure, the union was scored as a zero. If the epiphyseal joint showed any indication of fusion, was in the process of fusing, or was fused, but the epiphyseal suture was still visible, then the union was scored as a one. If the epiphyseal suture was completely fused with no visible remnants of the line, then the union was scored as a two.

Metric Data

Skeletal measurements of the subadults followed the recommended measurements laid out in (Buikstra and Ubelaker, 1994). Table 4.3 lists these measurements and the

associated measurement tool; measurements were taken using Mitutoyo Extended Pointed Jaw digital calipers to the hundredth of a millimeter (0.01 mm) or on a Paleo-Tech Lightweight Field Osteometric Board (to the nearest millimeter). Measurements were taken once due to a previously determined low error rate for these measurements (see below). When present both the right and left femur, tibia, fibula, humerus, ulna, and radius were recorded for all measurements, epiphyseal closure, and pathology. However, the metric measurement data from the left side was preferentially used for statistical analysis. In the case that an individual's right and left epiphysis closures were not at the same level of fusion, the lowest score of suture closure was used for determination of age.

Measurement error was assessed by conducting an intraobserver error study. Each measurement was taken and recorded three times on three separate days for a subset of the study sample (*n*=10). Those measurements errors are reported as a percentage in Table 5.2.

Some of the measurements taken on the long bones (Table 5.2) were used to calculate estimated dimensions for individuals. These dimensions were estimated stature, estimated body mass, and robusticity. In addition, the relative proportions of the radius length to humerus length (brachial index), and of tibia length to femur length (crural index) were calculated for assessing the possibility for distinguishing Middle Cumberland from East Tennessee populations based on body proportions (after Holliday, 1997; Temple et al., 2008; and Auerbach, 2010) (see Chapter 3).

Table 5.2: Measurements used for Stature, Body Mass, Crural Index, and Brachial Index.

Bone Element	Dimension Type	Dimension[1]	% Dimension Error[2]	Dimension Tool	Reference
Femur and Humerus	Bone Length	Diaphyseal Length	0.15(F) 0.20(H)	Digital calipers/ Osteometricboard	Buikstra and Ubelaker (1994)
Femur	Metaphyseal Dimensions	Distal ML Metaphyseal Breadth	0.25 (F)	Digital calipers	Buikstra and Ubelaker (1994)
Femur and Humerus	Diaphyseal dimensions[3]	ML diameter at midshaft	0.66(F) 1.34 (H)	Digital calipers	Buikstra and Ubelaker (1994)
		AP diameter at midshaft	0.41 (F) 0.62 (H)	Digital calipers	Buikstra and Ubelaker (1994)

1 Planes are abbreviated: AP, anterior-posterior; ML, medio-lateral.
2 Average difference of three measurement trials from their mean, divided by the mean and multiplied by 100 (following White, 2000). Elements are abbreviated: F, femur; H, humerus.
3 Taken at 50.% diaphyseal length (Buikstra and Ubelaker, 1994).

Body mass and stature were estimated based on the equations developed by Ruff (2007). Body mass estimations were made when the distal femoral metaphyseal breadth could be measured. The predictive stature equations for the combined femur and tibia length were given preference due to their lower standard error of the estimate. When those bones were not available, the predictive equations for the combined humeral and radius length were used. As a final resort, femur length alone was used to estimate statures. For individuals who were older than 13 years of age a conversion equation was used in order for use the predictive equations. This conversion equation was:

Diaphyseal length × (Femoral ratio=1.097) *or* (Humeral ratio=1.079) = Total bone length

Both Ruff's (2007) stature estimation equations, as well as his body mass estimations, were based on European American reference populations (the Denver Growth Sample). Much like the similar issues with age estimation, this means the predictive equations are not projecting the "true" stature and body mass, as differences between this reference sample and the Mississippian samples lead to mismatches in the predictor measurements and the outcome estimates. However, Ruff's equations are predicting *relative* estimations that would all be biased similarly among all of the Mississippian samples; estimates from his equations should, if anything, exaggerate group differences in stature and body mass.

Robusticity was estimated using a predictive equation formulated by Ruff (personal communication, 2013). Robusticity, as explained in Chapter 3, is a reflection of the amount of resistance to mechanical loading experienced by a skeletal element (Ruff et

al., 1993). This was calculated from external diameters obtained from the long bone diaphyses, which only provides a highly approximate measurement for robusticity (O'Neill and Ruff, 2006). The exact equation used is as follows:

$$[(ML_{50} + AP_{50}) \div 2]^3 \div (BM \times L_D)$$

ML_{50} and AP_{50} are mediolateral diameter and anteroposterior diameter at the midshaft, respectively, either for the humerus or femur. These are averaged, cubed, and then divided by the product of estimated body mass (BM) and the total length of the diaphysis (L_D).

Nonmetric Data (Pathologies) and Dental Defect Data

Skeletal pathologies and trauma were recorded by their presence or absence and location. Detailed descriptions of each case was recorded and given a general pathology type as outlined in (Buikstra and Ubelaker, 1994). Pathology was noted as type: cribra orbitalia, porotic hyperostosis, abnormal added bone, abnormal porosity, vertebral involvement, and trauma as described in Buikstra and Ubelaker (1994). The location of the pathology was also recorded by element as well as in skeletal region categories: cranium (skull and mandible); trunk (axial skeleton, including ribs, vertebrae, manubrium, sternum, scapulae, clavicles, and the pelvis); upper limb (humerus through hand phalanges), and lower limb (femur through foot phalanges).

Nonmetric data were also collected from the dentition as either present or absent, in addition to more specific study of the teeth; dental analysis of the deciduous and adult

dentition included notation of the presence, development, eruption status, and wear patterns of the teeth. Macroscopic observation of the teeth was performed with the use of a magnifying glass (10x). Dental caries frequency, dental traits and other dental anomalies were recorded by their presence or absence and location as additional health indicators. Information on dental occlusion was also collected. The location, depth, and type of all present enamel hypoplasias were recorded to measure the occurrence and frequency of growth disruptions. Both left and right sides of the dentition were examined for the presence of dental hypoplasias. The left side dentition was examined first, and if hypoplastic defects were observed, any hypoplasias on the right side were not counted; right side defects were included only in the case none were marked as present on the left side. This selection process prevents inflation of the number of hypoplasias per individual by eliminating the possibility of the same individual being count twice. If the labial surface was completely obscured due to damage or the tooth still being unerupted, then the tooth was excluded from the sample.

Enamel hypoplasias were measured with dental digital calipers to the hundredth of a millimeter (0.01 mm) from the center of the hypoplasia to the cemento-enamel junction. If the development of the tooth was not complete to the cemento-enamel junction, the presence of hypoplasia was not measured. This measurement was converted into a developmental age established according to the tooth developmental chronology of Swärdstedt (1966) as used by Goodman, Armelagos, and Rose (1980). The developmental age for each tooth was divided into half-year periods, beginning with birth to six months and continuing to six and half years to seven years. If at least four teeth were present and two or more teeth were hypoplastic at the same developmental period

then the event was considered a growth disruption. If there were at least four teeth present and only one or less were hypoplastic then the event was not considered a growth disruption. If there were less than four teeth present, the event was considered undeterminable (Goodman, et al. 1980).

To concentrate the statistical analysis of this study on the growth disruptions of individuals in a population, the frequency and time of formation of enamel hypoplasias were recorded in reference to the individual and not solely the episode as the unit of analysis (Martin et. al, 2008; Goodman et al., 1980). This approach provides a better understanding of the temporal patterns of health and growth disruptions for individuals. In light of this analytical model, statistics for the frequency of growth disruptions were calculated as the mean number of growth disruptions per individual and as the percent of individuals with at least one growth disruption.

A Comment about Scoring Dental Hypoplasias

Special consideration should be given to the methodology for scoring dental hypoplasias, as these are the only lesions measured on a scale other than presence/absence in this study. The methods for scoring hypoplasias have greatly varied, especially when the technique first began. Each researcher has their own technique for recording dental enamel hypoplasias deemed significant enough: the "bright lights and low magnification" technique, the "if my finger nail catches on it" technique, and the ever popular "if I can still see it after removing my glasses" technique (Rose, personal communication 2001). There was, and still is, a need for standardization. Most would agree that too much information is better than not enough; and therefore all hypoplasias,

no matter the size, should be recorded. While this seems straightforward, there are still many problems to be worked out. How much magnification is "low magnification" and what defines a true hypoplasia? Berti et al. (1995) concluded that in an attempt to record "all" dental enamel hypoplasia, no matter the size, the false positives made up only a very small percentage, and they concluded that all should be recorded. When using a standard criteria and methodology, Danforth et al. (1993) found that 65% of all individual hypoplasias in their study were replicable for location, size and severity[1].

Another method of dental enamel hypoplasia documentation consists of making replicas of dental remains and looking at the casts under a high-powered scanning electron microscope and/or light electron microscope. This requires several steps that are not always available for those working in the field or without proper resources. Hillson and Bond (1992) found that latex modeling compounds made the highest quality replicas but were harder to release than other compounds and only make one replica. Using a silicone modeling compound, multiple replicas could be made from the same cast, but they were not of as high a quality as latex casts. Hillson and Bond (1997) found that the width of a dental enamel hypoplasia is often overestimated when viewed under a scanning electron microscope. This size increase is due to the lighting used in the microscope, and Hillson and Bond recommend using the perikymata counts instead.

Compiling and comparing data becomes an issue when there are so many techniques for recording enamel hypoplasias. Most studies compare frequencies of dental

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[1] The severity of a growth disruption was at one time assumed to be related to the depth and width of a dental enamel hypoplasia. As continued research is done in this area, it has been shown that these factors have no correlation to the duration or severity of a growth disruption (Kreshover 1944; Hillson and Bond 1997).

enamel hypoplasia among tooth types, but Ensor et al. (1995) suggested that it is more important to look at what they call the "Individual Hypoplasia Area." This is an account of the number of dental enamel hypoplasias per person, which is important when looking at the health of an entire population (Ensor et al. 1995). Because this method requires recording the data differently than most others, comparing old data to new data becomes very difficult.

Hillson and Bond (1997) found some correlation between pitted and exposed-plane type enamel hypoplasia and the severity of an episode, but determining the timing of such an episode is harder than with furrow type enamel hypoplasia. The timing of the growth disruption within the development of the dental enamel will also affect its depth and width, as well as its ability to be seen. The appositional zone can hide dental enamel hypoplasias in incisors and increase their effects on cheek teeth (Hillson and Bond 1997).

Much of the analysis of dental enamel hypoplasias in relation to illness and the weaning process hinges upon assessing age at onset of the growth disruption. Dental development and eruption charts produced by Ubelaker (1978) and Goodman et al. (1980) have been a mainstay of bioarchaeology for decades. The charts made by Ubelaker (1978) have been tested and retested for accuracy. Although sex and birth weight do have some effect on dental eruption and formation, this change was found to be negligible (Delgado, 1975; Demirjian and Levesque, 1980; Saunders and Hoppa, 1993; Liversidge, 1994). Goodman et al. (1980) developed a dental development chart that would allow a researcher to measure the distance of the dental enamel hypoplasia from the cementum enamel junction (CEJ) and calculate the individual's age the time of the defect's formation. This chart has been used consistently since its conception because

of its ease of use and apparent solutions to many pertinent questions within bioarchaeology.

The Goodman et al. (1980) dental development chart assumes that all people from all time periods, in all environments, and with all health and nutrition statuses, have the same rate of dental development. Several scholars have rebutted this assumption (Hodges and Wilkinson 1990; Hillson and Bond 1997; Reid and Dean 2006, 2008; Martin et al. 2008; Ritzman et al. 2008). The first studies looked at how tooth crown size and shape affected correlation of the timing of a dental enamel hypoplasia and age (Hodges and Wilkinson 1990; Hillson and Bond 1997). Hodges and Wilkinson (1990) found it necessary to use an adjusted chart that took into consideration the average crown height for the specific archaeological sample in question.

As criticisms arise and problems are addressed, dental aging methods are being refined to better suit research samples. For example, Reid and Dean (2006) made a bold move away from the commonly used method of linear growth charts developed by Goodman et al. (1980). Reid and Dean (2006) use a curvilinear model of enamel development that is histologically based, as opposed to the linear regression model of Goodman et al. (1980). This has given dental anthropologists and bioarchaeologists two opposing methods to use. The Goodman et al. (1980) method has a standard deviation of only one to four months of age, which was determined to not be a significant difference when looking at weaning, stress, or contact studies of past populations (Martin et al. 2008). Additional findings by Martin et al. (2008) found that although Reid and Dean's method was more accurate, it needs to be refined to specifically address the variation in interpopulation dental development. Ritzman et al. (2008) found the difference among an

archaeological sample and simulated dental enamel hypoplasia data and the Goodman et al. (1980) control data set to be much greater. He concluded that the difference between using the Reid and Dean (2006) method and the Goodman et al. (1980) method could be as much as a year and a half, with Reid and Dean (2006) estimating ages of onset to be a year and a half older than Goodman et al. (1980) onset ages. Many studies both for and against the weaning hypothesis could be drastically altered if the age of onset was changed by as much as a year and a half.

In the end, dental enamel hypoplasia studies have shown advancement in the refinement of the method, as well as its interpretation. While recent validation studies have made it clear that research methods could be more accurate, it is important to remember that the best approach is attempting to do the most with the methods that are available at this time. Making clear the criteria for recording dental enamel hypoplasias is of the utmost importance to increase the ability to replicate and compare results across archaeological samples and studies. Given the still-common use of the Goodman et al. (1980) aging assessment for hypoplasia presence, and its comparability to other studies, it was chosen for use in this study. However, the raw measurements of each hypoplasia from the CEJ were recorded and these data will be publicly available to researchers upon request after publication of the dissertation analyses.

Dental age comparison with long bone age

As noted above, the chronological age-at-death estimates from the teeth were compared with the age-at-death estimates obtained from the development of the long bones. Giving preference to the development of the femur, the age of an individual was estimated using the predictive equations and table set forth by Maresh (1970) for

individuals with a femoral diaphyseal length of 87.2 mm and longer. The predictive equations and table from Fazekas and Kosa (1978) was used for those individuals with a femoral diaphyseal length of 79.0 mm or shorter. For those individuals whose femoral diaphyseal length was between 79.0 and 87.2 mm, it was presumed that they were greater in age than 40 fetal weeks, but not as old as 0.125 years. Individuals whose bone lengths fell between age ranges were given the age associated with the closest range. In cases where epiphyses were fused or fusing, but the maximum total femoral length of less than 299.8 mm, the lengths were converted to a diaphysis only length using equations developed by Ruff (2007) (see above) to predict total bone length from the diaphysis lengths. For the few individuals that did not have a femoral length, the tibia or humerus was used to estimate age from the appropriate equations and tables adapted from Maresh (1970). The resulting long bone age estimate was then compared with the age estimate obtained using dental development.

Statistical Analysis

Analyses of the metric and nonmetric dimensions detailed above were assessed among the samples obtained from East Tennessee sites, and then between East Tennessee and the Middle Cumberland sample. Most sample sizes were small, and so in many of the statistical tests comparisons were made using the full sample from each site (all ages), taking into account age as a covariate. Parametric statistical testing was used due to the fact that there was no non-parametric statistic appropriate to analyze the data. Non-parametric statistics (i.e., Mann-Whittney) would require the entire data set to be z-score

transformed to minimize the effects of age and do not have the statistical power of the ANOVAs used to compare between groups.

Intraregional and Temporal Comparisons

To test the effects of a possible large-scale population migration into the East Tennessee Region, the earlier Dallas Phase Dallas site was compared to the later Mouse Creek Phase Cox, Fains Island, and Ledford Island sites. Statistical analyses of variance (ANOVAs) were used to analyze the differences between individual sites, with age included as a covariate. If age was indicated to not be a significant covariate, univariate ANOVA was used to compare estimated stature, estimated body mass, crural index, brachial index, humoral robusticity, and femoral robusticity among the East Tennessee sites. Otherwise, the results of the ANCOVA (with age a covariate) were utilized for these dimensions.

It was important to establish whether or not the populations buried within the Dallas Village and the Dallas Mound were biologically homogenous or had a heterogeneous biological signature. Therefore, the Village and Mound were initially tested separately for all biological markers previously stated. Once it was found that there were no biological differences between the two mortuary populations of the Dallas Village and Mound (see Chapter 6) they were combined for all further analysis. The increased sample size provided by the Dallas site as a whole allowed for a more even sample from the Dallas Phase to compare to the Mouse Creek Phase for intra-regional comparison, as well as for inter-regional comparison.

Comparisons of pathological count data were performed using Fisher's Exact tests. As these are frequency data, they are best analyzed with these chi-squared based tests. Pathology rates were tested for equal presence among sites, with the expectation that the types of pathologies recorded would occur at similar frequencies among the sites. Because of the small sample sizes, ages were combined for these tests, though enamel hypoplasias were examined among estimated ages of incidence.

Regional Comparison

The second set of analyses examines differences between East Tennessee samples and the Middle Cumberland sample. A lack of statistical differences among the East Tennessee site samples would allow these sites to be aggregated. If differences exist among the East Tennessee sites (for example, between the Dallas Phase and Mouse Creek Phase sites), they would be compared in separate groups to the Averbuch site.

Statistical tests for these comparisons were generally the same as those described above for comparisons among East Tennessee sites. ANCOVAs were used to assess differences in metric body dimensions between the regions, with age as a covariate. Again, limited sample sizes and a desire to maximize statistical power led to combining the full age range within samples, with age used as a covariate. Pathological frequencies were again compared using chi-squared based statistical tests. In addition, discrepancies in the growth of long bones versus dental development were assessed to compare development among the groups from the two regions.

CHAPTER 6: RESULTS

This chapter presents the descriptive statistics for the sample described in Chapter 5, followed by the results of statistical analyses of body size and shape, in addition to results of pathology and dental analyses. Of these results, intraregional comparisons of the Mouse Creek Phase East Tennessee Regional site of Ledford Island and the Late Dallas Phase sites of Cox and Fains Island, and the Early Dallas phase Dallas Village and Mound are presented first, followed by the results of an inter-regional comparison of the East Tennessee regional sites and the Middle Cumberland regional site of Averbuch. The first set of analyses are performed to both assess the variation present between the contemporaneous Late Dallas and Mouse Creek phase sites and the Early Dallas Phase Dallas site in East Tennessee, as well as to ascertain if these samples may be statistically combined for comparisons with the Middle Cumberland region

While descriptive statistics are presented for the full sample, it is important to note that not all individuals are represented in the final analyses. There were a few individuals from the Middle Cumberland Region (*n*=4) with multiple unfused or fusing epiphyseal sutures, but when evaluating their dental age per the methods outlined in Chapter 5, were ascertained to be adults (21 years of age or older). These individuals were therefore excluded from the study altogether. In cases of missing data, individuals were left out of particular analyses. Individuals were included in all analyses possible, therefore sample compositions will vary among analyses. All statistical analyses were conducted using only the total number of individuals with that particular element present. Individuals who had no observable pathologies were recorded as such, however the

interpretation of these individuals will be further explained in Chapter 7 under Caveats and Limitations.

Descriptive Statistics for the Full Sample

As described in the Methods, measurements and pathology scores were obtained from a total of 96 subadult skeletons. The total sample is nearly evenly split between East Tennessee (n = 45) and the Middle Cumberland region (n = 51). Dentally estimated ages-at-death for both regions occur at different frequencies (see Figure 6.1): the Middle Cumberland region has more young subadults ($\leq$3 years old at time of death) than East Tennessee, from which more adolescent subadults (>10 years old at time of death) were observed. Some of this difference is due to sampling bias. As explained in Chapter 5, only individuals possessing at least two measureable elements were included in the study. Because currently available site mortuary information is uneven among the sites sampled, in addition to the problems of estimating living group demography from cemetery samples (Hoppa and Vaupel, 2002), it cannot be argued that more individuals died at a younger age in the Middle Cumberland. However, it is important to point out that the 1.5 to 3-year-old sample is underrepresented, and the adolescent sample is larger, in the East Tennessee samples.

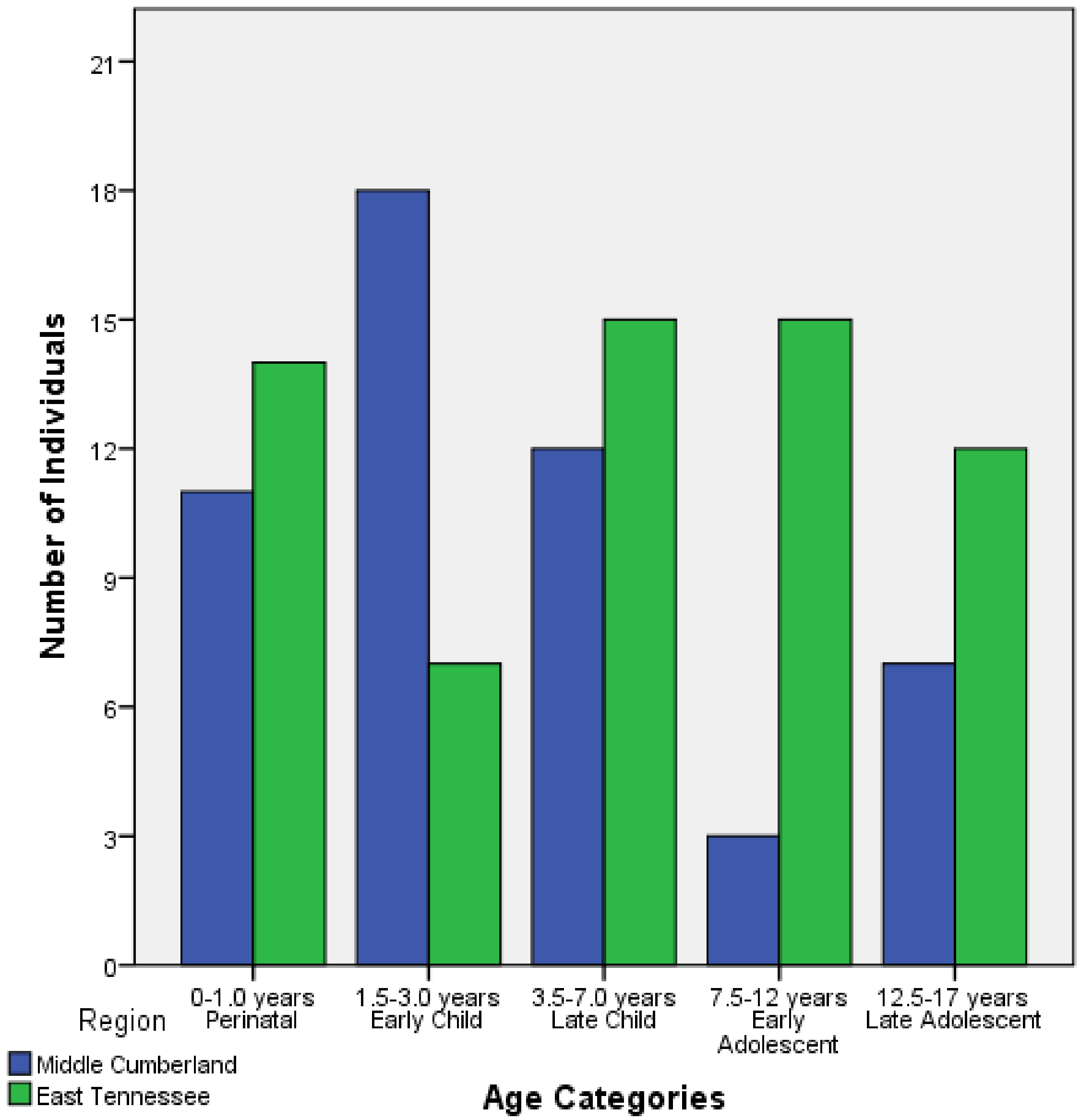

Figure 6.1: Study sample by age category

Table 6.1. Number of subadult skeletons measured for inclusion in samples.

Site	Age Category					Totals
	Perinatal (0-1.0)	Early Child (1.5-3.0)	Late Child (3.5-7.0)	Early Adolescent (7.5-12.0)	Late Adolescent (12.5-17.0)	
Ledford Island	5	1	8	5	2	22
Dallas						
Village	4	2	4	3	1	14
Mound	1	0	3	3	4	11
Cox Village	3	2	0	3	5	13
Fain's Island	2	2	1	2	0	7
East Tennessee Subtotal	14	7	15	15	12	67
Middle Cumberland Averbuch site	11	18	12	3	3	51
Total sample	**26**	**25**	**27**	**18**	**15**	**118**

The East Tennessee sites are listed separately, and are aggregated in a single subtotal.

Within East Tennessee, the frequency of ages among the sites further subdivides this sample. In Table 6.1, the number of subadults from each site in each age group is reported, as well as the subtotal of samples that are associated with the Dallas phase and the Mouse Creek phase. In order not to reduce the sample size, the data were analyzed using ANOVAs with age as a covariate. This statistical methodology maximized the total sample available in each site for comparisons and minimized the bias inherent in the different age distributions among sites.

Weighted and standard deviations for each dimension as calculated from the measured data are reported by site in Table 6.2. Because of uneven frequencies of individuals within each age category, the means are weighted by age category to minimize the effects of sampling bias, and to better reflect the analytical results of the ANCOVAs. In addition, Table 6.2 reports the unweighted means medians of the brachial and crural indices. Frequencies of pathologies and dental enamel defect statistics are reported in the sections that follow.

Table 6.2. Calculated Traits Weighted Means by Site and Region.

Site	Stature*		Body Mass*		Crural Index*		Brachial Index*		Humeral Robusticity*		Femoral Robusticity*	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Ledford Island	119.94	15.26	22.68	6.27	83.91	3.29	81.17	2.85	173.92	0.43	90.78	17.07
Dallas												
Village	123.21	28.81	27.24	7.11	84.52	3.27	79.90	2.85	122.21	24.99	97.95	19.30
Mound	129.47	28.97	19.62	4.78	83.12	2.07	78.09	4.72	144.64	51.39	120.08	37.57
Cox Village	137.87	27.17	38.39	14.30	84.71	1.95	78.24	5.57	112.85	2.46	91.87	21.89
Fain's Island	109.83	8.95	17.23	3.95	83.59	3.89	80.73	4.17	120.05	24.54	98.92	23.10
East Tennessee Subtotal	126.53	25.93	28.28	12.42	84.07	2.68	79.42	4.14	130.37	34.82	97.84	25.59
Middle Cumberland Averbuch	79.84	42.81	17.92	7.38	83.23	3.16	78.23	2.98	123.77	31.40	102.10	21.40

* All means reported are weighted by age category except for brachial and crural indices.

East Tennessee Intra-Regional and Temporal Comparison

Comparisons are made first between the temporally earlier Dallas site sample (see Chapters 2 and 4) and the more recent late Dallas Phase and Mouse Creek Phase sample. It is worth noting that the total sample size for the Mouse Creek phase is smaller than either the late or early Dallas phase samples, and that the frequencies of age categories represented in each is not the same (see Table 6.1). Use of the ANOVA analyses accounts in part for the unequal age group distributions, but some caution should be exercised when interpreting these results, as some age group biases may be affecting the analysis.

Intra-Regional Size and Growth Comparisons

Estimated statures, estimated body masses, crural indices, brachial indices, humeral robusticity, and femoral robusticity were compared between the two cultural phases using ANCOVAs. As explained in the Methods, ANCOVAs are used to account for the effects of combining individuals of different ages into a single sample, which is necessary in order to have enough individuals to allow for statistical analyses; if age was found not to be a significant covariate, the dimensions were compared using a one-way ANOVA. A conservative significance value was employed (α=0.01) this is a standard critical value used regularly in the bioarchaeological literature. There are no significant differences between sites for any measure of body size or growth (see Table 6.2 for descriptive statistics; Table 6.3 reports the *F*-test statistics for these comparisons).

Table 6.3. Intra-Regional ANOVA Results for Biological Difference

	Factor	Degrees of Freedom	*F*-value	*p*-value*
Intra-Comparison of East Tennessee Regional Sites	Stature[1]	4	0.880	0.485
	Body Mass[1]	4	1.890	0.159
	Crural Index[1]	4	0.679	0.613
	Bracial Index[1]	4	0.175	0.949
	Femoral Robusticity[1]	4	0.951	0.446
	Humeral Robusticity[1]	4	4.069	0.011

[1]Analysis performed with Dallas Village and Mound separately to establish that these separate burial areas are not statistically biologically different.
*No values were significant at $\alpha = 0.008$ or at $\alpha = 0.01$.

These results suggest that East Tennessee subadult population samples were experiencing little to no differences in levels of biological stressors that affect growth. Even though statures and body masses (the two dimensions that would most reflect the effects of stunted growth) are estimated, these use the same equations for all samples, and so no systematic bias should be the reason for the lack of differences between the sites. **The lack of differences in body size and limb proportions suggests that these populations are biologically related, if not the same population; at least there is no evidence for new gene flow or population replacement between the Early Dallas Phase and the Late Dallas Phase samples.** As the humeral and femoral robusticity of the samples for both cultural phases are likewise similar, this argues that, at least among the subadults, the mean activity levels are not different. The corroboration of this finding with the archeological evidence for cultural continuity between the Dallas and Mouse Creek Phases will be considered further in Chapter 7.

Pathology and Dental Enamel Defects

Chi-square and Fisher's Exact tests were used to compare frequencies of pathology among the Mouse Creek Phase and Dallas Phase sites (Table 6.4, Table 6.5, and Table 6.6). As explained in the Methods, all skeletons were evaluated for the presence of cribra orbitalia, porotic hyperostosis, abnormal bone growths, abnormal porosity, vertebral involvement, and trauma. Due to the large number of tests run (n=8), the adjusted alpha (using a Bonferroni correction) used to evaluate these tests was 0.006. The results for the Fisher's Exact Test (χ=4.44; p = 0.235) support independence of pathology incidence and site (Table 6.5). In other words, no single East Tennessee site's subadult sample had a prevalence of pathology exceeding what would be expected given random chance. Table 6.6 shows the results of a Bonferroni test used to compare between sites based on observed means of pathology per burial (Table 6.6).

Table 6.4. Intra-Regional Frequency of Pathology by Site

Site	Observed Pathology Count	Expected Pathology Count	% of Pathology Occurrence Within Site
Ledford Island	11	14.4	50
Dallas[1]	17	16.4	68.0
Fains Island	5	4.6	71.4
Cox	11	8.5	84.6

[1]Dallas Village and Mound combined as one site (see above).

Table 6.5. Intra-Regional Fisher's Exact Tests of Pathology Frequency

	Factor	χ -value	*p*-value*
Intra-Comparison of East Tennessee Regional Sites	Pathology Frequency by Site	4.442	0.235
	Skeletal Location of Pathology by Site	9.639	0.381
	Pathology Type by Site	18.610	0.127

***** No values were significant at $\alpha = 0.006$ or at $\alpha = 0.05$.

Table 6.6. Intra-Regional Bonferroni Post Hoc Comparison of Pathology Frequency

Site	Comparison Sites	Std. Error	*p*-value*
Cox	Dallas	0.411	1.000
	Fains Island	0.563	1.000
	Ledford Island	0.420	0.249
Dallas	Cox	0.411	1.000
	Fains Island	0.514	1.000
	Ledford Island	0.351	0.177
Fains Island	Cox	0.563	1.000
	Dallas	0.514	1.000
	Ledford Island	0.521	0.081
Ledford Island	Cox	0.420	0.249
	Dallas	0.351	0.177
	Fains Island	0.521	0.081

*No values were significant at α = 0.05.
[1]Dallas Village and Mound combined as one site (see above).

Chi Square and Fisher's Exact Tests were also used to evaluate the association between the six types of observed pathologies (noted above) and the location of the pathology on the skeleton within each of the Mouse Creek Phase and Dallas Phase sites (Table 6.7 and Table 6.8). As stated in Chapter 5, the skeletal locations were grouped into the categories of cranium, torso, upper limbs, and lower limbs. The results testing the association between type of pathology and the occurrence at each East Tennessee Regional site (χ=18.61; p = 0.127) indicated no significant association (Table 6.5) and the frequencies are presented in Table 6.7. Likewise, the skeletal distribution of the actual counts of pathologies were the same at the Mouse Creek Phase and Dallas Phase sites (χ =9.638; p =0.381) (Table 6.5) and the frequencies are presented in Table 6.7. Thus, no particular skeletal lesion was more prevalent, or more commonly associated with a particular region of the skeleton, among the sites sampled.

Table 6.7. Intra-Regional Frequency of Pathology Type and Site

	Frequency of Pathology by Skeletal Location					
Site		Cribra Obritalia	Porotic Hyperostosis	Abnormal Added Bone	Lytic Spinal Lesions	Trauma
Ledford Island	Observed Pathology Count	9	0	2	4	0
	Expected Pathology Count	4.5	0.6	4.5	5.4	0.7
	% of Pathology Occurrence at that Location Within Site	52.9	0.0	11.8	23.5	0.0
Dallas	Observed Pathology Count	9	2	10	10	2
	Expected Pathology Count	9.2	1.2	9.2	11.2	1.5
	% of Pathology Occurrence at that Location Within Site	25.7	5.7	28.6	28.6	5.7
Fains Island	Observed Pathology Count	5	1	3	5	0
	Expected Pathology Count	4.0	0.5	4.0	4.8	0.7
	% of Pathology Occurrence at that Location Within Site	33.3	6.7	20.0	33.3	0.0
Cox	Observed Pathology Count	1	0	9	10	2
	Expected Pathology Count	6.3	0.8	6.3	7.6	1.1
	% of Pathology Occurrence at that Location Within Site	4.2	0.0	37.5	41.7	8.3

Table 6.8. Intra-Regional Frequency of Pathology by Skeletal Location and Site

	Frequency of Pathology by Skeletal Location				
Site		Cranium	Trunk	Upper Limb	Lower Limb
Ledford Island	Observed Pathology Count	9	4	0	3
	Expected Pathology Count	6.7	3.4	2.7	3.2
	% of Pathology Occurrence at that Location Within Site	56.3	25.0	0.0	18.8
Dallas	Observed Pathology Count	13	3	7	5
	Expected Pathology Count	11.6	6.0	4.7	5.7
	% of Pathology Occurrence at that Location Within Site	46.4	10.7	25.0	17.9
Fains Island	Observed Pathology Count	5	6	4	4
	Expected Pathology Count	7.9	4.1	3.2	3.8
	% of Pathology Occurrence at that Location Within Site	26.3	31.6	21.1	21.1
Cox	Observed Pathology Count	10	6	4	6
	Expected Pathology Count	10.8	5.6	4.4	5.3
	% of Pathology Occurrence at that Location Within Site	38.5	23.1	15.4	23.1

In case frequency data erroneously masked higher *individual* counts of pathologies within sites, the average numbers of pathologies per burial per site were evaluated using an ANCOVA test with age as a covariate. The results showed that age was not a significant covariate, and therefore the data were reassessed using an ANOVA to evaluate the means. No significant differences were found between any of the East Tennessee Regional archaeological sites.

Finally, analyses were conducted to assess whether the East Tennessee sites differed in growth disruption patterns assessed by comparing the number of enamel hypoplasias per individual and the number of individuals with at least one growth disruption event (see Chapter 5) (Table 6.9). The growth disruption ratio did not follow a normal distribution for this sample, and so the data were log transformed for use in ANOVA comparisons. However, the log of the ratio value also failed to obtain a normal distribution, therefore the nonparametric Kruskal-Wallis test was used to compare East Tennessee regional sites. The Kruskal-Wallis test ($\chi = 2.02$; df = 3; $p = 0.568$) suggests a lack of differences in the growth disruption ratios between any of the East Tennessee sites. This lack of significance supports the findings stated above that there were seemingly no detectable differences in the biological stress level experienced by the subadults among the East Tennessee Regional sites. Again, this does not support the hypothesis that the Mouse Creek Phase and Late Dallas subadults were experiencing more biological effects of stress factors than the earlier Dallas Phase subadults.

Table 6.9. Intra-Regional Mean Dental Growth Disruption per Tooth by Site

Site	N	Minimum	Maximum	Mean[1]	Std. Deviation[1]
Ledford Island	11	0.000	0.130	3.720	5.4609
Dallas	25	0.000	0.263	2.405	6.5619
Cox	13	0.000	0.185	3.034	5.6780
Fains Island	7	0.000	0.100	1.429	3.7796

[1] Means and Standard Deviation were multiplied by 100

Table 6.10. Intra-Regional Percent of Population with One or More Dental Growth Disruption

Site	N	Percentage of Individuals with Growth Disruptions
Ledford Island	11	36.4
Dallas	25	16.0
Cox	13	30.8
Fains Island	7	14.3

The results stated above indicate that there is no age effect within the sample for the prevalence of skeletal pathologies, and there is no difference between subadults buried during either of the cultural phases in East Tennessee. Combined with the examination of skeletal dimensions (e.g., body mass, stature, etc.), there are no significant differences between any of the East Tennessee regional sites in health or growth, as determined by body size, proportions, pathology, or growth disruption, and activity levels were apparently similar. Thus, there are no biological differences between the fourteenth-century Dallas site and the fifteenth-century Cox, Fains Island, and Ledford Island sites. Therefore, these findings support the combination of all East Tennessee Regional sites into a single sample for inter-regional comparisons with the Middle Cumberland. These findings also suggest that the drought episodes of the fifteenth century did not have a different impact on the East Tennessee populations than did the episodes of the fourteenth century (Chater2, Figure 2.3).

Middle Cumberland & East Tennessee Inter-Regional Comparison

In this second set of analyses, samples from the East Tennessee sites were combined into a single sample for comparison with the Middle Cumberland subadults from the Averbuch site. Although there is variation in the body size, robusticity, pathology frequencies, and number of growth disruptions among individuals among sites in East Tennessee (see Table 6.2, for example), these differences were not sufficient to be statistically significant, as shown in the analyses above. There were also likely differences within sites among individuals, but these differences are beyond the scope of this dissertation. Thus, on statistical grounds, the East Tennessee sample consists of

combined sites that include both the fourteenth- and fifteenth-century Dallas and Mouse Creek Phases.

As above, the Middle Cumberland subadult sample is compared with this combined East Tennessee subadult sample in the following subsections. Dimensions reflecting body size, shape, and robusticity of the limbs are compared, as are the frequencies of pathologies and growth disruptions. Together, these are used to assess the second hypothesis presented at the end of Chapter 2, wherein the dietary and other environmental differences between the Middle Cumberland and East Tennessee regions are expected to be reflected in the subadult skeletons of each.

Size and Growth Comparisons Between Middle Cumberland and East Tennessee

Like the East Tennessee site comparisons, univariate ANCOVAs were used to test for differences between the two regions in stature, body mass, crural index, brachial index, humeral robusticity, and femoral robusticity (see Table 6.2 for descriptive statistics). Age was again used as covariate. Normality was tested using the Shapiro-Wilk test; equality of variance was tested using the Levene's F test and met for all comparisons except two. Estimated stature and humeral robusticity did not meet the normality assumption, but the log of these dimensions was normally distributed, so an ANOVA was conducted using the logged measurements. Again, a critical alpha was set at $\alpha = 0.01$. There were no statistically significant differences between regions for any of the calculated measurements, with the notable exception of stature. The results for stature, accounting for age as a covariate, showed an interesting trend between the East Tennessee and the Middle Cumberland regions for those individuals who had died at or

below the age of 15 years are exhibiting significant differences in stature (Table 6.11, $p = 0.023$). Subadults the age categories of early and late child (1.5-3.0 & 3.5-7.0, respectively) show the greatest amount of difference between the two regions (Table 6.12, $p = 0.012$). The shorter stature of Middle Cumberland subadults could indicate that they were under more biological stress at an early age, but this deficit in statures is less in adolescents compared to those from the Eastern Tennessee Region; stature among older adolescent subadults are not significantly different, despite taller statures again occurring among East Tennessee subadults (Table 6.13). Thus, these results support the original research hypothesis in Chapter 2, though only partially; body mass estimates did not differ between the two regions. The weighted means for each derived measurement for each region is reported by age category in Tables 6.13 through 6.18.

Table 6.11 Inter-Regional ANOVA Results for Biological Difference

	Factor	Degrees of Freedom	*F*-value	*p*-value
Inter-Regional Comparison of the Middle Cumberland and East Tennessee Regions	**Stature[ab]**	**1**	**5.425**	**0.023**
	Body Mass[a]	1	0.232	0.633
	Femoral Robusticity	1	1.407	0.239
	Humeral[b] Robusticity	1	0.469	0.496
	Crural Index	1	3.163	0.081
	Bracial Index	1	3.228	0.080

[a] Analysis conducted without the perinatal age category; stature and body mass estimations are unavailable for those under the age of 1 year old.
[b]Data were not normal and were therefore conducted using the log of the dimension.

Table 6.12. Inter-Regional ANOVA Stature Results for Early and Late Child Age Categories Biological Difference

	Factor	Degrees of Freedom	*F*-value	*p*-value
Inter-Regional Comparison of the Middle Cumberland and East Tennessee Regions	**Stature**[a]	**1**	**7.068**	**0.012**

[a] Analysis conducted on the early child (1.5-3.0) and late child (3.5-7.0) age categories, combined.

Table 6.13. East Tennessee and Middle Cumberland Regions Stature Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	60.85[a]	92.49	102.75	121.61	155.81	132.59
	Std Deviation	[a]	10.85	9.80	11.34	9.75	24.32
Middle Cumberland	Mean	[b]	70.92	71.72	129.31	139.59	98.55
	Std Deviation	[b]	32.95	48.02	5.48	15.873	45.59

[a] Only 1 individual in this age category
[b] No individuals in this age category have stature estimates available.

Table 6.14. East Tennessee and Middle Cumberland Regions Body Mass Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	[b]	11.88	15.87	26.14	49.98	23.85
	Std Deviation	[b]	1.140	2.937	6.340	12.134	11.304
Middle Cumberland	Mean	[b]	11.32	17.91	30.81	[b]	21.40
	Std Deviation	[b]	1.389	2.126	5.463	[b]	8.037

[b] No individuals of this age category.

Table 6.15. East Tennessee and Middle Cumberland Regions Femoral Robusticity Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	188.93	20.417	103.63	94.72	80.19	97.84
	Std Deviation	133.22	14.541	10.534	24.291	7.288	25.592
Middle Cumberland	Mean	193.87	118.59	103.13	88.59	85.35	102.10
	Std Deviation	21.408	12.946	8.806	1.384	2.890	21.402

Table 6.16. East Tennessee and Middle Cumberland Regions Humeral Robusticity Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	197.29	165.12	128.19	122.85	139.71	130.37
	Std Deviation	9.064	2.943	16.800	37.250	33.423	34.822
Middle Cumberland	Mean	176.30	161.10	128.96	96.47	100.18	123.77
	Std Deviation	96.534	17.140	13.672	0.976	8.257	31.395

Table 6.17. East Tennessee and Middle Cumberland Regions Crural Index Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	86.63	84.71	82.29	83.45	83.28	84.07
	Std Deviation	3.176	0.413	1.790	1.770	2.256	2.6778
Middle Cumberland	Mean	87.15	82.31	82.15	81.27	82.89	83.23
	Std Deviation	1.436	1.895	3.667	2.284	2.091	3.157

Table 6.18. East Tennessee and Middle Cumberland Regions Brachial Index Weighted Means Age

		0-1.0	1.5-3.0	3.5-7.0	7.5-12.0	12.5-17.0	Total
East Tennessee	Mean	82.91	82.50	79.08	78.90	73.91	79.41
	Std Deviation	2.109	1.651	2.510	2.426	5.180	4.143
Middle Cumberland	Mean	80.93	77.48	77.41	74.30	81.54	78.23
	Std Deviation	0.993	1.974	4.732	1.529	1.829	2.983

The lack of differences in limb proportions and limb robusticity deserve additional attention. The lack of differences in limb proportions signal that, at least among the subadults, even if the Middle Cumberland population migrated, it would not be possible to detect such a population incursion based on limb indices. Moreover, this may argue that both the Middle Cumberland and East Tennessee populations derived from a common ancestral group, or that there was gene flow between them. Findings by Auerbach and Sylvester (2011) suggested that allometry in the lower limb does not have any effect on stature differences (except in exceptionally tall populations), and so, even if the crural indices were different between the regions, the observed stature differences would be unrelated. Additionally, the results here support that there is no evidence for differences in activity among subadults between the regions, though without cross-sectional properties this cannot be definitively ascertained.

Pathology and Dental Enamel Defects

Chi-squared cross tabulation analyses of presence or absence of pathology were used to compare the East Tennessee and the Middle Cumberland regions. As described in the Methods and above, pathologies were recorded and compared by skeletal location. Table 6.8 includes the counts of presence/absence by skeletal location, the expected count if there was no association between skeletal location and the occurrence of pathology, the % of presence/absence by skeletal location, and the adjusted residual for each cell (Table 6.19). Table 6.20 also includes the chi-square test results. There are significantly more occurrences of pathology in the Middle Cumberland region than would be expected if there was no association between region and pathology (χ=11.41; p = 0.001). In the Middle Cumberland subadult sample, 92.2% of the individuals possessed at least one lesion, whereas only 65.7% of East Tennessee subadults exhibited any skeletal pathology. As seen in Table 6.9, the adjusted residual for Middle Tennessee is 3.4 with an expected count of about 39 and an actual count of 47. Alternatively, the adjusted residual for the East Tennessee Region is -3.4 with an expected count of pathology occurrence of approximately 52 and an actual count of only 44. These results support the research hypothesis that the subadults from the Middle Cumberland region were experiencing greater biological insults (or, at least they exhibited their impact more frequently) than the subadults from the Eastern Tennessee region.

Table 6.19. Inter-Regional Comparison of Pathology Frequency

Region	Observed Pathology Count	Expected Pathology Count	% of Pathology Occurrence Within Site
East Tennessee Region	44	51.7	**65.7**
Middle Cumberland Region	47	39.3	**92.2**

Table 6.20. Inter-Regional Fisher's Exact Tests of Pathology Frequency

	Factor	χ -value	*p*-value*
Inter-Regional Comparison of the Middle Cumberland and East Tennessee Regions	Pathology Frequency by Site	11.41	0.001**
	Skeletal Location of Pathology by Site	0.664	0.892
	Pathology Type by Site	10.256	0.098

Chi-square and Fisher's Exact tests were also used to evaluate the association between types of pathology recorded and the location of the pathology on the skeleton. These assessed whether the expression of the skeletal lesions differed between the Middle Cumberland Averbuch site and the East Tennessee sites. This follows the same protocol as described in Chapter 5 and above. Though there is a greater frequency of pathological lesions in the Middle Cumberland subadult sample, there is no significant

difference in the expression of pathology among skeletal locations (Fisher's Exact = 0.664; $p = 0.892$) (Table 6.21). In addition, the subsequent analysis showed no significant association between skeletal regions and a particular type of pathology (Fisher's Exact = 10.26, $p = 0.098$) (Table 6.22). Thus, the types of pathologies observed and their skeletal locations did not differ between the sites; only the prevalence was greater overall in the Middle Cumberland Averbuch site.

Table 6.21. Inter-Regional Comparison of Pathology Skeletal Location

	Frequency of Pathology by Skeletal Location				
Region		Cranium	Trunk	Upper Limb	Lower Limb
East Tennessee Region	Observed Pathology Count	37	19	15	18
	Expected Pathology Count	35.3	17.9	16.1	19.6
	% of Pathology Occurrence at that Location Within Region	41.6	21.3	16.9	20.2
Middle Cumberland Region	Observed Pathology Count	44	22	22	27
	Expected Pathology Count	45.7	23.1	20.9	25.4
	% of Pathology Occurrence at that Location Within Region	38.3	19.1	19.1	23.5

Table 6.22. Inter-Regional Comparison of Pathology Type

	Frequency of Pathology by Type and Region						
Region		CO	PH	Abnormal Added Bone	Lytic Spinal Lesions	Trauma	Infection
East Tennessee Region	Observed Pathology Count	37	19	15	18	4	0
	Expected Pathology Count	35.3	17.9	16.1	19.6	2.7	1.3
	% of Pathology Type Within Region	41.6	21.3	16.9	20.2	4.4	0.0
Middle Cumberland Region	Observed Pathology Count	44	22	22	27	2	3
	Expected Pathology Count	45.7	23.1	20.9	25.4	3.3	1.7
	% of Pathology Type Within Region	38.3	19.1	19.1	23.5	1.8	2.7

Given these results, as well as the shorter statures in the Middle Cumberland subadults, it is interesting to see whether the number of growth disruptions indicated by dental enamel hypoplasias were higher at the Averbuch site as well. The growth disruption ratio data did not meet the normality assumptions that are required for an ANOVA; therefore, a non-parametric test for the regional comparison had to be used. Due to the fact that there were only two regional groups, a Mann-Whitney test was used to compare the means between regions. Findings (see Tables 6.23 and 6.24) suggest that there were no significant differences in the growth disruption ratios between the Middle Cumberland and the East Tennessee Regions (U = 1326.5; p = 0.361).

Although the results were not statistically significantly different and therefore do not support the research hypothesis, there is an interesting trend that can be seen when the frequency of enamel hypoplasias are graphed by age group (see Figure 6.2). The trend shows an increased occurrence of enamel hypoplasias for the East Tennessee Region individuals at a younger age. Generally, a greater frequency of enamel growth arrests formed at an earlier age in both East Tennessee subadults and subadults of the Middle Cumberland population, *but* the trend was for them to occur more frequently at the youngest ages for East Tennessee subadults. This could indicate differences in weaning ages between the populations, or different sensitivities to stressors; without additional cultural data, no conclusion may be drawn about the causes of these differences (especially as they are not statistically different). A power analysis on the existing data show that, in order to detect this difference as statistically significant, a sample four times the size of the available sample would be necessary.

Table 6.23. Inter-Regional Frequency of Dental Growth Disruption

Region		N	Mean[1]	Std. Deviation[1]
East Tennessee	Number of Disruptions per Tooth	56	2.687	5.7692
Middle Cumberland	Number of Disruptions per Tooth	51	2.012	5.3266

[1] Means and Standard Deviation were multiplied by 100

Table 6.24. Inter-Regional Percent of Population with One or More Dental Growth Disruption

Region	N	Percentage of Individuals with Growth Disruptions
East Tennessee	56	23.2
Middle Cumberland	51	15.7

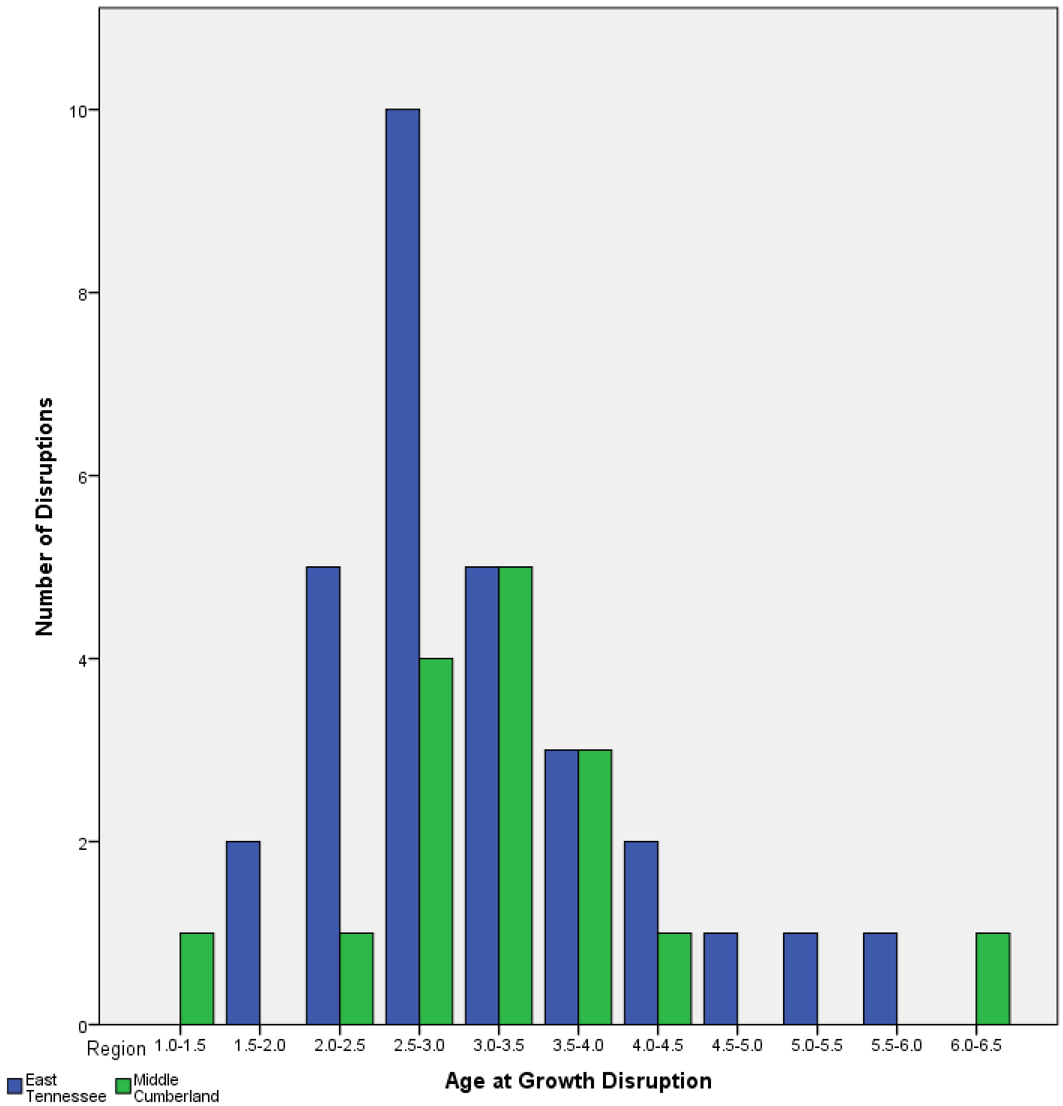

Figure 6.2. Inter-Regional Frequency of Growth Disruption by Age

Dental Age-at-Death Versus Long Bone Age-at-Death

Finally, an analysis was conducted to assess whether the timing of normal limb element epiphyseal fusions were different from the chronological ages-at-death as estimated from the teeth. As noted in Chapter 3, dental development is thought to be more resilient to the effects of factors that contribute to growth retardation, while long bones may have delayed or early fusion due to these factors. Thus, the chronological age estimates obtained from both skeletal sources were compared to assess whether the differences observed between the Middle Cumberland and East Tennessee subadults would be reflected.

A Pearson's correlation test was used to evaluate the relationship between the estimated dental age assigned to the subadults in this study and the estimated age based on those same individual's long bone lengths. These two are significantly correlated, with a Pearson's product moment (r) of 0.960 and r^2 of 90%. There is a high correlation between the two estimators of age. When using estimated dental age and the region (Middle Cumberland or East Tennessee) as predictors to formulate a predictive regression equation, the equation produced was the same. That region is not a significant predictor of long bone age further supports previous evidence for biological similarities between the Middle Cumberland and the East Tennessee Regions. In other words, the predictive value of dental age estimation does not differ from the predictive value of the age estimated by long bone length. This means that the overall growth of the subadults in either region is not so stunted that it significantly differs from the dental development (or both regions are affected equally in the discrepancies between the two age estimators).

Summary of Results

Overall, the East Tennessee regional sites showed no statically significant differences for any of the derived biological traits (i.e., estimated stature, estimated body mass, crural index, brachial index, humeral robusticity, or femoral robusticity). Grouping the sites into their respective cultural phases (Dallas and Mouse Creek) and also by time period (fourteenth vs. fifteenth centuries) also failed to present an intraregional distinction. There were also no significant differences in pathology frequency, skeletal locations of pathologies, or pathology type among the East Tennessee sites. Dental enamel hypoplasia frequency and timing were statistically no different between any of the East Tennessee sites. All these findings allowed for the comparison of the Middle Cumberland site of Averbuch to that of the combined East Tennessee Regional sites. Further implications for these concerning the cultural difference between the Dallas the Mouse Creek phases or the temporal shift from the fourteenth-century Dallas site to the fifteenth-century Cox, Fains Island and Ledford Island sites, as well as archaeological evidence for the relationship between these cultural phases and time periods , will be discussed further in Chapter 7.

What is interesting is that the comparison of the Middle Cumberland Averbuch site to the East Tennessee regional sites found evidence for shorter statures at the Averbuch site during the early and late child age categories (1.5-3.0 & 3.5-7.0 years of age). However, no significant difference in statures were found when analyses also included both adolescent age categories. None of the other skeletal dimensions—mass, intralimb indices, and limb robusticity—differed between the regions. Additionally, even though the skeletal location and type of pathology did not differ between the regions,

this does not diminish the fact that the overall frequency of pathology was greater in individuals from the Middle Cumberland Region. These two findings support the research hypothesis that, overall, the subadults from the Middle Cumberland Region were under more biological stress than the subadults from the East Tennessee Region during the late Mississippian Period. Additional consideration of this finding in the broader regional archaeological context is given in the next chapter.

CHAPTER 7: DISCUSSION AND CONCLUSIONS

This study was designed to evaluate the relationship between, and health of, the subadult populations from the Middle Cumberland Region, as represented by the Averbuch site, and the East Tennessee Region, as represented by the Ledford Island, Dallas, Cox and Fains Island sites during the Late Mississippian Period. These two regions had established cultural differences, and both of their populations' survival depended on varied sociopolitical and environmental conditions (Berryman, 1984; Crites, 1984a, b; Klippel and Bass, 1984). These factors may have all played a role in the biological stressors experienced by subadults from these regions. During the Thruston Phase (A.D. 1250-1450) of the Late Mississippian Period, the Middle Cumberland Region was experiencing a significant drought and increased climatic instability compared with earlier centuries; this climate change coincided with an increase in regional violence (Eisenberg, 1986; Smith, 1992; Cobb and Butler, 2002; Moore, et al., 2006; Cobb and Gillam, 2008; Worne, 2011; Vidoli, 2012; Cobb, et al., in press). These two factors, combined with the isolated settlement on land of low agricultural productivity, may have put the Averbuch population, especially their subadults, at an overall health disadvantage.

To compare the Middle Cumberland and East Tennessee Regions, it had to first be established that individuals sampled from the multiple sites in the East Tennessee Region were effectively from the same biological population who were presumably experiencing the same or similar biological stressors. The sites selected for study within the East Tennessee Region fall into two distinct temporal phases—the Early Dallas

Phase and the Later Dallas and Mouse Creek Phases—which both coincided with the occupation of the Averbuch site in the Middle Cumberland Region. The Dallas and Mouse Creek Phases have their own cultural distinctions, but encompass groups living within close geographical proximity. Therefore additional comparisons were made between these two culture phases to test for biological differences.

Addressing the Hypotheses and Aims of This Study

Hypothesis1: Intraregional variation in East Tennessee and Archaeological Implications

Within the East Tennessee regional sites of Ledford Island, Fains Island, Cox and both the Dallas site Village and Mound there were no statistically significant differences in either body size and proportions, or in skeletal pathological lesions. As reviewed in Chapters 2 and 4, individuals from these sites would have lived in settlements that had different geographical settings, in their resource access (especially arable land), and cultural practices. Even though there are temporal differences among the samples within and between phases, in addition to these other distinctions, the Mississippians of East Tennessee sampled in this study do not differ phenotypically. Specifically, these groups also show consistency in stature and body mass estimations, in addition to their crural and brachial indices. Subadult individuals from any given East Tennessee Regional site had similar rates of occurrence for both skeletal markers of pathology and dental enamel hypoplasia. Although the ceramics and the mortuary practices were markedly different between Dallas Phase and Mouse Creek Phase sites, results from this study indicate that, from a biological standpoint, these populations were under no more or less stress at any given site within the study. Moreover, the body size and proportion results suggest

biological continuity among these groups, or at least they cannot be distinguished based on the dimensions argued to be distinctive early in ontogeny and stable over long temporal periods (Ruff, 1994; Holliday, 1997; Auerbach, 2010; Cowgill et al., 2012).

The findings reported here are supported by studies of adult samples from the same region. Auerbach (2007; personal communication, 2013) did not detect any differences in limb proportions, body mass, or bi-iliac breadth among the Mississippians of East Tennessee Dallas Phase and Mouse Creek Phase sites. A biodistance study by Harle (2010) found that adults from the East Tennessee Region (including Ledford Island, Cox, and Fains Island) were morphologically very similar. This is especially noteworthy in light of Harle's finding (2010) of biological differences between the East Tennessee regional adults and adults from Northern Georgia. Harle's findings reinforce the argument that Late Mississippian peoples from surrounding regions were not likely infiltrating the populations of the East Tennessee region.

Thus, a conclusion of this study's results, in conjunction with the evidence provided by comparing adult remains, is that populations from the East Tennessee cultural phases dating roughly between A.D. 1300 and 1600 cannot be biologically distinguished. Therefore, they likely emerged from the same parent population, but coexisted in the same region. Whether this pattern is the result of gene flow between sites or they were actually a single regional population cannot be addressed by the skeletal remains alone.

One of the most noteworthy differences in the region early in the Dallas Phase is the archaeological evidence for the appearance of conflict in the region. There are signs of increased defensive measures, including the construction of palisades and evidence

for the burning of the Dallas site at the end of the fourteenth century. Of course, the presence of palisades does not inherently indicate the need for defense, and could have served other sociocultural functions, especially given low frequencies of interpersonal trauma evidenced among adult skeletons in East Tennessee (Smith, 2003). While a significant event, the reason for the burning of the Dallas site has not been ascertained; there are several reasons why the site could have burned, both accidental and intentional.

A localized conflict may have led to the site being intentionally burned by invaders (Sullivan, 2007), perhaps coming from the Middle Cumberland Region who fled the uninhabitable drought conditions that began in the fourteenth century (Chapter 2, Figure 2.3). If this were the case, one would expect to find evidence of invaders or immigrants in East Tennessee. Alternatively, it is possible that inhabitants of the Middle Cumberland began fleeing the region during earlier drought periods (see Chapter 2) and would therefore have already been biologically culturally and biologically homogeneous. McCarthy (2011) did find that adults buried at the Hixon site (dating to the late twelfth and thirteenth centuries—more than a full century before Dallas burned), located just across the river from the Dallas site, were biologically dissimilar from other groups in the area, including those at the Dallas site. This may be evidence to support the research hypothesis that non-native groups inhabited this region. However, they disappeared from the region (McCarthy 2011) before the fourteenth century. The present study shows that if there had been an incursion of outsiders into the area, whether peaceful or violent, it did not happen in large enough numbers to be biologically evident within the subadult population or it began in the fourteenth century and by the fifteenth century, the gene pools were integrated in eastern Tennessee.

A second possibility is that the burning of the Dallas site could have been completely accidental, such as a hearth fire that got out of control and spread throughout the village (Cook, 2012). If this were the case, an entire village of displaced people would have needed to move somewhere, and they would have likely rebuilt on top of the original village site, for which there is no evidence. Alternatively, they could have been incorporated into another area village or several villages as refugees. At this time, there is no evidence for either of these accidental burning scenarios, making it rather unlikely that the Dallas phase burning was not intentional; however there is no way to prove or disprove an accidental burning event. A third related option is that the burning and abandonment of the Dallas site was ceremonially intentional. This was a fairly common practice among the Mississippian people of the American Southeast (Smith, et al., 1994; Moore, et al., 2006; Lacquement, 2009; Cook, 2012). The archaeological evidence remains equivocal for this scenario. Yet, the biological evidence at least argues that, in any scenario, the population of the Dallas site could have relocated to sites like Ledford Island, Cox, or Fains Island; all three sites postdate the burning of Dallas (Harle, 2003; Sullivan, et al., 2009).

Hypothesis 2: Morbidity Differences Between the Middle Cumberland & East Tennessee

The preadolescent subadults (i.e., those under the age of thirteen) from the Middle Cumberland Regions were shorter in stature, and all the subadults had higher occurrences of pathology than comparable subadults from the East Tennessee sites used in this study. All other indicators of growth and biological health were similar among the regions: body mass estimation, crural and brachial indices, frequencies and timing of

dental enamel hypoplasias, as well as the type and skeletal location of pathology. This indicates a difference in the severity, frequency, and or type of biological stress that the subadults from the Middle Cumberland Region were experiencing compared to the subadults from the East Tennessee Region. Several previous studies on the adults from the East Tennessee sites found similar results of a lower rate of pathology and taller statures relative to individuals from the Averbuch site (Boyd, 1984, 1986; Boyd and Boyd, 1989). These studies also found the adult population from Averbuch to be biologically distinct from individuals from the East Tennessee Mouse Creek Phase sites of Ledford Island, Mouse Creek, and Rymer, as well as the Dallas Phase sites of Dallas and Toqua.

Ascribing causation to any particular set of factors for the differences observed between the regions is difficult, though some factors may be cited as possible contributors. As reviewed in Chapter 3, heavy reliance on starchy agricultural crops lacking sufficient levels of protein, minerals, and phytates, in addition to an increase in population size, may have been culprits that adversely affected the pathogen load and individuals' ability to recover from biological insults. Perhaps a more likely factor would be the increasing violence and warfare that was occurring in the Middle Cumberland during the fourteenth and early fifteenth centuries. It is likely that this violence pushed groups into more defensive positions geographically, as indicated by the increased the construction of palisades in many communities (Worne, 2012; Cobb et al., in press). During the Thurston Phase of the Late Mississippian Period, populations were moving to more remote locations, off the major waterways and onto secondary and tertiary water drainages, presumably for protection (Cobb & Gilliam, 2008; Smith, 1992). These areas

offered more seclusion but also provided less arable land, therefore reducing the resources available to the populations that occupied them. As an end result, the Averbuch population may have protected themselves from intergroup violence at the cost of their overall health (Armelagos and Hill, 1990; Danforth, et al., 2007; Powell, 2007).

The population from Averbuch appears to have biologically suffered from all these potential stressors. Their community was settled on the Drake Branch, a tertiary subsidiary of the Cumberland River, and a palisade wall reinforced the site (Klippel and Bass, 1984). The botanical and faunal findings from the site show that their substance economy relied very heavily on the production of maize, with little diversity in botanicals and a relatively low quantity of faunal remains, mostly consisting of deer (Crites, 1984a, b; Smith, 1992). Studies of the adults, as well as the findings reported in Chapter 6 for all of the subadults, have shown that the population was suffering from a high rate of infectious diseases and malnutrition (Boyd, 1984; Berryman, 1984; Worne, 2011). In addition, the preadolescent subadults from the Averbuch site were stunted in stature as compared to their East Tennessee counterparts. Despite this evidence for stress, the dental enamel hypoplasia data detailed in Chapter 6 shows that the subadults from the Averbuch site were not significantly different from the East Tennessee Regional sites.

A Paradoxical Interpretation

Interpretation 1

There are two ways of interpreting these data. Applying Wood et al.'s (1992) osteological paradox most literally, the presence of lesions and growth stunting should be interpreted as resilience and buffering (Table 7.1). Therefore the increase in pathological lesions in the Middle Cumberland would suggest that although biologically stressed subadult individuals were able to survive through the illness and produce a lesion. Overall, they would be healthier than those who do not have lesions, would not have survived long enough to produce them. However, it also cannot be discounted that individuals without lesions may have just been less biologically stressed overall. Within this interpretation, the decrease in growth disruptions seen in the Middle Cumberland, especially in the younger ages, could indicate that these individuals were just less frail and therefore have less stress markers. The increase in especially earlier growth disruptions in East Tennessee could indicate a more frail and overall less healthy subadult population. Reduced statures observed in the early subadult years could be interpreted as buffering protecting these Middle Cumberland individuals from added biological stress, whereas the East Tennessee subadults either did not experience stresses concomitant with such reduced growth, or they were unable to respond to nutritional and metabolic stresses through a buffering response (Table 7.1).

Table 7.1. Osteological Paradox Interpretation 1.

	Pathology	LEH/Growth Disruption	Stature at younger ages
MCR	↑	↓	↓
Interpretation	Decreased Frailty	Decreased Biological Stress	Biological Buffering = Decreased Frailty
ETR	↓	↑	↑
Interpretation	Increased Frailty & Mortality or Not Biologically Stressed	More Frail = Less Healthy	Increased Frailty

↑ indicates an increase in the values of the factor, and ↓ indicates a decrease in the values of the factor.
MCR = Middle Cumberland Region; ETR = East Tennessee Region

It is possible that the subadults who died at Averbuch simply had higher morbidity rates than the subadults from East Tennessee groups. Adolescent statures were not significantly different between the two regions compared in this study, and adult statures were not as noticeably different between the two regions as they were between the preadolescents (Boyd, 1984, 1986; Boyd and Boyd, 1989; Auerbach, 2011). Thus, it is possible that the youngest individuals at Averbuch represent those who succumbed to the stressors, and individuals who survived to adolescence and adulthood experienced some recovery (i.e., catch-up growth), diminishing the differences between them and their East Tennessee counterparts.

Interpretation 2

A second possibility is to interpret the results in light of the Milner et al. (2008) interpretation of the osteological paradox, in that the presence of greater rates of skeletal pathology indicates that individuals from Averbuch suffered but recovered from initial

stressors, only to succumb to later factors. An interpretation that fits both possibilities would be that the Averbuch subadults experienced chronic stress, especially during the years before puberty, from increased population density and violence, and due to a heavily maize-based diet. As reviewed in Chapter 3, a maize-based diet would have been low in protein and calcium, as well as high in phytates that may have sequestered what minerals were available in their diet. However, individuals surviving past 7 years of age may then have experienced some recovery before the end of primary growth. Hence, the greater skeletal pathologies observed in adults may have been, in part, an artifact of surviving higher morbidity that occurred during childhood.

Table 7.2. Osteological Paradox Interpretation 2

	Pathology	LEH/Growth Disruption	Stature at younger ages
MCR	↑	↓	↓
Interpretation	Increased Frailty & Mortality or Not Biologically Stressed	More Frail = Less Healthy	Increased Frailty
ETR	↓	↑	↑
Interpretation	Decreased Biological Stress = Decreased Frailty	Recovery = Decreased Mortality	Decreased Biological Stress = Decreased Frailty

↑ indicates an increase in the values of the factor, and ↓ indicates a decrease in the values of the factor.
MCR = Middle Cumberland Region; ETR = East Tennessee Region

Thus, the osteological paradox can also be used to interpret the results alternatively (Table 7.2). The increased pathology seen in the Middle Cumberland could be evidence that the subadult population was more stressed and therefore frailer than the

East Tennessee subadults, who exhibit a lower frequency of pathological lesions. The decrease in growth disruptions may mean that these frailer subadults just never recovered from the biological insults. The same biological insults may have been affecting the East Tennessee subadults, but they were able to recover. A decrease in stature for the younger subadults may represent growth stunning occurring due to increased biological stress and resulting in increased frailty. Based on the skeletal data alone, though, this alternative cannot be argued as any more or less plausible than Interpretation 1 above.

Resolving the osteological paradox through a multidisciplinary approach

As stated in Chapter 3, the only way to resolve the osteological paradox is to incorporate archaeological and other non-biological sources of data for context. Milner et al. (2008) especially emphasized that the problems with associated with interpreting skeletal data can be reduced by incorporating more lines of evidence to formulate the overall picture of health and not limiting the focus solely to that of the skeletal findings. The rapid and heavy reliance on maize, less variety in their diet, and climatic changes documented in Chapter 2 placed pressure on the people of the Middle Cumberland, especially affecting their main source of food. This would have caused great strain on young subadults, who have an increased need for nutrients during growth and are more vulnerable to dietary deficits (see Chapter 3). Nutritional status based mainly on a high carbohydrate, low protein diet may have sustained the Middle Cumberland subadults, but kept them in a precarious position where a major biological insult could cause death. If they survived past the age of seven years, then their chance for recovery and catch-up growth greatly improved. This may have been due to an increased access to nutritional

resources that could have been associated with social status changes (e.g., these subadults became more self-reliant, or were regarded as adults). It is also simply possible that the more resilient of the subadults survived through to become adolescents. Of course, all prehistoric populations were generally at an increased level of biological stress compared with modern postindustrial populations, and so assuming that the East Tennesseans were not stressed at all would be unlikely.

Taking all the data presented in Chapters 2 and 3 into consideration, and in light of arguments by Milner et al. (2008), as well as others (e.g., Wright and Yoder, 2003), the second interpretation of the evidence is a more likely scenario. This is based on multiple lines of evidence, including climate data, geographical location of the sites, access to resources, diet analysis, and the findings of previous research conducted using adults from these regions. In short, the East Tennessee and Middle Cumberland subadults may have represented biologically related populations, but the Middle Cumberland subadults had higher morbidity and mortality due to a number of factors, many of which were likely related to lower food abundance, limited (and reduced) nutritional breadth, and, possibly, psychosocial stresses.

The lack of differences in enamel hypoplasias between the two regions requires additional attention. This absence of differences could suggest that Averbuch subadults were experiencing less biological stress than those at the East Tennessee Regional sites, resulting in less dental enamel hypoplasias. Based on the discussion in the previous paragraph, though, this is unlikely. A second interpretation, and the more probable based on the findings presented in this dissertation and those from adult studies of the same site, is that these subadults were under such high levels of biological stress for the

majority of their lives that when a major biological insult, such as an acute illness, occurred, they were unable to recover. Without the nutritional stores and the immunological stamina provided by a healthy diet and living environment, subadults faced with a typically recoverable illness may not have been able to muster the immunologic response to fight off the illness. The loss of life before being able to recover from an illness would not result in an enamel hypoplasia, therefore it is likely that the resulting skeletal population would exhibit fewer enamel hypoplasias, but in reality have been more biologically stressed than a comparative population with more enamel hypoplasias.

Understanding the biological effects of modern populations with similar dietary deficiencies (e.g., iron, vitamin C, vitamin B12 etc.7) as those from past populations give a unique insight into the behavior and quality of life that people of the Late Mississippian Period may have experienced. Generations of individuals growing up on a diet deficient of essential nutrients at the Averbuch site may have created a population with significant biological symptoms, such as delayed cognitive and motor skills and reduced energy levels. Reduced energy levels for caregivers of subadults who may have needed increased care due to susceptibility for infection and developmental delays would have been a deadly combination, and potentially greatly influenced the survival rate of many subadults growing up at Averbuch.

Implication for Migration

The biological findings of this study in no way prove or disprove the possibility that immigrants or invaders from the Middle Cumberland Region —depending on how

they would have been perceived by the East Tennessee population—moved into the East Tennessee Region during the late Mississippian Period. It therefore remains uncertain whether the Middle Cumberland populations ever migrated into East Tennessee. What this study does indicate is that if subadults of the Middle Cumberland Region were arriving in the East Tennessee Region, their morbidity and mortality rate was not high enough to change the skeletal lesion or age-at-death distributions of subadult skeletal samples found at East Tennessee Region sites to resemble those of the Middle Cumberland Region. Yet it is important to point out that the differences between the subadults of these regions occurred in traits, namely stature and pathology occurrence rates, which have been shown to change in association with improved diet and living conditions (e.g., Malina et al. 2004). Middle Cumberland peoples might have migrated into East Tennessee and, upon reaching improved conditions, ceased to manifest the signs of individual stress found among the subadults sampled in this study.

Therefore, it can be assumed that the Dallas Phase and Mouse Creek Phase Mississippians from the East Tennessee region were not influenced by an overwhelming incursion of outsiders during the time period under examination in this research. This study is limited in that it can only test the presence of a swamping effect of a mass migration from an outside population on the existing population in the East Tennessee regional sites sampled. It is not possible to detect a slow infiltration of outsiders over a long period of time using skeletal metrics or pathology. A slow migration of people from the Middle Cumberland Region into the East Tennessee Region would have created an environment of dynamic culture, where beliefs and practices were incorporated into the local culture over time, and may have not been visible archaeologically. As shown in the

Results it is equally likely that such as slow integration of people would be invisible based on comparisons of body size and shape, or on signs of disease and stress that would be inherent to the local living conditions of the Middle Cumberland populations.

It is also possible that the incursion wave of Middle Cumberland Region groups into the East Tennessee Region actual occurred during earlier temporal phases. As discussed in Chapter 2, major droughts began affecting the Middle Cumberland Region in the mid-fourteenth century. This could mean that evidence of the a large incursion needs to be addressed in a study of the sites from the Early Mississippian phases in the East Tennessee Region, such as during the Hiwassee Island Phase (A.D. 1000-A.D. 1300). Comparisons between sites from this earlier phase and earlier sites from the Middle Cumberland may give insight into a time when these two regions were more biologically and culturally distinct.

Special Considerations: New Dates for Averbuch

During the course of completing this dissertation, new research has been conducted on the Averbuch site and the role it played in the Middle Cumberland region. As stated in Chapter 2, most researchers have been working under a model that the Middle Cumberland Region was nearly abandoned by A.D. 1450, postulated as having been due to drought conditions the region between the Ohio Valley and western (Williams, 1980, 1990; Butler, 1991; Blitz, 1999; Mainfort Jr., 2001; Cobb and Butler, 2002; Cobb, 2003; Milner, 2004). Recent research that is soon to be released by Cobb, et al. (in press), however, presents new radiocarbon dates for the Averbuch site, which itself previously had been thought to be abandoned no later than A.D. 1450 based on

relative dating. These new dates bring into question the validity of the Vacant Quarter hypothesis that has for so long shaped ideas and research regarding the Middle Cumberland region.

As explained in Chapter 4, the Averbuch site has three cemeteries in addition to twenty-two domestic structures and a palisade cutting through part of the site (Klippel & Bass, 1984). At the time this research began, only relative dating was available for the cemeteries, structures, and palisade wall. Cemetery 1 was located over the top of several structures and within the palisade wall along with Cemetery 2. Cemetery 3 was situated away from Cemeteries 1 and 2, and in one location the palisade was built over the top of graves in the southwest corner. This implies that Cemetery 3 was older than Cemeteries 1 and 2. Thus, the chronology of these burials requires the refinement provided by radiocarbon dating, which further helps organize the construction of cemeteries and structures from Averbuch.

The new dates provided by Cobb et al. (in press) reveal an alternate timeline for Averbuch that pushes forward the abandonment of the site by at least half a century. Cobb et al. (in press) report occupation dates for Averbuch from A.D. 1255 to 1490. The palisade dates between A.D. 1440-1490, from a sample that was taken from a post used in the construction or repair of the wall. Structure 8, which is located below the palisade, dated to between A.D. 1250-1425. Cemetery 1, located completely within the palisade, is reported to have a use period between A.D. 1435-1495, whereas Cemetery 3, cut into by the palisade, has a date that ranges between A.D. 1255-1460. Cobb et al. (in press) also estimate that use of Cemetery 1 was initiated 1.5 to 220.5 years after Cemetery 3. The skeletal sample from the Averbuch site used in this study was not selected based on

the location of burials but by their preservation level. Selection based on the presence of complete and measurable long bones did not provide a sample evenly dispersed between Averbuch's three cemeteries. Therefore, an intra-site comparison was not an option (see Future Directions section later in this chapter). However, this does provide information confirming that the regional comparisons (i.e., comparing the Middle Cumberland Regional site of Averbuch to the combined East Tennessee Regional sites containing both Dallas and Mouse Creek Phase sites) made here in this study are justified, given the temporal overlap of Averbuch with the East Tennessee sites.

More importantly, theses new dates provide definitive evidence that the Averbuch site was populated well into the 15th century (Cobb et al., in press). The radiocarbon dates presented show that there was a much larger population living at Averbuch through the late 1400s. The population was not only present but had enough resources to build a substantial palisade and populate Cemetery 1 and most likely Cemetery 2 as well (Cobb et al. in press). The climate shifts that were occurring during this time were still greatly affecting the resources available to the area's residents, but this new evidence suggests that the populations may have attempted to persevere through the drought in smaller fortified communities. An interesting aside is that the fact that the palisade wall at Averbuch was constructed over the top of a sacred cemetery, which contained stone-box graves and therefore was most likely not lost or forgotten, speaks to the hastiness and necessity of the palisade. One may conclude, based on the available archaeological evidence, that the pressures and tensions of hard environmental conditions created a regional social environment filled with violence and hardship as

evidenced by increased pathology and trauma (Berryman, 1984; Boyd and Boyd, 1991; Worne, 2011; Hsiang et al., 2013a,b).

Caveats and Limitations

As mentioned in Chapter 6, a few older subadult individuals analyzed in this study were skeletally immature, meaning they had multiple unfused epiphyses or epiphyses in the early stages of fusion. These individuals were therefore originally classified as subadults but were later removed from the study sample due to conflicting estimated age ranges given by dental aging techniques. Using the Moorees et al. (1963a, b) dental charts, these older individuals were estimated to be adults because their third molars were fully erupted and, when the roots were visually assessed, they were found to be nearly or completely formed. As with all the individuals included in this study, when available, dental age was used as the final estimation of age; therefore, older individuals whose dental age estimation placed them at 21 years of age or older were excluded from the study. It is interesting to note that the skeletal sample at Averbuch contains a subset of older adolescents, perhaps young adults, whose fusion rates and dental eruptions are discordant, further supporting the skeletal evidence of increased biological stress at this site. A follow up study will include a larger sample size to determine if the percentage of individuals with delayed fusion is significant for the entire site and, if so, if the delay is at a standard rate compared to that of dental development.

It should be remembered that, when interpreting the findings of this research, the category of subadult is a skeletal biology classification, which may not match the cultural status of these individuals in their society. As discussed in Chapter 3, not all of the study subjects would necessarily have behaved in a manner that could be interpreted

as like that of a “child.” Some of the older individuals (12-15 years of age) were likely participating in the same activities as adults, despite their biological classification. This blurs the line between adults and subadults, making it nearly impossible to create a direct correlation between behavior and skeletal markers of biological stress, as well as confuses social status interpretations. Thus, this study has avoided making any cultural arguments based on the biology of individuals, other than broader interpretations about social diet and defensive behaviors noted above.

In the analysis summarized above and reported in Chapter 6, the research hypotheses regarding the similarities in the health status among the subadults from East Tennessee regional sites, as well as compared to the health status of subadults from the Middle Cumberland region, were somewhat equivocal; at times the hypotheses were supported, but at other times were left unsupported by the results. A general lack of statistical significance in many comparisons may suggest a lack of statistical power due to a relatively small sample size. A larger sample size may have altered the results of the analysis conducted in this study. For instance, as previously stated in Chapter 6, with a sample size four times larger than the one used in this study, the non-significant results for differences between the frequency of dental enamel hypoplasias between the East Tennessee Region and the Middle Cumberland Region would have become significant. At that much larger sample size, the subadult population from the East Tennessee Region would have had significantly more dental enamel hypoplasias than the subadults from the Middle Cumberland Region.

Furthermore, there is the continuing difficulty of interpreting pathology in past populations, discussed at more length in Chapter 2 (see the discussion there on the

osteological paradox). There is a critical caveat to keep in mind with any research that classifies individuals as "healthy" simply because they do not show skeletal signs of disease. Individuals have to live long enough with a disease or illness to develop a skeletal lesion, and, especially in the case of dental enamel hypoplasias, the individual not only has to remain alive while under a metabolic insult, but also has to recover from that illness to register the skeletal effects. An individual who is completely overwhelmed by disease may not live long enough to form a skeletal lesion or a dental enamel hypoplasia. The ability to tease out who was healthy and who was simply overtaken by an acute illness becomes tenuous. Nevertheless, the discrepancies in stature and in pathology frequencies between the regions—the two factors most likely affected by stressors—do require explanation. Only one interpretation, based on my perspective of the osteological paradox, is argued in the preceding pages, though the alternative interpretation is presented may deserve additional consideration with expanded samples.

Future Directions and Continued Studies

This project was an initial study into subadult-based research on a multi-regional level. The results discussed here have shed light upon the possible interaction between the Mississippians of the Middle Cumberland Region and the East Tennessee Region. However, there have been many more questions raised at the same time. Much more research can be and needs to be accomplished to further evaluate the possible population movements that occurred within the Late Mississippian Period in the southeastern portion of the country.

Due to preservation issues typical of subadult archaeological remains, the East Tennessee site of Hixon was not able to be included in this study. After visually inspecting each of the subadults, there was only one long bone complete enough to measure total length from the entire site. McCarthy (2011) indicated that the Hixon site adults differed from those of other Eastern Tennessee sites, so perhaps looking at the subadult population with fewer or different criteria would allow for at least some of the subadults to be compared with other East Tennessee Regional subadults. This is especially important given the possible uniqueness of this earlier Mississippian settlement among other East Tennessee sites.

The subadult population used in this study from the Averbuch site is by no means exhaustive of the possible available sample. In light of the recent research by Cobb et al. (in press), adding a larger sample of subadults from Averbuch that represents all the cemeteries would allow for temporal analysis within the site. The ability to analyze the differences, if any, between temporal groups at the Averbuch site may reveal a progression of subadult health status caused by a rapid increase in the reliance on maize or changes in social stress. In addition, the now-known temporal depth would enable comparison of the overall health of subadults before and during the drought, and provide greater insight into its effects on the subadult population in the region. These data could inform overall population health for the Middle Cumberland region and the likelihood that mass migrations out of the area occurred. In addition, expanding the subadult sample to include multiple Middle Cumberland Region sites would improve the overall picture of the biological stress that the drought is presumed to have had on the population there. The expansion to include other sites in the region would also strive to

eliminate any bias that may occur from relying solely on one site to represent an entire region.

The advancements made in less invasive DNA testing open the door for more definitive analysis on the relationships between populations of not only the Middle Cumberland and East Tennessee Regions, but also those from the Northern Georgia Area. Methodology established by Bolnick et al. (2012) provides a means of successfully amplifying sections the mitochondrial DNA without pulverizing samples and has been validated on forensic-age and ancient samples; instead, ancient DNA may be acquired through a process of exposing bone or teeth to a solution, leaving the bone intact while extracting DNA from the soaking solution (Echeverry, et al., 2013; Pack, et al., 2013). It has also been demonstrated that there were not significant differences in dental metrics before and after DNA extraction using this method (Pack et al., 2013), rendering it ideal for use with archaeological sample where destructive analysis is prohibited.

Final thoughts

An important point is not explicitly stated in this dissertation, but is one that this dissertation implicitly demonstrates: subadults matter in understanding past populations. Subadult research in biological anthropology has been perceived to be increasing in frequency, but there is a disconnect between the amount of studies that the research community as a whole thinks are happening and the quantity of research that is actually being disseminated (Scopa Kelso, 2012). Relative to the total number of articles published and presentations given at national meetings, the amount of research

conducted to answer questions about "children" has actually reduced since the early 2000s (Scopa Kelso, 2012). Although subadults are easily ignored in the archaeological record, there is a real need to incorporate this large segment of populations into bioarchaeological research programs and studies. As noted in the introductory chapters, "children" are not only being acted upon by their society and culture, but they also have their own agency and effect upon that same society and culture (Gottlieb, 2000). Despite some of the limitations presented in the study of subadult remains from archaeological contexts, their inclusion is imperative to provide a holistic understanding of past human populations.

Expansion of subadult research to include more archaeological analysis would give a more complete picture of who the subadults were within their communities. Inclusion of burial artifacts, burial placement, and body placement within the burial would vastly increase the knowledge base from which assumptions are made about who was considered culturally a "child," not just a skeletally immature subadult, in the study culture groups. Thus, adding mortuary analyses, in addition to explorations of the agency of "children" in archaeological investigations of the Mississippian, especially in the Middle Cumberland and East Tennessee, will expand our understanding of these past cultures and provide a more complete picture of not only biology, but the lifeways of peoples from the past.

Conclusions

- Even though there are cultural and temporal differences between the Early Dallas, Late Dallas, and Mouse Creek Phases, in addition to these other

distinctions, the Mississippians of East Tennessee sampled in this study do not differ biologically. The findings reported here are supported by previous studies conducted on adults from this region.

- Despite the presumed signs of increased conflict at the site of Dallas, the subadult population does not exhibit any differences in frequency or type of pathology or growth disruptions.
- Within the results of this research there are no findings that support the idea that there was a large-scale incursion of an outside population into the East Tennessee Region during the Late Mississippian Period, or if one occurred, it is biologically invisible.
- Regardless of the fact that there are clear cultural differences between the Mississippian culture of the Middle Cumberland and East Tennessee Regions, the subadults sampled from those regions for this study do not differ biologically.
- The subadult population from the Middle Cumberland Region does, however, display a higher frequency of pathology than those from East Tennessee.
- The findings discussed above provide evidence that the subadult population of the Middle Cumberland Region were under increased biological stress during their early years (1.5-7.0 years old), but as they progressed through early and late adolescence the stress either lessens or only the more biologically robust individuals survive past early stages of growth.

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