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The Southeast in Context: An Assessment of the Trauma Associated With Agriculture

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THE SOUTHEAST IN CONTEXT: AN ASSESSMENT OF THE TRAUMA ASSOCIATED WITH AGRICULTURE

by

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Introduction:

Hunter-gatherer tradition prevailed as the dominant subsistence pattern for most of human history. Between 9,000 and 13,000 years ago peoples in the Levant, New World, and Asia began the domestication and cultivation of wild flora and fauna, creating a subsistence pattern that subsequently spread to neighboring regions (Abbo et al. 2010; Bellwood 2009; Purugganan & Fuller 2009; Richerson et al. 2001). The influence of this agricultural transition on human populations is manifested in various forms in the human skeleton, many of which have received intensive study: dental caries, degenerative joint disease, decreased stature, and increased birth rates (Bridges 1991; Larson 1997, 2006; Tayles et al. 2000). However, few studies have focused on the fracture trauma associated with agriculture. As early as 1976, Steinbock noted a slight decrease in the number of fractures that populations in the southern U.S. exhibited as they moved from a hunter-gatherer lifestyle to floodplain agriculture. More recently, Domett and Tayles (2006) examined changes in fracture patterns through time in prehistoric rice agriculturalists in Thailand, hypothesizing that increased intensification of agricultural activities was responsible for increased rates of long bone fracture.

Though trauma is commonly attributed to agricultural activities (Djurik 2006 and Judd and Roberts 1999), findings supported by modern clinical research (Brison and Pickett 1992; Nordstrom et al. 1995; Purschwitz and Field 1990; Stallones 1990), the influence of historic and prehistoric agriculture on skeletal fracture trauma remains poorly understood. Furthermore, no study has yet sought to statistically test the trends noted by Steinbock (1976) and Domett, and Tayles (2006) on a global scale. Populations of the prehistoric southeastern U.S. provide an opportunity to introduce a new dataset to the scientific community, and to investigate the skeletal trauma of a subsistence agriculture society in a culture area in which limited evidence for interpersonal violence is known (Milner et al. 2013).

This paper builds upon the work of Steinbock (1976) and Domett and Tayles (2006), using agricultural and non-agricultural populations from various world regions to provide a context for interpreting trauma in floodplain agricultural societies of North Carolina and Virginia. In doing so we seek to evaluate the extent to which subsistence activities influenced the risk of fracture trauma. We first retest Domett and Tayles (2006) hypothesis that fractures will increase alongside agricultural intensification, and then test the hypothesis that different subsistence patterns will result in different fracture patterns among globally selected groups, as seen by Steinbock (1976) relative to hunter-gatherers.

Agriculture, Culture, and Geography of the Southeast:

Horticulture in the southeastern United States is first recorded in the Late Archaic Period from 4000-800 BC (Fritz 1990; Yarnell 1993).This period is also marked by the adoption of semi-sedentary villages and the advent of ceramic production (Ward and Stephen Davis 1999). Early agricultural efforts generally involved native plants including knotweed, sumpweed, squash, bottle gourds, sunflower, maygrass, and goosefoot (Scarry and Scarry 2005; Yarnell 1993). Hickory nuts, walnuts, acorns, white tailed deer, rabbit, raccoon, and squirrel, and other wild resources are known to have supplemented the diet throughout the Archaic, Woodland, and Mississippian periods (Trinkley 1995; Wilson and Hogue 1995).

The ensuing Woodland Period (800 BC- AD 1650) saw increasing sedentism, the introduction of maize, and increasing social complexity apparent in Pisgah phase mountain settlements and Pee Dee culture of the Southern Piedmont (Ward and Stephen-Davis 1999). Maize was first introduced to the Southeastern United States around AD 200, but did not become a dietary staple until AD 1000 (Fritz 1990; Scarry 2008). Beans and squash became significant contributors to the diet between AD 1200-1400 as a result of introduction and independent domestication (Scarry 2008; Ward and Stephen Davis 1999). Scarry (2008) asserts that early Woodland Period populations could be termed farmers due to their reliance on cultigens for subsistence. However, it is important to note that even with the increasing importance of cultivars, native crops and wild resources such as hickory nuts and white tailed deer remained important to the Southeastern diet (Ward and Stephen Davis 1999; Wilson and Hogue 1995).

Geographically and culturally, North Carolina is commonly broken down into several distinct regions. The Appalachian mountains, composed of the Blue Ridge and Great Smokey mountain ranges, occupy the western third of the state and were occupied by the Appalachian Mississippian Pisgah to which the Mountain Region sites in this study belong. Though averaging between 2000 and 4000 feet in elevation at their peaks, most settlements and agricultural fields in the Appalachians are found in river valleys and flat plateaus within the mountain region (Ward and Stephen-Davis 1999). Extending east from the Appalachians is the Piedmont, or foothills region, divided into the Northern and Southern Piedmont during the Late Woodland and Mississippian Periods based on the cultural differences exhibited by the occupants of the region. Geographically the two piedmont regions are characterized by forested, gently rolling, and well watered foothills. Culturally, they are home to Late Woodland tradition peoples in the north and the Pisgah phase and Pee Dee Mississippian culture in the south. The Coastal Plains extend from the eastern edge of the Piedmont to the coast and is dominated by wetlands.

The samples presented here originate from the Piedmont and Mountain regions. The Southern Piedmont and the Mountain Regions exhibit Mississippian characteristics including mound construction and cranial deformation. Little has been published on prehistoric sites in the Northern Piedmont region. Agriculture is thought to have been less important to the diet of the Woodland tradition occupants of the region (Ward and Stephen-Davis 1999) and the work of Lambert (2000) suggests that these people were less healthy than in either of the neighboring culture areas. Regardless, both early native cultigens and later maize, squash, and beans, supplemented by local wild resources including hickory nuts, rabbits, squirrels, turkeys, and white tailed deer are known to have played a key role in the subsistence of the prehistoric inhabitants of all three areas (Trinkley 1995; Ward and Stephen-Davis 1999; Wilson and Hogue 1995).

Prehistoric agricultural methods in North America, even regarding the Mississippians or Eastern Woodlanders alone, are reported to have been varied by a number of authors (Johannessen 1993; Scarry 1993, 2008). In both cases women are believed to have been the primary horticulturalists, forming mounds or hills to hold seeds, planting seeds, and weeding using hardwood digging sticks (Scarry 2008). Men contributed by girdling trees, clearing fields, burning stumps, and trenching/turning over soil with stone hoes (Scarry 2008). Around ceremonial centers such as Cahokia the Mississippians are thought to have intensified production by clearing increasingly large fields in the bottomlands and floodplain valleys (Scarry 1993). Less important settlement areas such as the periphery settlements of North Carolina likely remained small scale (Scarry 2008, Ward and Stephen-Davis 1999).

Trauma in agriculture:

Trauma is a general term referring to everything from torn ligaments to dislocations and, the focus of this study, fractures. Skeletal trauma reflects the risks associated with an individual's interaction with their physical and social environment. Repeated engagement in an activity, such as subsistence activities, may expose an individual to physical risks and increase the chance of injury. Populations engaging in similar lifestyles should accrue similar fracture patterns on both individual and population levels.

Today, agricultural occupations are ranked among the ten most dangerous occupations (Bureau of Labor Statistics 2012). Many clinical studies serve to highlight the risks of farming (Bryne 2011; Cogbill et al. 1991; Drudi 2000; Jones 1990; Nordstrom et al. 1995; Purschwitz and Field 1990; Virtanen et al. 2003). Fractures are attributed primarily to accidents involving farm equipment and encounters with animals (Jones 1990; Nogalski et al. 2007; Virtanen et al. 2003). However, while consistent in identifying primary causes of fracture, studies show great variability in how much each factor contributes to the overall pattern.

Injuries associated with operating hand tools and machinery accounted for 60 percent of farmer injuries in Nogalski et al.'s (2007) review. In small scale, non-mechanized farming such as that practiced by the Amish, injury while completing farming chores, including falls, kicks, and encounters with farming equipment accounted for 58.3 percent of observed fractures (Jones 1990). Domestic animals are a commonly cited source of potential injury, contributing over 65 percent of all the farm related injuries reported in three different studies (Bryne 2011; Drudi 2000; Virtanen et al. 2003). When separated by farm type Virtanen and colleagues (2003) found that falls and entanglement in objects were the most common causes of injury among pig, poultry and crop farmers, while being kicked, pushed, or trampled was most common among farmers specializing in cattle.

The Ideal Free Distribution Model: A Theoretical Mechanism of Explanation

Fracture patterns are intrinsically tied to variables such as the physical environment a population exists in and the activities in which they engage, predictions the Ideal Free Distribution (IFD) model is designed to generate. The IFD model (Fretwell and Lucas 1970) assumes that: 1) Individuals have an ideal understanding of the landscape in which they live; 2) Individuals will seek to maximize their access to resources; and 3) Individuals are free to select the most suitable habitat within their local environment. In particular, population density, soil fertility, and water availability are commonly applied to organizing habitat suitability in agriculture-based studies and have the potential to influence fracture rates.

Applications of the IFD model have suggested that early agriculturalists will position themselves in fertile, well watered environments (i.e. floodplains) minimizing their necessary investment in landscape modification (McClure et al. 2006). Over time, increasing population and decreasing soil fertility decrease individual access to resources within a specific agricultural locale (Larsen 1997; Lukacs 2008; McClure et al. 2006). The IFD model predicts that when caloric returns from the cultivation of prime, floodplain locations reaches a threshold, the cultivation of a less suitable environment will become equally profitable and individuals will relocate. A well-dated temporal settlement pattern in Valencia, Spain reflects this pattern. Neolithic I occupation is characterized by the dispersed settlement of prime environments in the valleys (McClure et al. 2006). Later, Neolithic II occupations reflect increased use of marginal areas (McClure et al. 2006).

The IFD model contains several premises that enable us to hypothesize that floodplain agricultural populations will exhibit lower fracture rates than more intensified populations. First, floodplain agricultural populations are predicted to occupy flatter, more fertile topography as seen in McClure and colleagues study in Spain (2006). Second, they participate in less intensified agricultural activities, minimizing agricultural labor inputs and the risk of fracture associated with those activities (McClure et al. 2006). Third, they tend to live in lower density settlements (McClure et al. 2006), enabling them to avoid the potential link found between crowding and violence observed in archaeological, clinical, and experimental contexts (Walker 1997, Kumar and Ng 2001, and Calhoun 1962). Together these factors support the hypothesis that floodplain agriculturalists will exhibit lower fracture rates than intensified agriculturalists, for whom all three factors are either necessary or more likely.

Hunter-gatherer population's fracture rates are harder to predict because they may or may not be tied down to a specific location depending upon their subsistence strategy (Kelly 2007). However, I expect them to exhibit fracture rates which are, in general, higher than floodplain agriculturalists. This prediction arises from their greater range of mobility, occupation of widely varying environments, and exploitation of many resources (Kelly 2007; Morgan 2009). Hunter-gatherer subsistence and mobility includes many extremes from high elevation hill slopes, to rocky shorelines and deserts, to humid rainforests (Kelly 2007). Subsistence activities could range from encounters with large and small game in hard to reach locations, for example mountain goats in steep, high elevation, environments to collecting fish or shellfish collection while balancing on slippery stones each of which is imbued with its own risks.

Materials and Methods:

The southeastern U.S. sample (Figure1, Tables 1 and 2) consists of 375 individuals (282 adults, 93 juveniles) from North Carolina studied by Patricia Lambert and variously reported on previously (Coe 1995; Cunningham 2010; Lambert 2000, 2001, 2002). It originates from nine sites: four located on the Northern Piedmont (VIR-150, VIR-196, VIR-199, VIR-231), four located in the Mountains (Bn-29, Hm-1, Hw-2, Ma-34), and one located on the Southern Piedmont (Mg-2/Mg-3) associated with Town Creek. All of these date to the Mississippian/Late Woodland and Early Contact Periods (AD 800-1700). Fourteen skeletal elements (clavicle, humerus, radius, ulna, femur, tibia, and fibula) were selected for study, as they are commonly reported on in other studies. These were evaluated macroscopically with the aid of a 10x hand lens for evidence of trauma by Lambert. For this study only elements of 66 percent or greater completeness were included to minimize preservation biases.

To place the southeastern sample in perspective, 16 other human skeletal samples from the published literature were assembled for comparative analysis. These include: six hunter/gatherer populations, defined as those practicing no substantial horticultural subsistence strategies (Jurmain 2001; Keenleyside 1998; Lovejoy and Heiber 1981; Smith 2003); five floodplain agricultural populations, groups occupying the floodplain and not investing in irrigation or other substantial land modification strategies (Domett and Tayles 2006; Papathanasiou 2005; Pietrusewsky and Douglas 1997; Powell 1988; and the southeastern sample); and six intensified agricultural populations, defined as those practicing animal domestication, irrigation, terracing, plowing, and other forms of significant landscape modification (Djuric et al. 2006; Domett and Tayles 2006; Judd 2002; Kilgore et al. 1997; Neves et al. 1999; Novak and Slaus 2012). The Ratio Statistic in Cross Tabs operations in SPSS was used to calculate a mean fracture rate and standard deviation. Graphs and tables were created in Microsoft Excel.

The six hunter-gatherer population samples (Table 3) included in this study include both coastal and continental subsistence patterns. Included are two samples from California (Jurmain 2001 and 2009), two Aleut and Eskimo samples (Keeleyside 1998), a sample from Windover, Florida (Smith 2003), and Lovejoy and Heiple's (1981) Libben sample. The two California populations (SC1-038 and ALA-329), reported on by Jurmain (2001 and 2009), occupied the San Francisco Bay area, and likely subsisted primarily on marine resources, deer, and acorn. Keenleyside's (1998) Aleut and Eskimo samples originate from the Aleutian Islands and Northern Alaska and subsisted primarily on marine resources including whale, walrus, fish, shellfish, and seabirds complemented by caribou. Smith's (2003) Windover population from Florida occupied a coastal plain setting and is reported to have subsisted primarily on riverine resources. Finally, Lovejoy and Heiple's (1981) Late Woodland Libben sample occupied a riverine setting in Ohio where fish and small game provided a foundation for their diet.

Floodplain agriculture (Table 4) here encompasses agricultural practices employing minimal landscape modification. We include the southeastern U.S. sample presented here, Powell's (1988) Moundville sample, a Neolithic population from Thailand (Domett and Tayles 2006), Pietrusewsky and Douglas' (1997) sample from the Marianna Islands, and Papathanasiou's (2000) Aleoptrypa Cave sample from Greece. Both the southeastern sample and Powell's Moundville sample likely practiced hoe-agriculture coupled with burning to clear bottomland fields (Scarry 2008). Domett and Tayles' (2006) Neolithic population from Thailand who probably practiced dry rice farming, as wet paddy farming is not known in the region until after 1000 BC. Agriculture in the Mariana Islands included the cultivation of coconut, banana, breadfruit, taro, yam, and possibly rice, though the population is known to have had a diet rich in marine resources (Pietrusewsky et al. 1997). Aleoptrypa Cave from mainland Greece is a Neolithic cave occupation from which both domestic cereals and animal remains have been recovered. However, the Aleoptrypa Cave sample represents a group at the transition to agriculture which should place them on par with the other input-minimizing groups, assuming they were able to occupy a prime environment (Papathanasiou et al. 2000; Papathanasiou 2005, 2009; Papathanassopoulos 1996).

The intensive agriculture group (Table 5) consists of six populations practicing a variety of intensified agricultural techniques designed to increase the agricultural productivity of marginal environments. Included is a South American group from San Pedro de Atacama (Neves et al. 1999), two Baltic groups (Djurik et al. 2006; Slaus et al. 2012), a medieval British group (Judd and Roberts 1999), a Bronze Age Thai sample (Domett and Tayles 2006), and an African sample from Kulubnarti, Sudan (Kilgore et al. 1997). The high elevation desert occupants of San Pedro de Atacama invested in small scale agriculture utilizing alpacas and llamas and possibly investing in irrigation, lithic mulching, and terracing (Lightfoot 1994; Londono 2008; Rivera 1991). Medieval agriculture in the Baltic included the use of a hand plow and, later, an ox driven plow in the production of millet, olives, and grapes among other things alongside the herding of sheep, goats, horses and cattle. Medieval British agriculture included plowing using either oxen or horse teams and also dairying. Bronze Age Thai agriculture focused on wet paddy rice farming. The occupants of Kulubnarti farmed the Nile floodplain, but likely invested in the water wheel irrigation employed by other groups in the region to get enough water to their crops in addition to oxen driven plowing, herding of sheep, goats, cattle, horses, and camels (Edwards 2004; Wilson 1991).

These groupings separate early floodplain agriculture from more intensified land modification techniques and close association with domesticated animals, commonly cited as influencing injury rates in agricultural populations (Djuric et al. 2006; Judd and Roberts 1999). They also allow us to assess the extent to which floodplain and intensified agriculture compare to the preceding hunter/gatherer lifestyle. Thus we seek to use the floodplain agriculturalist groups to provide a baseline perspective from which to view later additions to agricultural technology as well as the extent to which changing subsistence practices influences the fracture patterns observed within a population.

Results:

The Southeast:

The frequency of affected bones in the southeastern sample (Table 2) is low. However, the Fisher Exact test finds that individuals from the Northern Piedmont sites (VIR-150, VIR-196, VIR-197 VIR-199, and VIR 231) exhibit a significantly higher fracture rate (1.2) than the mean (0.1) associated with the two Mississippian regions (p=.002). This elevated fracture rate is interesting considering the elevated occurrence of both cribia orbitalia and carious lesions observed on these same Virginian sites by Lambert (2000). Furthermore, though fracture frequencies from the Mountains and Southern Piedmont would appear to support the hypothesis that the mountain topography increases the number of fractures, this is not supported when comparing the Mountains and Northern Piedmont, though both the Mountain and Southern Piedmont regions each exhibit only a single fracture.

When considered as a regional sample, fractures occur only in males and equally affect both sides of the skeleton with three on the left and four on the right. However, only 7 fractures were observed in 1593 total elements, for a fracture rate of 0.4 percent. When considered in terms of individuals affected, only six of the 375 individuals are affected representing only 1.6 percent of the sample. Of these, five have single fractures and one has two fractures (left clavicle and right radius). The most commonly fractured element is the clavicle at 1.5 percent, followed by the radius and ulna at 0.5 percent each. Six of the fractures exhibited by these populations occur in the upper limb, and the other occurs in a femur. As a whole the southeastern U.S. sample's fracture rate compares most closely with Powell's (1988) Moundville sample, with a fracture rate of 0.4 percent, the mean value for the Floodplain sample as a whole.

Global Context:

A graphical comparison of 14 osteological samples of varying subsistence types reveals that floodplain agriculturalists appear to exhibit a lower fracture rate than either intensified agriculturalists or hunter-gatherers. The radius and ulna exhibit the strongest pattern across subsistence traditions (see Figures 2 and 3) appearing elevated in several hunter-gatherer and intensified agriculturalist groups. More robust elements, including the humerus, femur, and tibia, show little variability. A summary graph of all fractures (Figure 4) shows the same pattern. When upper and lower limb fractures are considered separately the differences in fracture rate between floodplain agriculturalists and the other two groupings is even more apparent (Figure 5).

Statistical analysis (Ratio statistics using SPSS) reveals that few comparisons within and between groups identify significant differences in either element or total fracture breakdowns. However, significantly higher rates than expected in all cases occur in hunter-gatherer and intensive agriculturalists, and only one significantly low fracture rate occurs in any group other than the floodplain agriculturalists (Table 6).

Discussion:

The Southeast:

While topography is an important element in the IFD model's structure, topographical differences do not appear to be the primary influence on fracture rates within the southeastern sample. The fracture rate from the Northern Piedmont foothills (1.2 percent), is higher than those from the Mountains (0.2 percent), or the Southern Piedmont (0.1 percent). This could be due to differing subsistence activities between the Late Woodland period occupants of the Northern Piedmont and the two Mississippian regions. Although cultivars did make up a significant portion of the Northern Piedmont diet, the occupants of this region during the Late Woodland period are thought to have relied more heavily on wild resources than their Mississippian Pisgah and Pee Dee neighbors in the Mountains and Southern Piedmont respectively (Ward and Stephen-Davis 1999).

Global Context:

As predicted using the IFD model, the southeastern sample falls within the range of fracture rates suggested by other floodplain agricultural groups, a range below either the hunter-gatherers or the intensified agriculturalists. At 0.4 percent the fracture rate for the southeastern sample is fairly average for the grouping and closely resembles the Moundville sample reported on by Powell (1988). Together these suggest that both the groupings we have constructed here and the predictions of the IFD model are holding true for this selection of samples.

The seemingly low fracture rates for floodplain agriculturalists included in this study would appear to support Steinbock's (1976) suggestion that the adoption of agriculture can be correlated with an initial decline in fracture frequency. Wild resources undoubtedly continued to contribute significantly to many agricultural societies' diets, though reduced in significance. Thus when we evaluate the change from the hunter-gatherer lifestyle to an agricultural one we must account for the decreased risk somehow. As discussed previously, trauma is incurred both as a result of intentional conflict between people and through interaction with the natural and built environments through the activities an individual engages in. The IFD model's prediction that early agriculturalists occupied floodplain settings when available, to maximize individual access to resources while minimizing the necessary inputs, provides such an explanation.

The IFD model predicts occupation of the most productive and least costly environments first. In agricultural pursuits this is commonly a relatively flat, well watered region, with fertile soil, such as a flood plain. Occupation of floodplain regions reduces the risks associated with rough terrain that could be encountered when traversing distances or pursuing game in their natural environments, for instance wild goats at high elevations in rugged mountain settings. Similarly, floodplains usually require less of the physical inputs involved in improving and maintaining the agricultural suitability of marginal environments such as mountain slopes, dry flats, and rocky soils. Such investments commonly require annual or even seasonal investments and expose participants repeatedly to the risk of injury for example injury from falling or tripping while maintaining irrigation systems or creating terraced fields on slopes. Horticulture further serves to tether participants to the location where their crops are planted, ensuring they spend at least some of their time in the floodplain environment, although the division of labor involved may determine just how much time. Thus, while many agricultural groups engage significantly in the collection of wild resources, they cannot range as widely into unfamiliar territory. It may be that participation in floodplain cultivation buffered individuals from risks associated with unfamiliar, or rugged, topography by influencing the environment they chose to occupy and restricting their mobility.

Hunter-gatherers appear to have the greatest range of fracture rate variability. Some of this could be due to the terrain they occupy, which varies here from coastal to continental in nature. Some of this variability may be due to interpersonal violence as Jurmain et al. (2001) suggests is the case at ALA-329. California as a region presents one of the most studied traditions of interpersonal violence in the archaeological record (Lambert 1997, 2007 among others). Lambert (2007) suggests non-lethal violence peaked between 1500 BC- AD 1380 when as much as 25 percent of the population exhibited healed depressed fractures attributed to the use of wooden clubs. Both California groups presented here (Jurmain 1991; Jurmain et al. 2001) overlap this period, suggesting that at least some of the fractures observed in these populations could have been inflicted intentionally. However, removing the California samples from the group results in only a 0.4 percent (1.9 percent to 1.4 percent) decrease in overall fracture rate for this sampling, which is still nearly double that of the floodplain agriculturalists.

The fracture rates of the Aleut and Eskimo populations reported by Keenleyside (1998) are lower than other hunter-gatherer populations and most closely match the floodplain groups in almost all the graphs constructed for this study. Some of this may be attributed to the lack of data on the clavicle for both populations. However, the lack of fractures overall suggests this is unlikely to significantly alter the fracture frequency in either sample. Keenleyside (1998) does report a statistically significant difference in cranial trauma between the Aleut and Eskimo samples, which could potentially be related to warfare, which both the Aleut and Eskimo people are known to have engaged in. However, she also points out that the lower fracture rates in post-cranial elements calls into question the role of warfare in fracture accumulation.

In the intensified agricultural group, Kilgore et al.'s (1997) Kulubnarti sample and Judd and Robert's (1999) British Raunds sample both exhibit substantially elevated fracture frequencies for individual elements. Interestingly, despite both population's engagement in what we have termed intensive agriculture, the elements most at risk are not the same, reflecting the variability of activities included in this grouping. Kilgore et al (1997) report a 13.1 percent (34/260) fracture frequency for the ulna and a 6.2 percent (16/259) fracture frequency for the radius. Fractures of the radius are primarily attributed to falls, either in the extremely rugged Batn el Hajar region or from Christian Period two story buildings. In contrast Raunds agriculturalists were most at risk for fractures in the clavicle (7.0 percent or 12/171) and fibula (7.0 percent or 6/86), which Judd attributes to falls (the clavicle) and being kicked by cows while milking (the fibula).

The 0.7 percent fracture rate Djurik et al. (2006) report in their Serbian study is less than half that observed in any of the other intensified agricultural groups. Interestingly, the next closest population is the Croatian sample at 1.5 percent, reported by Novak and Slaus (2012), suggesting that something about Medieval Period Balkan wheat and legume agriculture reduced the risks associated with intensified agricultural occupations. Little is published on Balkan agriculture during this period, so assessing why this risk is reduced is difficult. The abundance, or absence, of some domestic animal species, or the nature of their role within the society are all possible explanations.

No pattern of upper-to-lower limb fractures differentiates any of the groups presented. In all cases upper limb injuries are more common, presumably due to their reducted thickness relative to that of the femur and tibia. Not surprisingly, few fractures occurred in the femur, tibia, or humerus, some of the largest bones in the body. Unfortunately, the comparative analysis contains many more skeletal elements for hunter-gatherer and intensified agricultural samples than did the sample for floodplain agriculturalists, which could influence the comparability of these samples. Regardless, it is interesting that floodplain agricultural populations appear to exhibit lower fracture frequencies in general than either of the other subsistence groups tested here.

Conclusion:

Further testing of each of the IFD model's basic premises will provide a better understanding of the interaction between these variables. However, the fracture patterns observed in different subsistence regimes appear to support the hypothesis that different subsistence strategies will result in differential fracture patterns on a global scale. Hunter-gatherer fracture rates exhibit the most variability, but further testing should be done to verify this using population samples from additional environments. Floodplain agriculture is shown to be associated with lower fracture rates, as suggested by others (Larsen 1997; Steinbock 1976), a trend predicted by the IFD model's emphasis on subsistence-based habitat selection. Intensified agricultural groups, whose practice of landscape modification and interaction with domesticated animals was expected to increase the risks they were exposed to, exhibit increased fracture rates.

Comparison of specific agricultural methods would likely have been informative, but was not possible due to the limited number of published datasets. Future studies using a body of osteological samples from populations whose subsistence activities were well studied and recorded would further the understanding of what is truly a continuum of wild and domesticated resource exploitation, and not distinct stages of agricultural intensification.

Further, although topography does not appear to be the primary factor involved in fracture trauma for the southeastern sample, it remains an important variable to consider in light of the IFD model. Geographical Information Systems could provide a means of testing this hypothesis by comparing fracture rates to the slope or ruggedness of the region in which they occurred. A study investigating the influence of topographical characteristics on fracture frequency would be a valuable addition to the archaeological literature, considering the common use of falls to explain fracture trauma.

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Tables and Figures:

Table 1: Southeastern Sample Region, Site, Demographic, and Age Data																		
Region	Mountains												South Piedmont					
Site	BN-29 (NC)			HW-1 (NC)			HW-2 (NC)			MA-34 (NC)			MG-2 (NC)			MG-3 (NC)		
Sex	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U
0-4.9	0	0	1	0	0	4	0	0	0	0	0	4	0	0	7	0	0	19
5-9.9	0	0	1	0	0	0	0	0	0	0	0	6	0	0	2	0	0	10
10-14.9	0	0	3	0	0	0	0	0	0	1	0	2	0	0	1	0	0	9
15-19.9	0	3	3	0	5	1	0	0	0	2	2	5	2	3	4	4	5	7
20-24.9	1	5	0	0	1	2	0	0	0	1	2	2	2	6	1	8	9	4
25-29.9	2	2	2	1	2	0	0	0	0	3	1	0	0	3	0	2	6	0
30-34.9	2	0	1	1	1	1	0	1	0	10	6	3	3	4	1	7	4	1
35-39.9	4	2	0	1	0	0	0	0	0	7	2	0	1	0	0	4	4	0
40-44.9	3	2	0	0	1	0	0	0	0	5	1	2	4	0	1	7	5	0
45-49.9	3	1	0	0	0	0	2	0	0	0	0	0	3	1	0	3	6	0
50-54.9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Sex Total	15	15	11	3	10	8	2	1	0	29	14	24	15	17	17	35	39	50
Site Total			41			21			3			67			49			124

Table 1: Cont'd.																
Region	Northern Piedmont															
Site	VIR-150 (VA)			VIR-196 (VA)			VIR-197 (VA)			VIR-199 (VA)			VIR-231 (VA)			Total
Sex	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	
0-4.9	0	0	6	0	0	1	0	0	0	0	0	3	0	0	4	49
5-9.9	0	0	1	0	0	3	0	0	0	0	0	2	0	0	2	27
10-14.9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	17
15-19.9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	47
20-24.9	1	1	0	0	2	0	0	0	0	0	0	0	0	2	0	50
25-29.9	2	1	0	0	1	0	0	0	0	1	1	0	0	0	0	30
30-34.9	2	1	1	0	0	0	0	0	0	0	0	0	0	1	0	51
35-39.9	3	1	0	0	1	0	0	0	0	0	0	0	1	3	0	34
40-44.9	2	2	0	1	0	0	1	0	0	2	0	0	5	1	0	45
45-49.9	0	1	0	0	0	0	0	0	0	0	0	0	1	2	0	23
50-54.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sex Total	10	7	9	1	4	4	1	0	0	3	2	5	7	9	6	375
Site Total			26			9			1			10			22	

Table 2: Southeastern Fracture Rate by Region			
Region	N	n	%
Mountain	455	1	0.2
S. Piedmont	739	1	0.1
N. Piedmont	399	5	1.3

Table 3: Hunter-Gatherer Populations

Site	Windover			Aleut			SC1-038			ALA-329			Libben			Eskimo		
Location	U.S. (FL)			Canada			U.S. (CA)			U.S. (CA)			U.S. (OH)			Canada		
Dates	?-5000 BC			1500 BC- AD 1000			240 BC- AD 1770			200 BC- AD 1769			AD 0-800 (?)			AD 500-1850		
MNI	168			65			162			?			?			128		
Type	Hunter/Gatherer			Hunter/gatherer			Hunter/Gatherer			Hunter/Gatherer			Hunter/Gatherer			Hunter/gatherer		
	N	n	percent	N	N	percent	N	n	percent	N	n	percent	N	n	percent	N	n	percent
Clavicle	217	2	0.9				159	0	0	291	2	0.7	260	15	5.8			
Humerus	226	1	0.4	99	1	1.0	142	3	2.1	300	1	0.3	450	3	0.7	165	0	0
Radius	207	3	1.4	81	1	1.2	161	6	3.7	301	13	4.3	369	20	5.4	154	1	0.6
Ulna	227	15	6.6	88	0	0.0	144	10	6.9	290	15	5.2	351	11	3.1	163	0	0
Femur	238	2	0.8	102	1	1.0	119	2	1.7	313	0	0	347	9	2.6	169	0	0
Tibia	222	1	0.5	97	0	0.0	164	1	0.6	315	5	1.6	349	5	1.4	163	2	1.2
Fibula	209	2	1.0	77	1	1.3	129	1	0.8	237	0	0	257	9	3.5	150	1	0.7
Total	1546	26	1.7	544	4	0.7	1018	23	2.3	2047	36	1.8	2383	72	3.0	964	4	0.4

Table 4: Floodplain Populations

Site	Aleoptrypa Cave			Thai			Mariana Islands			Southeast			Moundville		
Location	Greece (Mainland)			Thailand			Pacific			U.S. (NC & VA)			U.S. (AL)		
Dates	5000-3200 BC			2000-1500 BC			AD 1-1521			AD 800-1700			AD 1050-1550		
MNI	161			68			383			476			564		
Type	Ag. Transition			Floodplain			Floodplain			Floodplain			Floodplain		
	N	n	percent	N	n	percent	N	n	percent	N	n	Percent	N	N	percent
Clavicle	50	0	0	106	2	1.9	126	0	0	194	3	1.5	178	2	1.1
Humerus	171	0	0	104	0	0	134	1	0.7	232	1	0.4	216	0	0
Radius	107	0	0	102	0	0	135	1	0.7	208	1	0.5	182	3	1.6
Ulna	102	1	1.0	74	0	0	129	2	1.6	192	1	0.5	189	1	0.5
Femur	186	1	0.6	85	0	0	118	1	0.8	325	1	0.3	237	0	0
Tibia	117	0	0	90	0	0	104	0	0	296	0	0.0	242	0	0
Fibula	94	0	0	48	0	0	101	0	0	146	0	0.0	189	0	0.0
Total	827	2	0.2	609	2	0.3	847	5	0.6	1593	7	0.4	1433	6	0.4

Table 5: Intensified Agriculturalists

Site	Thai			Dugopolje			San Pedro de Atacama			Kulubnarti			Raunds			Compilation		
Location	Thailand			Croatia			Chile			Sudan			Britain			Serbia		
Dates	1400-400 BC			AD 100-1500			AD 250-1240			AD 500-1500			AD 900-1100			AD 1000-1800		
MNI	231			209			244			146			170			861		
Type	Intensive			Intensive			Intensive			Intensive			Intensive			Intensive		
	N	n	percent	N	n	percent	N	n	percent	N	n	percent	N	n	percent	N	n	percent
Clavicle	72	2	2.8	221	2	0.9	408	9	2.2	262	1	0.4	171	12	7.0	299	3	1.0
Humerus	71	0	0	280	2	0.7	423	1	0.2	276	10	3.6	178	2	1.1	468	1	0.2
Radius	79	3	3.8	257	8	3.1	402	17	4.2	259	16	6.2	167	8	4.8	403	0	0.0
Ulna	59	6	10.2	252	8	3.2	412	17	4.1	260	34	13.1	164	6	3.7	334	8	2.4
Femur	67	1	1.5	322	0	0.0	427	3	0.7	281	3	1.1	186	2	1.1	608	1	0.2
Tibia	58	0	0	308	5	1.6	403	3	0.7	232	0	0	163	3	1.8	548	3	0.6
Fibula	33	1	3.0	270	4	1.2	404	3	0.7	218	3	1.4	86	6	7.0	141	4	2.8
Total	439	13	3.0	1910	29	1.5	2879	53	1.8	1788	67	3.7	1115	39	3.5	2801	20	0.7

Table 6: Ratio Statistics Results

	Clavicle		Humerus		Radius		Ulna		Femur		Tibia		Fibula	
Population	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Windover	0.009		0.004		0.014		0.066		0.008		0.005		0.010	
Aleut	NA		0.010		0.012		0.000		0.010		0.000		0.013	
SC1-038	0.000		0.021		0.037		0.069		0.017		0.006		0.008	
ALA-329	0.007		0.003		0.043		0.052		0.000		0.016		0.000	
Libben	0.058		0.012		0.054		0.031		0.026		0.014		0.035	
Eskimo	NA		0.000		0.006		0.000		0.000		0.012		0.007	
Aleoptrypa	0.000		0.000		0.000		0.010		0.005		0.000		0.000	
N Thai	0.019		0.000		0.000		0.000		0.000		0.000		0.000	
Mariana is.	0.000		0.007		0.007		0.016		0.008		0.000		0.000	
Southeast	0.015		0.004		0.005		0.005		0.003		0.000		0.000	
Moundville	0.011		0.000		0.016		0.005		0.000		0.000		0.000	
B Thai	0.028		0.000		0.038		0.102		0.015		0.000		0.030	
Dugopolje	0.009		0.007		0.031		0.032		0.000		0.016		0.015	
San Pedro	0.022		0.002		0.042		0.041		0.007		0.007		0.007	
Kulubnarti	0.004		0.017		0.062		0.131		0.011		0.000		0.014	
Raunds	0.070		0.011		0.048		0.037		0.011		0.018		0.070	
Serbia	0.010		0.002		0.000		0.024		0.002		0.005		0.028	
Overall	0.017	0.021	0.006	0.006	0.025	0.021	0.036	0.038	0.007	0.007	0.006	0.007	0.014	0.018

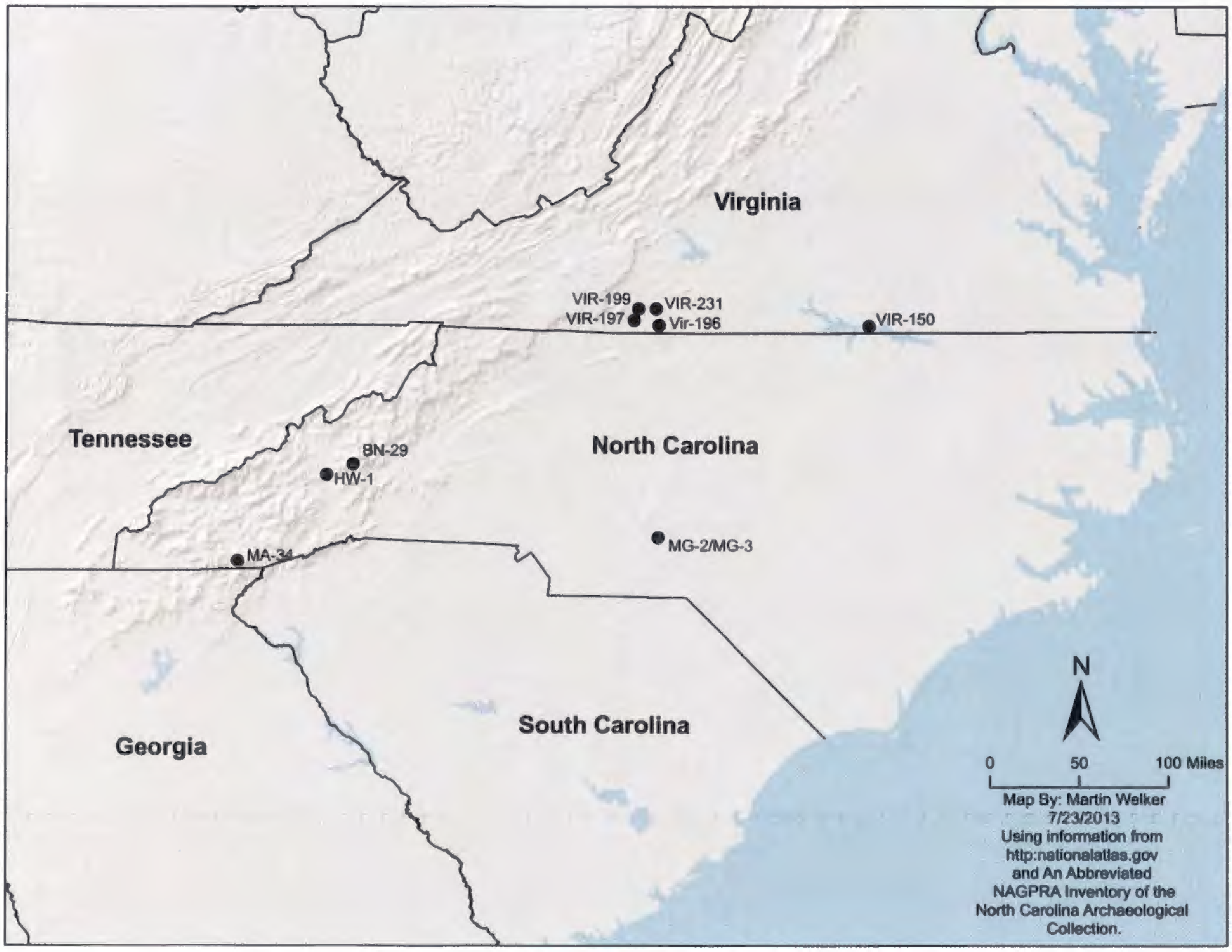
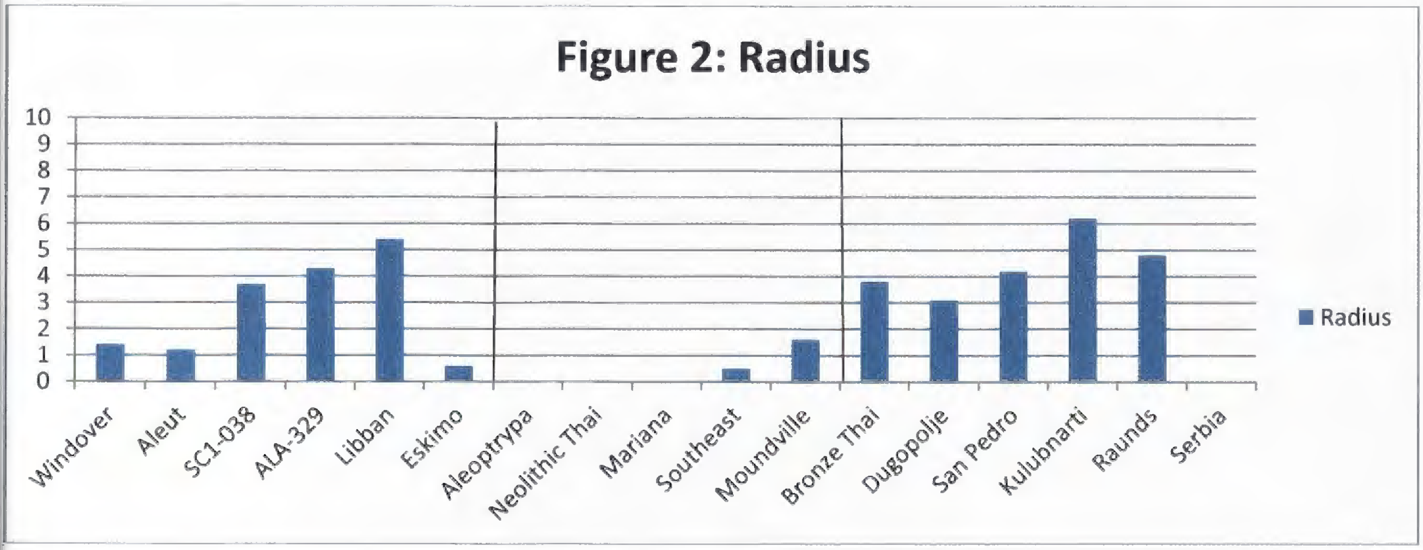


Figure 1: Sites included in the southeastern sample.



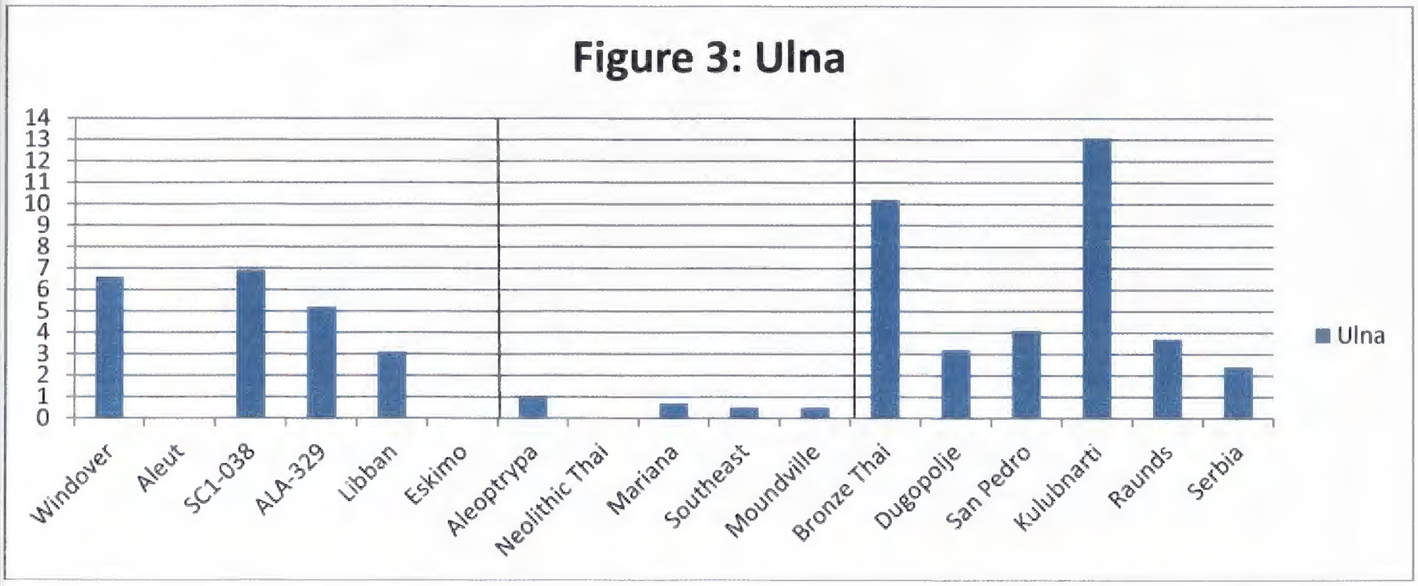


Figure 3: Ulna
14
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4
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2
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Ulna
Windover
Aleut
SC1-038
ALA-329
Libban
Eskimo
Aleoptrypa
Neolithic Thai
Mariana
Southeast
Moundville
Bronze Thai
Dugopolje
San Pedro
Kulubnarti
Raunds
Serbia

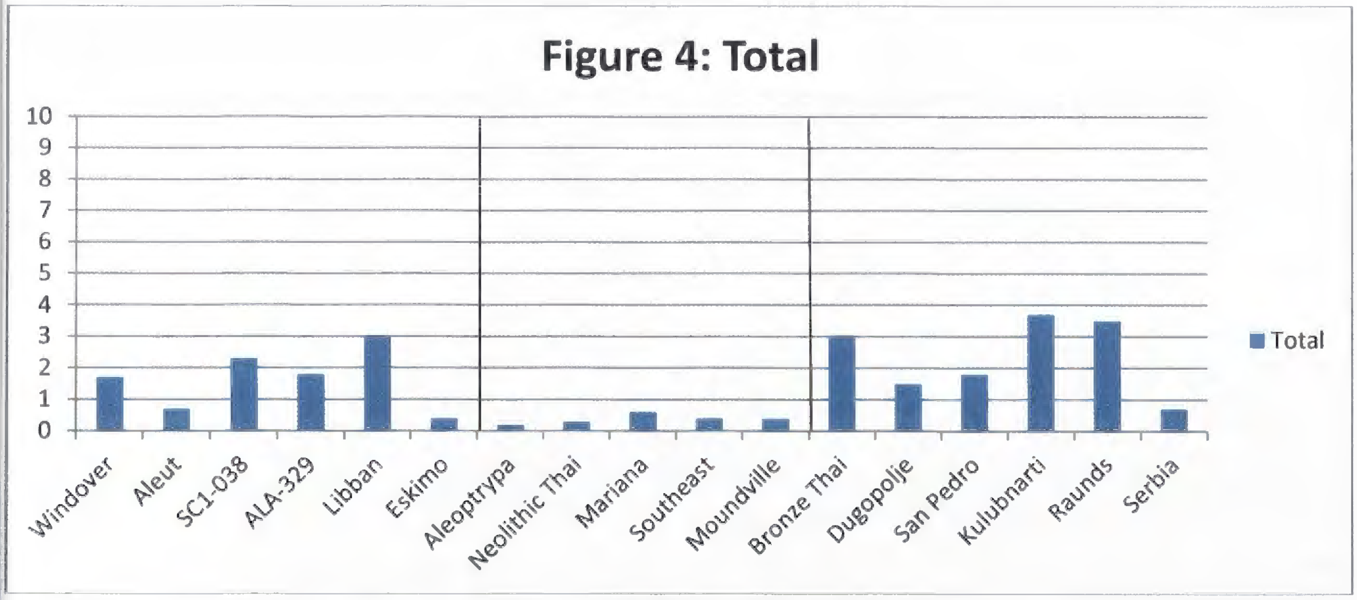
Figure 4: Total
10
9
8
7
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5
4
3
2
1
0
Total
Windover
Aleut
SC1-038
ALA-329
Libban
Eskimo
Aleoptrypa
Neolithic Thai
Mariana
Southeast
Moundville
Bronze Thai
Dugopolje
San Pedro
Kulubnarti
Raunds
Serbia

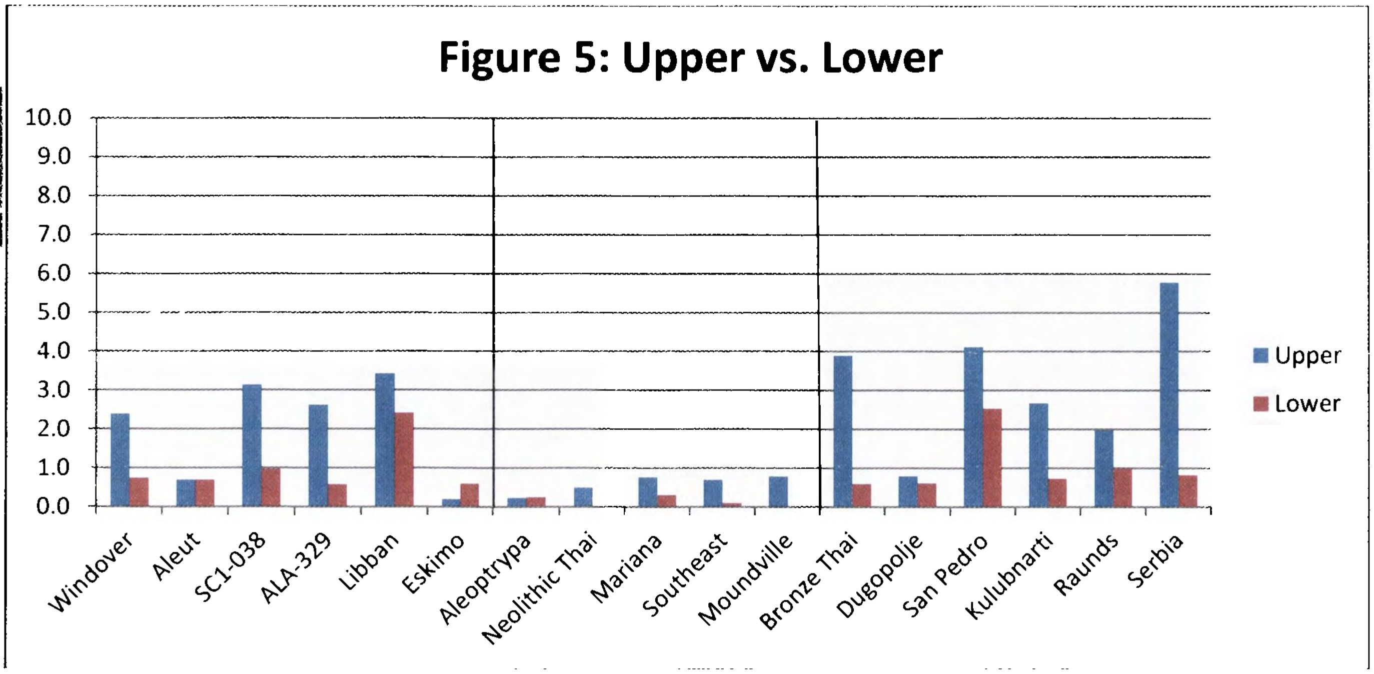
Figure 5: Upper vs. Lower
10.0
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8.0
7.0
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3.0
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Windover
Aleut
SC1-038
ALA-329
Libban
Eskimo
Aleoptrypa
Neolithic Thai
Mariana
Southeast
Moundville
Bronze Thai
Dugopolje
San Pedro
Kulubnarti
Raunds
Serbia
Upper
Lower