DOCUMENTATION OF MISSOURI WHITE-TAILED DEER CHRONOCLINES: IMPLICATIONS FOR ARCHAEOLOGY, PALEOECOLOGY, AND CONSERVATION BIOLOGY

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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This thesis is dedicated to my mother, Donna. She never doubted my ability to accomplish anything I was determined to do and she worked selflessly to made sure her children felt loved and supported in their endeavors. I love you and owe you everything. I thank my husband, Jordan, for being my “rock” and never reinforcing my doubts on my ability to be successful. To my twin sister, Amy, and brother, Alex, I thank you and love you for being a never-ending source of enthusiasm and support throughout my life. To my grandparents, Marcia and Robert, I thank you both for collectively being my second parent and for giving all of yourselves to your grandchildren.

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ABSTRACT

Multiple ecological factors (e.g., Bergmann's rule, competition, food quality and quantity) can be responsible for changes in animal body size over time. White-tailed deer (*Odocoileus virginianus)* serve as an ideal candidate for studying these variables due to their importance today (to hunters and to wildlife enthusiasts), their known phenotypic plasticity in response to ecological factors, and their high frequency in zooarchaeological collections. Using post-cranial, weight-bearing bone measurements as a proxy for body size, this study determines that stunting occurred from prehistoric to modern times in Missouri white-tailed deer. Forage availability and intraspecific competition were the major influences on body size. A diminution event occurred ~1600–1300 radiocarbon years B.P. and is associated with fluctuating climatic conditions at the time. Modern deer in Missouri are smaller relative to an early prehistoric (ca. 3500 – 1300 B.P.) sample but smaller than a late prehistoric (ca. 1300 – 200 B.P.) sample. The historic diminution event seems to stem from modern management goals favoring large population sizes. Advantages of incorporating paleozoological data with modern conservation biology are exemplified by this study.

CHAPTER 1: Introduction

White-tailed deer (*Odocoileus virginianus*) are one of the most studied large mammals in the world because of their importance today to hunters and to wildlife enthusiasts. They are also important to paleozoologists because of their high frequency in zooarchaeological collections, their exploitation as a food resource throughout the ~13,000 years that humans have lived in the Americas, and their shifts in size as responses to ecological factors (Ellsworth et al. 1994; Purdue et al. 2000). The popularity of the species and its presence throughout North America has fostered a growing body of research addressing the affects of this large herbivore on both natural ecosystems and human modified environments. There is a growing consensus in recent scientific literature that modern white-tailed deer populations have exponentially exceeded previous population levels (Côté et al. 2004; McShea et al. 1997; Wolverton et al. 2007). One manifestation of abundance in many mammalian species is changes in body size in response to fluctuating population densities. Low population densities are characterized by low intraspecific competition for forage and often are associated with individuals attaining large body sizes. High population densities resulting from a combination of factors including predator eradication and increased net primary productivity can cause stunting (decreased body size) from increased intraspecific competition (Côté et al. 2004; Fowler 1981; Kie et al. 1983; Lesage et al. 2001).

Determining the presence of stunting in a population can be accomplished in a variety of ways, most of which involve recording live weights of a population's adult members over the course of several years. If one hopes to identify the cause of the stunting, such as overabundance and a high level of intraspecific competition, then the researcher needs data on population size and density that correspond temporally with deer body size. Most studies of modern stunting, however, lack large-scale temporal duration. The paleozoological record (information recovered from both archaeological and paleontological contexts) provides a wealth of information in regards to prehistoric animal populations and long-term data on animal populations for which modern ecology and conservation biology have no record (Lyman and Cannon 2004; Wolverton and Lyman 2012).

In this thesis I use the paleozoological record to expand upon Steve Wolverton's (2007, 2009) observations on the historical relationships between white-tailed deer body size, climatic variation as reflected in primary productivity or forage availability, and hunting pressure. In particular, I compare prehistoric (pre Euro-American settlement) white-tailed deer in Missouri to modern Missouri deer using size of long bones as a proxy measure for body size. It has been suggested that deer populations are reaching pest-levels (McShea et al. 1997; Wolverton et al. 2007); that is, deer are overabundant, creating deleterious intraspecific competition and stunting. Changes in mean body size may, however, be occurring as a result of the interaction of several variables. Two variables that seem to be of primary importance are considered here: 1) the increase in ecologically relevant net primary productivity (eNPP) (Wolverton et al. 2009) and forage quality and quantity as a result of widespread farming, and 2) the decrease in large carnivores and strictly managed human hunting today relative to these variables during prehistory. It is the interaction of these two variables—eNPP and population density—that body (bone) size measures. We must first, however, determine whether or not stunting is occurring within today's Missouri white-tailed deer population because there is some debate about this. My interest in determining whether or not stunting is occurring within Missouri is to evaluate the success of current management practices regarding white-tailed deer. I use paleozoological research to better inform modern studies of white-tailed deer ecology and population biology, and to also add information attainable in no other way that should be considered in modern management strategies.

There are several management strategies employed for white-tailed deer populations but all share an emphasis on some kind of population density control. Most states support management practices that keep deer population densities in check while maximizing the number of deer to further attract human interest groups (e.g., hunters, wildlife enthusiasts) to a specific location (Messner 2011). The Missouri Department of Conservation's (MDC) current management strategy falls under this category. In a publication promoting management guidelines for landowners and the general public MDC (2011) stated: "Current management attempts to maintain deer populations at levels high enough to provide adequate opportunity for hunters and for people who enjoy watching deer but low enough to ensure a healthy herd and minimize problems."

Given that there are approximately 1.4 million white-tailed deer in the state and hunting seasons contribute $1.1 billion annually to the state's economy (Pierce et al. 2011), current management strategies for Missouri should be continuously evaluated and revised using all relevant resources, including paleozoological research. This will ensure that this commodity continues to be profitable for the state. In this regard, a subsidiary goal of this thesis is to gain a better understanding of the applications of paleozoology to modern conservation issues.

Chapter Two outlines the evolutionary history and recorded history of white-tailed deer. Pertinent historical details are followed by discussion of how predator eradication and eNPP relate to population densities of white-tailed deer and some issues associated with high deer populations. In Chapter Three I formalize how the paleozoological record of white-tailed deer documents differences in bone size (and population density) relative to modern deer samples. Chapter Four compares modern and prehistoric white-tailed deer samples to determine if differences in bone size exist between the two time periods. Lastly, in Chapter Five I address how management practices should be changed in Missouri to compensate for the results documented in Chapter Four and discuss how the paleozoological record can help inform and potentially result in better management practices.

CHAPTER 2: Problem Summary and Research Goals

In order to correlate changes in body size of organisms to specific causal variables one needs to have an intimate knowledge of these variables and to understand how each influences body size (Eisenberg 1990; McNab 1990). Although many of these factors are difficult if not impossible to exclude from size-related analysis, if one has a thorough understanding of how each relates to body size, their individual effects can be assumed to be negligible and the significant causal factors can be identified. This chapter is divided into four sections, each outlining basic information pertinent to understanding why a difference in size may have occurred and deciphering which factor of interest (predator eradication or eNPP) may be responsible for that change. To demonstrate the critically important nature of the variables under consideration, the first section of this chapter summarizes the known evolutionary history and historical record of white-tailed deer and includes comments on the causal relevance of the variables of interest.

White-tailed Deer in North America

White-tailed deer or a similar ancestor first arrived in North America approximately 3.5 million years ago and were quite rare until after the terminal Pleistocene extinction event when their competitors disappeared (Geist 1998; Smith 1991). The subsequent success of the species and its ubiquity in North America today may have been due to the species’ ability to thrive in unstable, young (early ecological succession) environments (Geist 1998). During the Holocene, Missouri landscapes were a mixture of hardwood forest and grassland habitats that fluctuated in dominance with changes in temperature and moisture (O'Brien and Wood 1998; Semken 1983). Native Americans likely took advantage of this by modifying the landscape through the use of fire (Geist 1998). Human use of fire removed understory litter, brush buildups, and invasive species from prairies and forest-floors. The newly exposed, fertile soils enabled grassy colonizer plant species and new tree growth, which provided nutritious food resources for deer. Edge habitats were maintained by Native Americans to provide food resources for white-tailed deer and simultaneously increased visibility for deer hunters (O'Brien and Wood 1998). During unstable climatic conditions coupled with continued land modification by Native Americans during the Holocene, deer likely were naturally abundant. The zooarchaeological record indicates they were a main prey source for prehistoric people. For instance, deer remains comprise 84.4% of the mammal remains (total NISP >28,000) recovered from Tick Creek Cave, Missouri, a middle through late Holocene zooarchaeological assemblage representing human food waste (Parmalee 1965; see also Parmalee et al. 1976; Wolverton 2007).

Historical records indicate that there were widespread declines in white-tailed deer populations coinciding with unrestricted market hunting and habitat destruction in the Eastern United States in the late 19th century (Russell et al. 2001; Pierce et al. 2011). By the early 20th century deer were either extirpated from areas of their former range or population densities were low (McCabe and McCabe 1984; Russell et al. 2001); in Missouri an estimated 400 individuals remained in 1925 (Pierce et al. 2011). After legislation restricting hunting and land modification in parts of North America (Russell et al. 2001) was passed, deer were translocated into Missouri from Michigan and Wisconsin. This translocation was quickly followed by a closed deer-hunting season in

Missouri from 1938-1943 (Pierce et al. 2011). Through hunting restrictions, restoration of populations, and the extirpation of predators (*Canis lupus*, *Felis concolor*, *Lynx rufus*, *Ursus americanus*), white-tailed deer populations rebounded and the species once again occurs throughout its former range and in abundance (DeYoung et al. 2003; McShea et al. 1997; Messner 2011; Wolverton et al. 2007).

The significance of deer history in relation to this thesis concerns the fact that the species is rather adaptively plastic. The species has undergone various population highs and lows since first immigrating to the area, and has survived. Known historical details concern population size and density, important ecological variables that respond to selective forces. White-tailed deer body size is another important ecological variable that also responds to pressures of natural selection. The following, then, is a brief discussion of physiological, behavioral and ecological factors that are correlated with body size.

General Influences on Body Size

Like the study of many biological variables, body size studies are very complex. This is so because single factors responsible for size change are rarely identified. Instead, several interacting factors are typically thought to be the cause of a phenotypic character change. It is for this reason that several causes of body size, some of which are more closely linked than others, are outlined in the following.

Physiological aspects are internal responses of an organism to changes in the external environment and may linger long after the external stimuli is removed. For instance, metabolic changes are the umbrella under which all other factors are related. Larger bodies in general require a higher total rate of energy input and metabolism for growth and maintenance (Klein et al. 1987). As the rate of metabolism increases, the intake of energy and the amount of food available in an organism's external environment must also increase (McNab 1990). Locomotion is also highly correlated with metabolic rate in that larger mammals may travel faster than smaller mammals but the increase in speed does not help conserve energy (McNab 1990). Once again, an increase in metabolic rate and food intake is required, but the per-gram cost of speed is higher for small-bodied organisms than larger ones (Eisenberg 1990). Lastly, size of a female during reproduction often imposes size constraints on offspring. Gestation period and the time from birth to sexual maturity increases with mass and both neonate mass and litter size vary with body size (which is correlated with food quality and availability) of the mother (Toïgo et al. 2006). As an example, Ozgul et al. (2009) found that if a female Soay sheep (*Ovis aries*) had not reached adult body size at the time of its first pregnancy (due to any of the factors mentioned in this section), offspring were of smaller body size at birth than the mother was at her birth.

Ecological/behavioral stimuli for changes in body size are those that cause local adaptation to environmental change (Millien et al. 2006). Intraspecific competition due to isolation or habitat fragmentation (Klein et al. 1987; Millien et al. 2006) or interspecific competition within the same niche (Eisenberg 1990) is often exacerbated by an increase in population density and causes a decrease in body size (Toïgo et al. 2006; Wolverton 2007). General climatic variation in temperature and precipitation operating in conjunction with increasing population density can both decrease body size and stimulate increase in population size (Millien et al. 2006). For instance, a decrease in the length of harsh winters can extend the growing season of plants and reduce the length of time herbivores have to rely on fat stores during the winter. This in turn can allow for smaller, slow-growing individuals within an herbivore population to survive a winter they would not have if environmental conditions had not changed. Consequently, these smaller individuals survive to reproduce small offspring that then add to the population density and lower individual mean body size of the population (Côté et al. 2004; Ozgul et al. 2009).

Any one or more ecological factors (e.g., Bergmann's rule, competition, reproductive rate, home range size, food quality and quantity) may be responsible for changes in animal body size over time (Wolverton et al. 2009). However, the study of body size in discrete populations living in distinct ecological conditions allows causal variables for changes in body size to be identified (Wolverton et al. 2009).

Predator Eradication and Net Primary Productivity

The success of white-tailed deer in surviving the three Plio-Pleistocene North American faunal ages (from the Blancan to the Irvingtonian, to the Rancholabrean [the Holocene or Recent geological epoch spans only the last 11,700 years]) can be attributed to the species' behavioral flexibility and generalist life history (Geist 1998), yet its current success and population densities may be anthropogenic in origin. As mentioned above, most natural predators of white-tailed deer were extirpated or disappeared (e.g., Native Americans, wolves (*Canis lupus*)) during the early 20th century. Although there are some areas where these predators still occur or have been reintroduced (e.g., northern Minnesota, Rocky Mountains, Yellowstone National Park), modern sport hunting is the primary source of deer population control (Wolverton 2007). Hunting is legally restricted to certain seasons and hunters tend to favor the killing of males despite game laws allowing, and pressure from conservation agencies promoting, the hunting of females and fawns. The lack of hunting pressure year-round and the ability of a male white-tailed deer to mate with multiple females, coupled with the favoritism of hunters for males, has led to low deer mortality rates, particularly females, leaving many local populations capable of significant increases in density. The number of hunters has remained unchanged or has declined in response to lower acceptance of hunting in society and the added expenses to hunting (i.e. license fees, less access to hunting land) (Murphy 2011). Municipalities also prohibit hunting, as do some landowners due to public safety concerns (Côté et al. 2004), further diminishing predation pressure and decreasing population regulation. White-tailed deer are reproductive polymorphs and display life history traits that are intermediate between r- and K-selected strategies. This allows deer to exploit changing habitats and with a lack of interspecific competition, to potentially become overabundant (Fowler 1981; Geist 1998; Messner 2011; Seal et al. 1983; Wolverton 2007). It is the overabundance or high population density that can lead to increases in intraspecific competition and decreases in body size.

Another significant factor influencing deer body size is the increase in forage quality and availability as a product of increased NPP (the amount of plant biomass produced per unit of time [Wolverton et al. 2009]) resulting from agriculture. Although terrestrial animals such as white-tailed deer have access to a small portion of the total NPP in their local environment, we can assume that the amount available to them is positively correlated with the total NPP of that location (Wolverton et al. 2009). It is well documented that net primary productivity (food availability) heavily affects ontogenetic growth in phenotypically plastic species (Guthrie 1984; Klein et al. 1987; Ozgul et al. 2009; Toïgo et al. 2006) such as white-tailed deer (Wolverton et al. 2009). Assuming that body size in animals is a function of ontogenetic growth of an individual and that ontogenetic growth rate is a function of food availability per individual (Wolverton et al. 2009), an increase in primary productivity may contribute to increased body size of white-tailed deer in Missouri and elsewhere. Based on assumptions about ontogenetic growth affecting the adult size of individuals, the ecologically relevant NPP (eNPP), or the plant biomass available to animals during both the animal's and the plant's growth and reproduction, is of importance here. However, because eNPP data are recorded in terms of large geographic regions, much larger than the scope of this study, crop productivity, which is recorded at the state-level, will serve as a surrogate measure for eNPP following Wolverton et al. (2009).

In Missouri, corn, wheat, sorghum, and soybean crops provide forage for white-tailed deer (Wolverton et al. 2009) and within agricultural areas these farm crops provide up to 78% of the total diet for deer (Smith 1991). Crop yield data in Missouri over the past 30 years are listed in Table 2.1. Agriculture and the addition of nutrients and water to crop areas have greatly increased the productivity of the landscape above the already high eNPP observed at temperate latitudes (Geist 1998; Huston and Wolverton 2009). This increase in eNPP will decrease intraspecific competition and allow more individuals to be supported and, possibly, larger body sizes (Wolverton et al. 2009). However, in a hypothetical situation where population densities continue to increase while the influence of humans on primary productivity becomes static or decreases, the same affects seen with predation eradication could occur. That is, the increase in population density would cause competition for food to increase and over time, with no added primary productivity, could cause decreases in body size. To the best of my knowledge this potential scenario has not been tested and in some cases the possibility of it happening has been excused (see next section). It is this potentiality that I seek evidence for with this research.

Table 2.1 Crop yield data for the state of Missouri.

	2012	2002	1992	1982
Corn				
Acres	3,302,499	2,677,491	2,445,489	1,892,882
bushels/acre	68.5	100.2	126.3	94.4
Wheat				
Acres	690,245	811,586	1,319,575	2,044,839
bushels/acre	55.2	43.0	44.1	33.4
Sorghum				
Acres	54,885	204,007	586,559	746,547
bushels/acre	57.4	81.4	90.4	73.5
Soybean				
Acres	5,250,275	5,001,858	4,208,729	5,286,129
bushels/acre	28.3	33.0	35.7	29.1

***Note:* Data from 2012 Agricultural Census

The relationship between deer population density and both predation intensity and eNPP is a complicated one. With the right balance of these and other factors outlined above large, healthy deer populations can be maintained. Nevertheless, once the population density exceeds the environment's ability to maintain mean individual body size, the lack of predation, despite the large food supply, can lead to a decrease in body size and in health of the population. Thus far influences on body size, particularly those related to population density, have been mentioned. In the remainder of this chapter my focus shifts from influences on body size to the influences large white-tailed deer populations can have on humans living in close proximity to the deer populations, as well as influences deer have on ecosystems (Côté et al. 2004; Russell et al. 2001; Wolverton et al. 2007). This is necessary because modern wildlife management attempts to maintain population densities at levels that the environment can support and that satisfy interest groups while keeping conflicts between people and wildlife at a minimum. If current white-tailed deer populations are causing significant damage to both ecosystems and the state's economy as a result of deer-caused damages, management should put more effort into reducing current population densities.

Conservation Issues Concerning White-tailed Deer

Based on estimates of pre-European settlement deer population size, however imprecise these estimates might be, many researchers have suggested that current deer populations have exponentially risen above prehistoric sizes and have reached pest-levels (Côté et al. 2004; McShea et al. 1997; Messner 2011; Wolverton et al. 2007). Researchers who believe deer are overabundant suggest high populations only occur in certain areas of the species' current range, such as Texas (Wolverton 2007) and not in areas of increased agricultural land use, such as areas of the Midwest and Eastern United States (Geist 1998; Hansen et al. 1997; Schmitz and Sinclair 1997; Wolverton et al. 2007). The increase in agricultural land and the eradication of predators in areas such as Missouri is thought to have offset overabundance and stunting. This claim has, however, not been empirically tested in many agricultural regions. If modern deer populations within

Missouri are not stunted as a result of a dense population created by increased net primary productivity, then wildlife managers are faced with interesting questions. Even though current levels of eNPP can support large deer populations, should deer population densities be allowed to increase? If so, what are the potential consequences?

The issue with determining the management status of any wildlife population stems from the term “overabundance” being a value judgment; the definition changes based on the context in which it is used. All definitions of overabundance include two effects of too many deer: threat of damage to human welfare, and ecological or habitat degradation (Côté et al. 2004; McShea et al. 1997; Wolverton 2007). With respect to the first, high population densities can lead to major economic costs. Within the United States the annual estimated cost of deer-induced damage is $750 million (Conover 1997). Deer damage to agricultural crops and households totaled $351 million as of 1991 (Côté et al. 2004). Deer-vehicle collisions are also of growing concern. The Missouri Department of Transportation (MoDOT) (2009) reported deer caused 3,066 on-road accidents in 2009. A report by the Center of Disease Control and Prevention (CDC) (2004) using data collected from the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) stated that 22,498 motor vehicle crashes in the United States during 2001-2002 involved large game. White-tailed deer were involved in the majority of these incidents (86.9%) (CDC 2004). This study also reported that persons injured in motor vehicle accidents involving large animals were treated most often during the months of October and November, which corresponds with white-tailed deer mating season (CDC 2004; Smith 1991).

In terms of ecological degradation, white-tailed deer have been shown to dramatically alter species diversity within an ecological community (Russell et al. 2001; Simard et al. 2008). When in high densities, deer can change the dominant species of herbaceous plants through predation, leading to decreases in the recruitment of young trees and other preferred browse. In early succession stages commonly seen in areas of timber harvesting or prescribed burns, direct consumption of juvenile trees and nutrient rich plants by deer has changed the species composition leading to slowed succession or a complete change in the direction of succession within the forest community (Russell et al. 2001).

In this chapter I have identified key historical and ecological variables that concern body size of white-tailed deer. In the next chapter I outline how bone size and its relationship with body size is used to test whether prehistoric white-tailed deer in Missouri are different in size than modern deer.

CHAPTER 3: Materials and Methods

This chapter describes the analytical techniques used to document and compare modern white-tailed deer body size to the size of prehistoric deer. I also outline how I will determine which factor (predator population size or eNPP) (Wolverton et al. 2007; Wolverton et al. 2009) is currently responsible for deer population density and body size in Missouri. Detailed descriptions of both modern and prehistoric samples and procedures with which data were collected are outlined, beginning with the modern white-tailed deer sample.

Bone Size and Body Size

I assume that the size of a bone is directly correlated with body size or mass (see Chapter Two) (Albarella 2002; Eisenberg 1990; Klein et al. 1987; McNab 1990; Millien et al. 2006; Ozgul et al. 2009). No single skeletal element correlates perfectly with body mass; that is, for any dimension measured the mean correlation coefficient between bone size and body mass is <1.0 (Mendoza et al. 2006). The coefficient is, however, typically >> 0.1 and statistically significant (e.g., Emerson 1978; Purdue 1987), else this study of the size of prehistoric bones as proxies of body size is futile. Additionally, morphological traits are influenced by several interacting adaptation factors (as mentioned in Chapter Two). Therefore, the use of multiple skeletal elements and their measurements can compensate for differences in selection on each element and can provide a correlation coefficient greater than a coefficient provided by study of a single skeletal part (Damuth 1990; Mendoza et al. 2006).

Combining measurements from different skeletal elements of the same species also allows relatively small bone assemblages to provide a large sample of measurements for rigorous biometric studies (Albarella 2002). Here, twenty-seven dimensions of bones were measured to the nearest 0.01 mm (Figure 3.1) on both modern and prehistoric samples of white-tailed deer bones. I used a digital caliper and measured each dimension on each specimen three consecutive times and calculated and used the mean of those measures in my analyses. This procedure should eliminate much measurement error (Lyman and VanPool 2009). The dimensions incorporate both length and width measurements since bone size estimates based on length alone may not be as accurate without the shape of the bone (determined by width measurements) being taken into account (Albarella 2002). Although a shape analysis of white-tailed deer bones could be performed with the data collected, only bone size is of interest here. The dimensions chosen for this study correspond to either parts of skeletal elements or complete skeletal elements that tend to preserve well in archaeological collections and are standard ones in zooarchaeology (Driesch 1976).

Raw data on the prehistoric skeletal elements are presented in Appendix 1 and raw data on the modern skeletal elements are in Appendix 2. Average values for each dimension among modern and prehistoric specimens are listed in Table 3.2 and Table 3.3, respectively. These measurements correspond specifically to the proximal and distal ends of long bones and astragali, and provide more accurate estimations of body size than craniodental measurements (Davis 1996; Driesch 1976; Munro et al. 2001; Scott 1983).

When population density is high, intraspecific competition slows the growth rate of individuals, producing smaller bone sizes and smaller maximum body sizes in deer

(Wolverton 2007). Long bones and astragali are used here because their sizes at maturity are the result of the organism's access to resources during ontogenetic growth and each element's size sets an upper boundary on the adult body size the organism can attain (Wolverton 2007). That is, the body cannot be larger than what the limb bones can mechanically support. The relationship between bone size and body size in phenotypically plastic organisms, such as the white-tailed deer, is a response to ecological conditions and population density and is known as scaling or skeletal allometry (Alexander 1985).

Scaling involves the biomechanical relationship between bone size and body size and study of that relationship is based on the premise that as the body mass of an organism increases, the skeleton of the individual will both elongate and widen in order to accommodate the additional weight load while continuing to allow movement of the body. In this sense, long bones and other weight-bearing bones heavily affected by gravity are those most closely linked to changes in body mass, as opposed to craniodental specimens that tend to be influenced by factors unrelated to bearing weight (Reynolds 2002). The scaling relationship, although determined by numerous environmental (nutrition, competition) and genetic/physiological factors, provides a method with which accurate estimates of body mass can be made (Alexander 1985; Mahoney et al. 2011; Scott 1990). Here, the response of bone size to changes in intraspecific competition and eNPP is evaluated. Differences in population density between Missouri prehistoric and modern populations are assumed to influence the intensity of intraspecific competition, and are assumed to be influenced by differences in eNPP.

Modern Skeletons

Collections of modern skeletons at the University of Wyoming and University of Kansas were chosen because each consists of a large number of white-tailed deer skeletons, and they were readily accessible; no such collection of modern Missouri deer curated in Missouri is known to me. If specimens from these collections are similar in size to the few modern Missouri deer specimens to which I had access, they will be lumped with Missouri samples and will represent my modern sample. If both University of Kansas and University of Wyoming skeletal collections are statistically different in bone size than the Missouri specimens, then geographical and other variables responsible for the differences will be addressed. University of Missouri specimens were collected from Boone County, Missouri, and Wyoming specimens were collected from the Black Hills region. The University of Kansas specimens represent Adair and Mercer counties in Missouri, as well as Franklin and Leavenworth counties in Kansas.

Student *t* tests comparing mean skeletal dimensions of the University of Missouri sample and the University of Wyoming sample are provided in Table 3.4 and Student *t* tests comparing the University of Missouri and University of Kansas collections are listed in Table 3.5. These results indicate the University of Missouri, University of Wyoming and University of Kansas skeletal collections may be combined into the modern sample as none of the various pairs of means are statistically significantly different. In lumping these collections my intention was to provide descriptive data on white-tailed deer bone size that were statistically powerful because of the large (total) sample size.

Prehistoric Skeletons

The prehistoric sample consists of white-tailed deer specimens recovered from the archaeological site known as Helmreich Shelter (23CP40) in central Missouri (Figure 3.2). Located in Cooper County (approximately 123.5 miles south of Adair County and 160.0 miles south of Mercer County in Missouri), Helmreich Shelter is a rock shelter at the base of a bluff overlooking the Lamine River flood plain (Greer 1992). Excavated over the course of 5 years, the oldest deer bones from Helmreich Shelter have an estimated age of 3210-3620 +/- 90 B.P. calendar years based on two radiocarbon dates (Table 3.1) (Greer 1992). Two additional radiocarbon dates suggest deer bones were also deposited 1600 +/- 30 B.P. calendar years ago (1555-1410 calibrated years B.P.) and 1270 +/- 30 B.P calendar years (1280-1175 calibrated years B.P.) ago (Table 3.1). Discussion of the environmental history of Missouri refers to radiocarbon years B.P., as opposed to calendar years B.P. or AD/BC time scales. All subsequent mention of ages in this thesis are phrased in terms of radiocarbon years B.P.

Table. 3.1 Radiocarbon dates Helmreich Shelter (23CP40) listed from shallowest to deepest, by level.

Specimen	Provenience	Level	Measured Radiocarbon Age	Conventional Radiocarbon Age	Calibrated Age (95% probability)
23CP40-2015-03	SD 12-18" 12-18"	2	1200 +/- 30 B.P.	1270 +/- 30 B.P.	BP 1280-1175
23CP40-2015-02	SQ 5-L2 30-36"	3	1540 +/- 30 B.P.	1600 +/- 30 B.P.	BP 1555-1410
GaK 504	SQ 15-R3 60-66"	6A	n/a	3210 +/- 90 B.P	BP 3639-3212
GaK 1005	SQ 15-L1 72-78"	7A	n/a	3620 +/- 90 B.P.	BP 4224-3650

***Note:* Calibrated Age of GaK 504 and GaK 1005 calculated using CALIB Radiocarbon Calibration on-line program.

Based on previous reports for Helmreich Shelter by Greer (1992) the current interpretation of the site is that it was occupied sporadically during the Dalton cultural period (roughly 9950 B.P. calendar years) to Mississippian cultural period (approximately 1050 B.P. calendar years ago). Although the Dalton period is said to be the earliest occupation of Helmreich Shelter, the only evidence to support this are lithic materials found at the site. The age discrepancies (earliest occupation believed to be during the Dalton period, while the oldest faunal remains are ~3600 years BP) at Helmreich Shelter are the result of several factors. For instance, all faunal remains dating to the Dalton period or any period before 3600 BP may have deteriorated, thus not evidencing any earlier date of occupation, or due to limited funds, were not selected for radiocarbon analysis. Also, few white-tailed deer remains were recovered from excavation level 7 and one deer remain found in excavation level 8. Thus, I only focus on remains recovered between levels 1-6 for this analysis. Lastly, Helmreich Shelter is said to have been inhabited sporadically during its depositional history and so any periods earlier than the Late Archaic may not be represented.

Missouri forms the eastern border of mule deer (*Odocoileus hemionus*) geographic home range (Easterla 2004); this species does not presently occur in Missouri (Schwartz and Schwartz 1981). However, as a precaution, a sample of well-preserved skeletal elements from Helmreich Shelter was identified using taxonomically diagnostic attributes of postcranial remains documented by Jacobson (2003). All specimens were identified as white-tailed deer and so I classified all deer remains in the assemblage as such.

Figure 3.1 Skeletal element dimension measurements (mm).

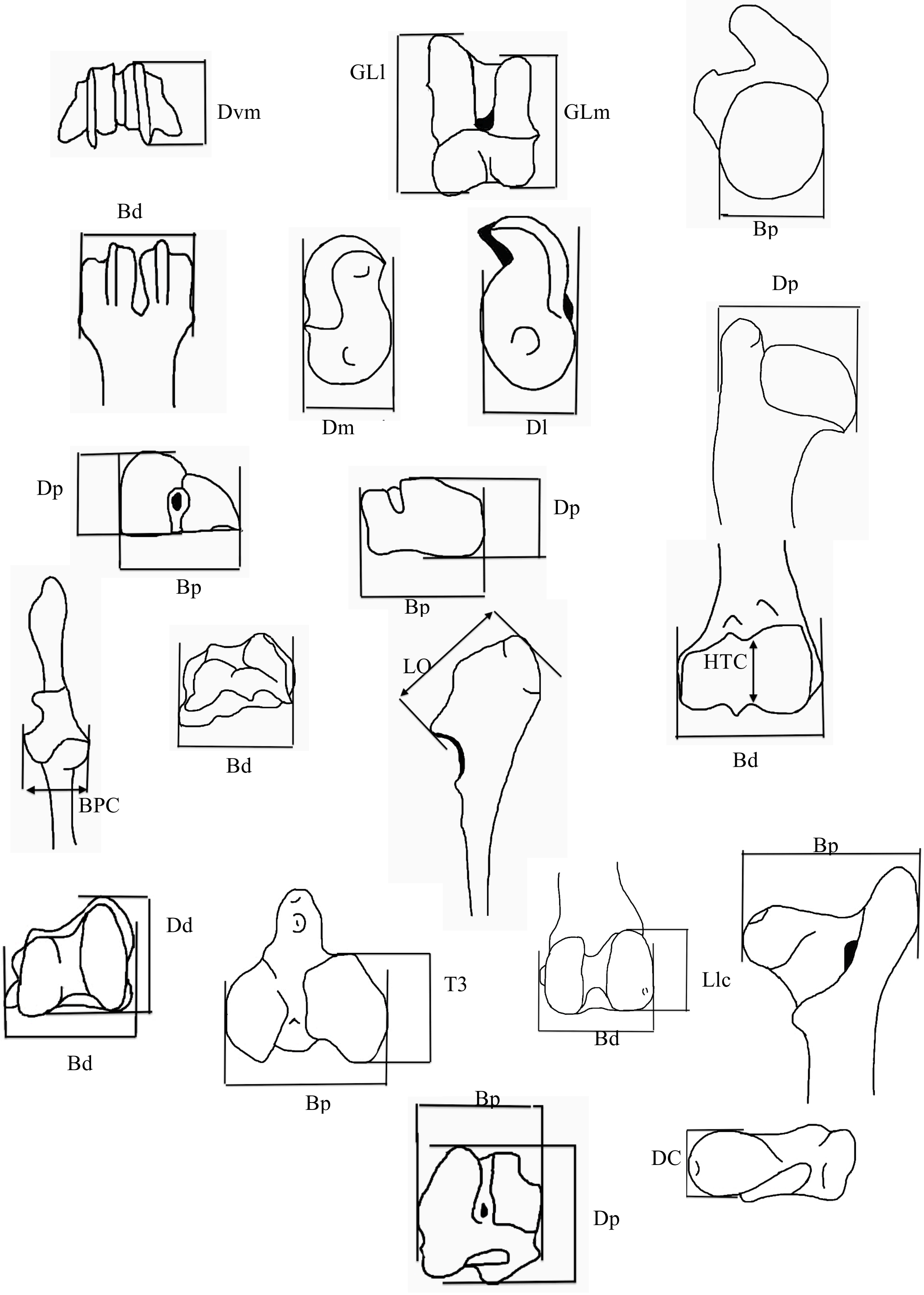


Table 3.2 Descriptive statistics of modern white-tailed deer sample.

Element/Dimensions	Mean (mm)	Standard Deviation	n
Metacarpals			
Bp	29.15	2.30	74
Dp	21.49	1.65	74
Bd	31.05	2.52	37
Dvm	20.82	1.16	37
Metatarsals			
Bp	27.56	2.06	69
Dp	28.33	2.24	69
Bd	32.38	2.80	37
Dvm	22.15	1.06	37
Astragali			
Dl	22.77	2.81	64
GLl	40.48	2.88	64
Glm	38.06	1.95	64
Dm	24.39	1.55	64
Humeri			
Dp	57.70	4.07	17
Bp	45.78	4.44	17
Bd	39.94	2.40	24
HTC	21.20	1.09	24
Radii			
BP	38.19	2.13	25
Dp	22.35	1.24	19
Bd	35.01	2.84	19
Ulnae			
BPC	21.75	1.67	18
LO	56.06	5.25	17
Femora			
Bp	59.45	4.08	21
DC	25.37	1.72	21
Bd	43.51	5.87	21
Llc	33.78	2.10	21
Tibiae			
Bp	57.32	2.72	17
T3	35.79	2.67	17
Bd	35.71	1.89	21
Dd	27.59	2.11	21

Table 3.3 Descriptive statistics of the prehistoric white-tailed deer sample.

Element/Dimensions	Mean (mm)	Standard Deviation	N
Metacarpals			
Bp	29.04	1.61	11
Dp	22.08	3.35	11
Bd	30.69	3.62	20
Dvm	20.97	1.32	18
Metatarsals			
Bd	32.83	1.17	10
Dvm	22.23	1.22	9
Astragali			
Dl	22.57	1.33	45
GLl	40.12	2.46	45
Glm	37.84	2.14	43
Dm	23.09	1.41	43
Humeri			
Dp	60.79	7.81	2
Bp	46.21	9.43	2
Bd	40.74	1.90	17
HTC	21.68	1.11	20
Radii			
BP	38.19	2.49	25
Dp	22.89	1.56	24
Bd	35.17	1.91	9
Ulnae			
BPC	20.67	1.56	27
LO	53.77	7.63	4
Femora			
Bp	62.45	3.58	4
DC	26.41	0.82	7
Bd	50.94	3.35	2
Llc	35.32	0.98	2
Tibiae			
Bp	51.77	8.81	5
T3	36.72	11.25	5
Bd	36.06	2.46	28
Dd	27.38	2.20	27

***Note:* No measurements could be taken for metatarsal dimensions Bp and Dp.

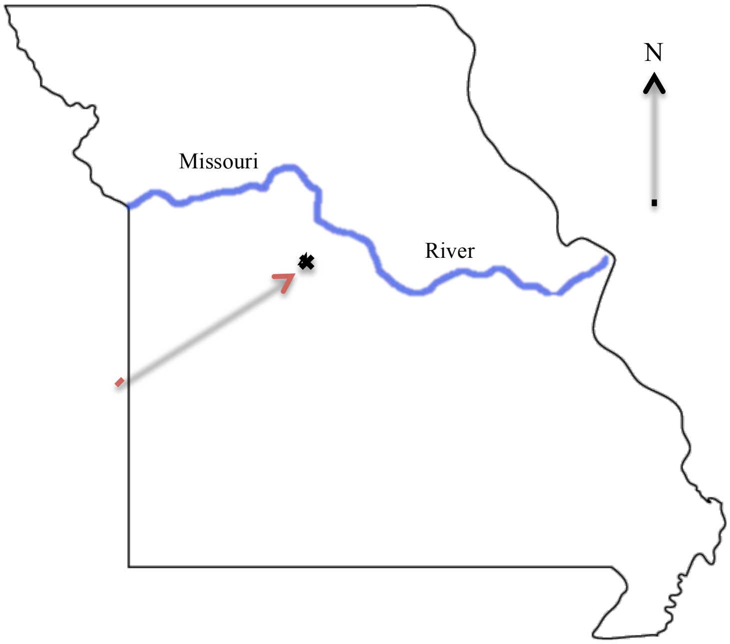
Table 3.4 Results of Student *t* tests of University of Missouri and University of Wyoming collections.

Element/Dimensions		t-statistic	p-value
Metacarpals			
	Bp	0.368	0.643
	Dp	0.544	0.706
	Bd	-1.831	0.038
	Dvm	-1.67	0.052
Metatarsals			
	Bp	-0.651	0.259
	Dp	-1.081	0.142
	Bd	-2.607	0.007
	Dvm	-0.571	0.286
Astragali			
	Dl	-0.793	0.215
	GLl	0.902	0.815
	Glm	1.388	0.915
	Dm	-3.276	0.001
Humeri			
	Dp	1.627	0.938
	Bp	-1.489	0.079
	Bd	0.067	0.526
	HTC	-0.04	0.485
Radii			
	BP	-0.25	0.402
	Dp	1.222	0.881
	Bd	-1.236	0.117
Ulnae			
	BPC	1.116	0.860
	LO	-0.196	0.424
Femora			
	Bp	1.071	0.851
	DC	-1.587	0.065
	Bd	-1.303	0.104
	Llc	-1.006	0.164
Tibiae			
	Bp	-0.347	0.367
	T3	-0.542	0.298
	Bd	0.47	0.678
	Dd	-1.616	0.061

Table 3.5 Results of Student *t* tests of University of Missouri and University of Kansas collections.

Element/Dimensions		t-statistic	p-value
Metacarpals			
	Bp	-0.322	0.374
	Dp	-0.714	0.239
	Bd	1.789	0.957
	Dvm	0.676	0.747
Metatarsals			
	Bp	0.148	0.559
	Dp	-0.632	0.265
	Bd	-0.238	0.407
	Dvm	1.269	0.891
Astragali			
	Dl	-0.202	0.420
	GLl	0.109	0.543
	Glm	0.624	0.732
	Dm	-1.973	0.027
Humeri			
	Bd	0.065	0.525
	HTC	-0.759	0.234
Radii			
	BP	0.003	0.501
	Dp	-0.770	0.242
Ulnae			
	BPC	-1.227	0.143
Femora			
	Bp	0.059	0.522
	DC	0.293	0.610
	Bd	-3.054	0.011
	Llc	0.720	0.751
Tibiae			
	Bd	-0.392	0.354
	Dd	-0.748	0.239

Figure 3.2 Location of prehistoric site 23CP40 (Helmreich Shelter), indicated by the “X”.



CHAPTER 4: Results

The manner in which modern white-tailed deer body size compares to prehistoric deer body size should reveal the affects of both predator eradication and increased eNPP on deer population density and size in Missouri. Recall from Chapter Three, bone measurements (bone size) are used as proxy measures of body size.

Figure 4.1 compares the prehistoric sample and the modern sample using a ratio diagram. First described by Simpson (1941), the diagram's utility resides in its simple construction and its clear display of how multiple dimensions differ between the modern and prehistoric samples. All mean values are first converted to their logarithm. The log10 values for skeletal dimensions in the modern sample are used as the "standard" to which prehistoric log10 values are compared. The modern "standard" is the "0.0" bold vertical line in Figure 4.1. The difference in log10 values between the modern and prehistoric samples is plotted horizontally by dimension (Figure 4.1) (Simpson 1941). Values plotted as greater than 0.0 represent mean prehistoric values larger than the modern standard; values less than 0.0 (negative values) represent mean values smaller than the modern standard (Albarella 2002; Simpson 1941).

To account for potential biases resulting from differential preservation of skeletal elements or skewed collections of elements in the prehistoric sample, I distinguished between dimension means calculated on fewer than 10 specimens (designated as small samples) and dimension means calculated on the basis of 10 or more specimens (designated as large samples) (Figure 4.1). The decision to use 10 as the cut off between large and small prehistoric samples was based on the fact that the majority of skeletal element dimensions consisted of 10 or more specimens. Testing the small and large samples individually would allow for sample size differences to be more easily seen and therefore, would help eliminate sample size biases should any be detected. Student *t* tests comparing the large prehistoric samples to the modern samples are listed in Table 4.1, while Student *t* tests comparing the small prehistoric samples to the modern samples are listed in Table 4.2. Neither sample size (<10 versus ≥10) made a difference in the comparisons between the modern sample and the prehistoric sample and tests suggest the prehistoric white-tailed deer population is not significantly different in size from the modern population.

It is critical to recognize that the prehistoric population of deer represented by the Helmreich Shelter collection of remains spans the last 3600 radiocarbon years (see Table 3.1). The modern sample spans only the last century or so. More importantly, the prehistoric sample could contain evidence of change over time in the mean size of deer that is masked by lumping all specimens, irrespective of their age, into one time-averaged sample (e.g., Kowalewski et al. 1998). At some point during the time span represented by the prehistoric collection, deer may have on average been smaller, or larger than modern deer. Fortunately, there is a way around this smearing and blending of data. The prehistoric sample was excavated in arbitrary levels (12 inches thick) and cannot be sorted into stratigraphically delimited assemblages. However, we can assume that those arbitrary levels still reflect the principle of superposition—that the material that is deeper was deposited before the material that is shallower. Available radiocarbon dates (see Table 3.1) from the levels suggest this is a reasonable assumption as the older dates occur in deeper levels than the younger dates.

Time Averaging and the Paleozoological Record

Time averaged assemblages, also called "palimpsests" (Binford 1980), represent multiple accumulation events of objects that are analytically treated as having been deposited together in the paleozoological record (Kowalewski 1996; Olszewski 1999). Deposits can experience overcompleteness (a concentration of objects from a long time period included in a depositional unit formed during a short time interval) or incompleteness (quickly formed deposits which lack objects) (Kowalewski 1996). The extent to which time averaging is a burden or a blessing for a paleozoologist depends on what Kowalewski (1996) termed the "time-averaging threshold," or the time-scale of the process of interest (Olszewski 1999). In short, the time-scale of the process of interest acts as the temporal point of reference for the phenomena being studied. If the process of interest has a temporal duration that is longer than the extent of time represented by an assemblage, then a paleozoologist need not be concerned. Time averaging has a negative connotation when the extent of temporal lumping represented by a collection exceeds the temporal duration of the process of interest (Kowalewski 1996). The most frequent consequences of time averaging are (Kidwell and Behrensmeyer 1993; Kowalewski 1996): reduction of resolution, elimination of noise, and generation of false patterns.

Figure 4.1 Ratio diagram of prehistoric dimension measurement means compared to the modern standard. Samples of less than 10 specimens are represented by open circles and samples with 10 or more specimens are represented by filled squares.

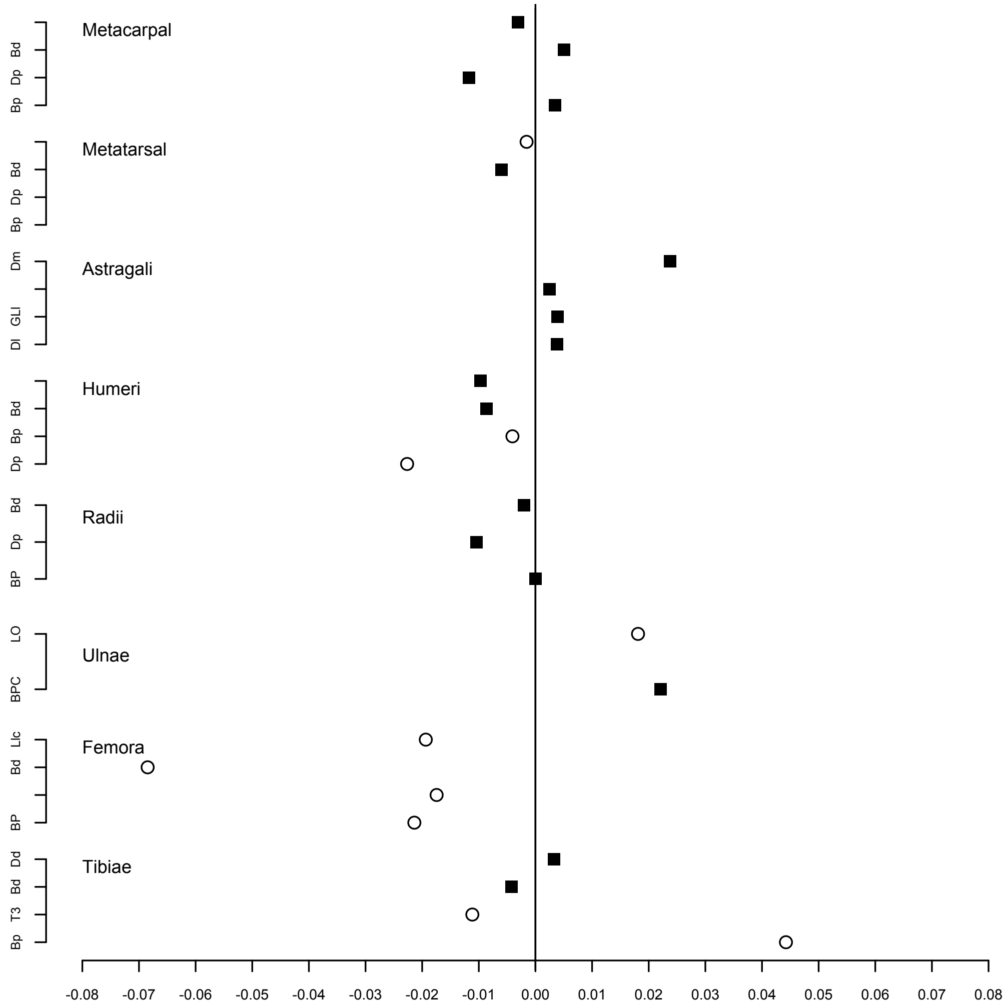


Table 4.1 Results of Student *t* tests from Missouri modern and prehistoric "large" samples.

Element/Dimensions	t-statistic	p-value
Metacarpals		
Bp	0.452	0.674
Dp	0.204	0.580
Bd	0.518	0.697
Dvm	0.486	0.686
Metatarsals		
Bp	NA	NA
Dp	NA	NA
Bd	-0.111	0.456
Astragali		
Dl	0.306	0.620
GLl	-0.033	0.487
Glm	0.229	0.590
Dm	-4.292	<0.001
Humeri		
Bd	-0.718	0.239
HTC	-1.03	0.155
Radii		
BP	2.78	0.996
Dp	-0.82	0.209
Bd	1.083	0.856
Ulnae		
BPC	-1.845	0.036
Tibiae		
Bd	0.187	0.574
Dd	0.644	0.739

Table 4.2 Results of Student *t* tests from Missouri modern and prehistoric “small” samples.

Element/Dimensions		t-statistic	p-value
Metatarsals			
	Dvm	1.040	0.848
Humeri			
	Dp	0.460	0.674
	Bp	1.856	0.960
Ulnae			
	LO	0.260	0.601
Femora			
	Bp	-0.861	0.199
	DC	-1.774	0.044
	Bd	-1.137	0.134
	Llc	-0.841	0.205
Tibiae			
	Bp	-0.740	0.234
	T3	1.126	0.863

The first consequence occurs because time averaging literally averages results of processes and lowers the temporal resolution of events represented in a deposit; all of those events are analytically contemporaneous. The elimination of statistical ‘noise,’ the second consequence, may be a desired affect as noise is caused by short-term and interpretively insignificant (e.g., random) fluctuations in the process of interest (Kidwell and Behrensmeyer 1993; Kowalewski 1996; Olszewski 1999). An example of the elimination of ‘noise’ is relative taxonomic abundance data. Relative taxonomic abundance information often provides an overestimation of the actual abundances of the species present at any given time in a community (Peterson 1977). This is so simply because the species’ present often differ in lifespan and those with shorter life spans tend to be overrepresented in the fossil record and are perceived as being more abundant than longer-lived species as a result (Peterson 1977). Time averaging in this case pools remains of individuals of species with different temporal durations (life spans) into a single temporal unit. In this instance, time averaging would be an undesirable affect because many relative abundance studies are focused on determining a community’s relative species abundances at a specific moment in time. With no adjustment for differences in lifespan between species, relative abundance measures obtained from a time averaged sample will be higher, or lower (depending on lifespan) than the abundances of those species during the time period of interest (Peterson 1977).

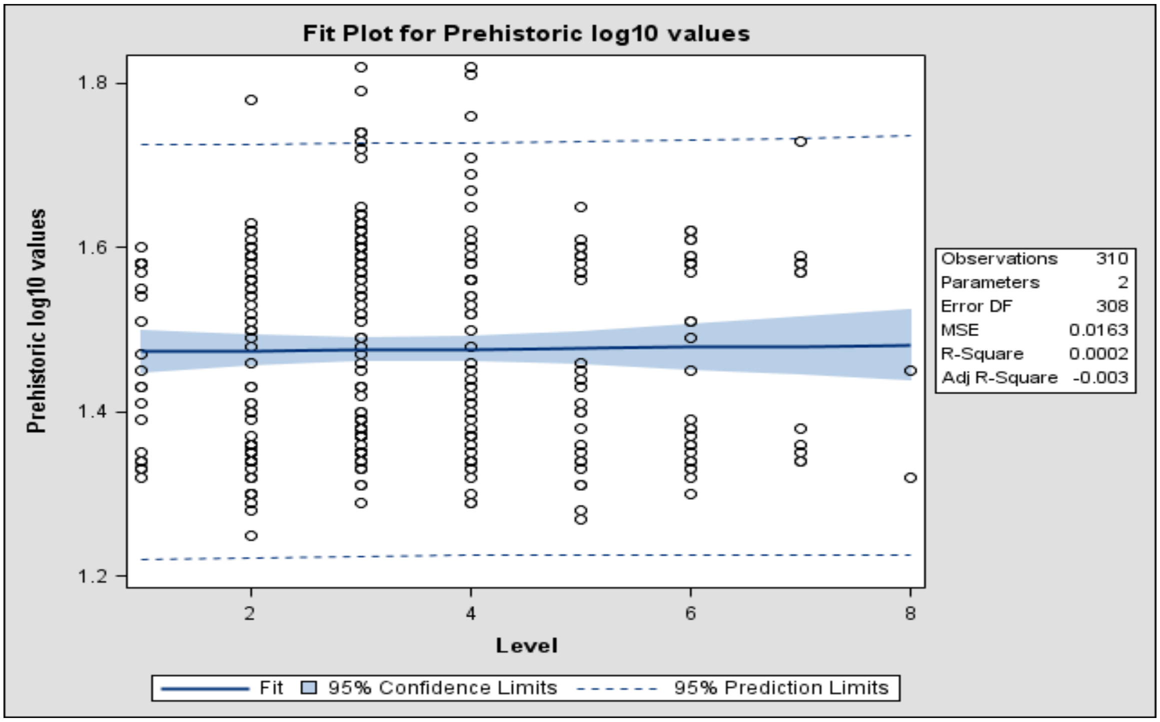
Lastly, the third consequence of time averaging is that it creates false patterns such as late extinctions, sudden extinctions, or disharmonious (no-analog) communities (Kidwell and Behrensmeyer 1993; Kowalewski 1996). A fossil representing an extinct species may have a particular time period in which it is widely accepted to have gone extinct. However, if a deposit in which the fossil species is found is time averaged, the extinction event could appear to have occurred at an earlier or later time than the species' true extinction date. This is time averaging creating a false pattern. Time averaging can also cause the gradual extinction of multiple species to appear sudden if the species-specific extinction events are combined into a single depositional event due to, say, low sedimentation rates (Kowalewski 1996). Lastly, no-analog communities can be created through time averaging. For example, following Hibbard (1955), Webb and Barnosky (1989) noticed that many extant species that occurred side by side in many late Pleistocene communities now live in different geographic areas with vastly different climatic conditions. It is these differences in climatic preferences that make a prehistoric community appear to not have a modern analog. Before the reality of such no-analog communities was generally accepted, one explanation for such anomalous faunal communities was stratigraphic mixing or time averaging.

To address the possibility of time averaging at Helmreich Shelter, the sizes of individual skeletal elements from the site are arrayed according to their vertical provenience (arbitrary excavation level) (Figure 4.2). Log10 values for each prehistoric skeletal dimension were grouped according to arbitrary vertical level. This allowed determination of whether a level contained more or fewer large or small skeletal elements than any other level. If so, then the total prehistoric sample is time averaged with respect to deer bone size. Based on the linear regression line shown in Figure 4.2, the size of skeletal elements does not seem to be consistently or uniformly related to the provenience level to which the elements belong (R^2=0.0002). In other words, the regression line suggests the prehistoric sample is not time-averaged in any major way. However, Student *t* tests comparing each adjacent pair of provenience levels' (level 6 to level 5; level 5 to level 4; etc.) mean log values of all dimensions suggest there is a single significant decrease in mean bone size from the earlier level 3 to the chronologically later level 2 (*t*=-2.778, p<0.01) (Table 4.3).

Table. 4.3 Results of Student *t* tests comparing mean sizes of each pair of adjacent levels.

Provenience Level	t-statistic	p-value
Level 1 vs Level 2	0.952	0.828
Level 2 vs. Level 3	-2.778	<0.01
Level 3 vs. Level 4	-0.189	0.425
Level 4 vs. Level 5	-0.529	0.299
Level 5 vs. Level 6	1.210	0.884
Level 6 vs. Level 7	0.054	0.522
Level 7 vs. Level 8	-0.923	0.180

Figure 4.2 Linear regression displaying log10 values of the means representing the prehistoric sample compared to the provenience of skeletal elements measured.



The Student *t* test (Table 4.3) indicates a significant decrease in mean size between 1600 and 1270 radiocarbon years B.P. (see Table 3.1). I next investigate the environmental history of Missouri during the last 3600 radiocarbon years in order to determine if a change in eNPP or human predation intensity occurred and resulted in the decrease in mean size.

Cause(s) of Size Change in Prehistoric White-tailed Deer

The Midwestern United States has been an area of great interest to paleoecologists and archaeologists alike for its unique environmental history and the affects of that history on human populations. This region of mixed deciduous, oak (*Quercus*) dominated forests and tallgrass prairie is known as the Prairie Peninsula (Transeau 1935). It stretches from the Great Plains to central Indiana (O'Brien 2001); central Missouri is its southern border (McMillan and Klippel 1981). Environmental information for the Prairie Peninsula has focused heavily on the upper Midwest (Iowa, Michigan, Wisconsin, Nebraska) and the Illinois River Valley, some distance (~250 miles) from Helmreich Shelter; that information is used cautiously here. More importantly, regional and local climate conditions could have significantly mediated the extent of habitat change within areas of the Prairie Peninsula. Therefore, until detailed, site-specific paleoecological studies are done within central Missouri, interpretations of past environments outlined here are coarse estimations for the area.

Environmental conditions following the Hypsithermal climatic event (~8000-5000 B.P.) suggest a return to cooler and wetter conditions and the reestablishment of a mesic deciduous forest within the Prairie Peninsula (Chumbley et al. 1990). This transition to more mesic conditions corresponds to the sub-Boreal (~5000-2800 ^{14}C B.P.) climatic episode (Wendland 1978). Archaeological evidence dating to the sub-Boreal (Late Archaic cultural period; 3600-2000 B.P.) within Missouri suggests that a shift from low-rank prey to solely high-ranked white-tailed deer (Parmalee et al. 1976) for subsistence occurred in response to the increase in forested area. This time period also coincides with the beginning of small-scale plant cultivation in Missouri (Kay 2009).

The climatic episode following the sub-Boreal, the sub-Atlantic (2800-1700 B.P.), is generally associated with a gradual increase in temperature that spanned both the Scandic (begins ~1680 B.P.) and the neo-Atlantic climatic periods (begins ~1260 B.P.) (Wendland 1978). Data from the neo-Atlantic in much of the Midwest suggest that during this time conditions were not only warmer, but also moister (Bernabo 1981; Swain 1978; Wendland 1978). It is this warmer and moister period that corresponds with the decrease in white-tailed deer bone size evident in level 2 at Helmreich Shelter.

O'Brien and Wood (1998) argue that although drier conditions did occur in the Late Woodland and Early Mississippian periods, associated changes may not have been as great as during previous climatic episodes (i.e. the Atlantic) nor were they likely severe enough to alter the local biotic community. Instead, localized, short-term fluctuations in temperature and water availability often resulting in severe flooding or drought may have been a prime concern of prehistoric people living in Missouri during the neo-Atlantic. The archaeological record in Missouri during the Late Woodland-Early Mississippian periods (~1300-750 radiocarbon years B.P.), suggests that a significant part of prehistoric people's diet involved oily and starchy-seeded plants, most of which are tolerant of a range of soil types and moisture (e.g., goosefoot, barley, maygrass, knotweed, and marsh elder) (Asch et al. 1979). Maize also became one of the staple food sources around 1200 B.P., although it did not fully replace oily and starchy plants in importance until much later (O'Brien and Wood 1998). And by 1350 B.P. prehistoric people from central Illinois were completely sedentary and relied on both horticulture and aquatic resources for food (Braun 1987).

In central Missouri from 1600-1270 B.P. conditions changed frequently and rapidly within the Prairie Peninsula but with an unknown influence on both prehistoric people and the habitats in which they lived. Braun (1987) outlines several cultural trends that occurred from the Archaic through Woodland periods within the Central Midwest including human population growth, decreasing residential mobility, and increasing exploitation of aquatic resources and overall subsistence diversity. Of these trends, the fact that prehistoric people within Missouri were somewhat sedentary and shifted to a more plant-based subsistence strategy at roughly the same time that white-tailed deer from Helmreich Shelter became smaller, is of the utmost importance here. The amount of animal protein consumed by local prehistoric people does not appear to have changed during the Late Woodland (Buikstra et al. 1986), meaning that prehistoric people still relied heavily on animals for subsistence. However, the extent to which white-tailed deer contributed to the consumed animal protein is not known and cannot provide any insight into the predation pressure deer faced as the diet of prehistoric people diversified.

Given the cultural and climatic changes occurring during the neo-Atlantic episode, I propose the following scenarios as potential causes for a decrease in white-tailed deer bone size between 1600 and ~1300 years ago. The likely fluctuations in temperature and water availability in Missouri during the neo-Atlantic (~1260 B.P) and the likely decrease of plant productivity and eNPP in association with a warming climate (Hatfield et al. 2011), as well as the potential decrease or stable predation pressure on deer by prehistoric hunters in relation to changing subsistence patterns, may have operated simultaneously to result in a decrease in deer size. If climate shifts between 1600 and ~1300 B.P. brought warm and moist conditions that increased plant productivity and a decrease in the harvest of white-tailed deer occurred, deer may have become overpopulated and decreased in size in order to lower the energetic needs per individual in crowded conditions. Alternatively, the size trend evident from level 3 to level 2 times may document a short-term period in which the local climate was more arid than the overall moister conditions of the neo-Atlantic, causing decreases in both natural and domesticated plant production, lowering eNPP and decreasing size in deer. Purdue (1989) proposed solar insolation, the total amount of solar radiation energy on a surface at a particular time, was a direct cause for climate fluctuations and changes in forage quality and availability during the middle Holocene.

Although the changes in deer size Purdue (1989) documented do not correspond to the time periods of interest here (i.e. the neo-Atlantic), the suggested reason for the size change does provide some relevant information for this discussion. When solar insolation was at its highest during the middle Holocene, conditions were at their peak in terms of temperatures and evaporation. During this time period, Purdue (1989) found that Illinois deer were smaller and that small size may have been related to rapid maturation in plants in less favorable conditions, which provided less high-quality forage for deer or a shorter duration of availability, thus a lower eNPP per annum. In contrast, during the late Holocene, Purdue (1989) noticed that deer bone size increased and continued to do so until the historic period when deer were reintroduced. This increase in size may have correlated with a decrease in solar insolation leading to a reduction in summer temperature and evaporative rates. As a result, plants could have continued to grow and provide high protein forage with low levels of fiber (Purdue 1989); in other words, eNPP was greater per annum. Perhaps such a change in solar insolation occurred roughly 1300 years ago and caused short-term fluctuations in climatic conditions that mirror those seen by Purdue (1989) in central Illinois during the Hypsithermal. Since Purdue (1989) did not document a similar decrease in body size at a period that matches that seen in Missouri, the factors influencing the decrease in Missouri deer ~1300 years ago were likely caused by the interaction of several short-term, local processes.

Regardless of which scenario, if any mentioned above, is responsible for the size trend seen in deer during the neo-Atlantic, similar findings for this time period in different locations within Missouri are needed in order to rigorously determine a cause for the size change. Deppen and Cook (2014) recently suggested a potential environmental and anthropogenic cause for deer diminution roughly 1300 years ago. In their study, deer remains from three Fort Ancient sites in southwestern Ohio were assessed to test whether environmental stress affected deer hunting and the utilization of deer parts. Deppen and Cook (2014) hypothesized that drought conditions would cause both an increase in deer harvest pressure because it would lower the productivity of agricultural crops for prehistoric people, forcing them to rely more heavily on wild game for subsistence, and a decrease in the amount of forage available for deer. When these two processes occur simultaneously, Deppen and Cook (2014) argue that the deer population will experience either no change in body size or a slight reduction in size, the latter of which is of interest here. In order for this affect to be tested with the deer remains from Helmreich Shelter, both the age structure of the deer populations and the size of the remains will need to be observed. Mortality profiles provide an age structure of a population at the time of death and reveal which age classes in the community have the highest mortality rate. If a deer population is hunted, as in Missouri, the recruitment (reproductive) rate needs to increase relative to increased mortality from hunting in order for the population to remain stable (Lyman 1987). Based on evidence that prehistoric people during the prehistoric diminution event (~1300 B.P.) were highly agricultural, drought conditions would cause these communities to face shortages in plant resources. To accommodate for the instability of these resources, people would have relied more heavily on animal resources, particularly high ranked prey such as white-tailed deer (Deppen and Cook 2014). Populations experiencing high predation rates (and low recruitment rates) will have fewer old/senile individuals than unhunted populations (Lyman 1987). Thus, if the number of young deer relative to older deer increases (e.g., Lyman 1987) and if a slight decrease or no change in the size of deer remains occurs during the suspected drought period, then one can assume that environmental conditions during the prehistoric diminution event caused both an increase in hunting pressure and a decrease in forage availability (Deppen and Cook 2014).

Now that a potential cause for the prehistoric change in white-tailed deer body size has been identified, the issue of whether or not modern white-tailed deer in Missouri are stunted can be investigated. A comparison of modern deer size to prehistoric samples of deer follows.

Prehistoric and Modern White-tailed Deer Body Sizes

A decrease in bone size occurs during the shift from level 3 to level 2 within the prehistoric Helmreich Shelter materials. For analytical purposes, I treat deer remains from levels 3–6 as an early (pre-diminution) prehistoric sample and deer remains from levels 1–2 as a late prehistoric (small-bodied) population of deer. Student *t* test comparisons between the modern sample and the late prehistoric (levels 1-2) small-bodied sample are listed in Table 4.4, and between the modern sample and the early prehistoric (levels 3-6) pre-diminution sample are listed in Table 4.5. Figure 4.3 compares skeletal dimension means from both prehistoric samples to the modern sample "standard." As discussed in the previous section, the early prehistoric sample (levels 3-6) is larger in bone size than the late (levels 1-2) sample. Figure 4.3 shows that 6 mean dimension measurements from the early prehistoric sample are larger than the modern standard whereas 21 are smaller; and, 11 mean dimension measurements from the late prehistoric sample are larger than the standard whereas six are smaller. This trend is misleading, however, particularly when seen in relation to Tables 4.4 and 4.5. There are skeletal dimension measurements that are significantly different between compared samples. Between the modern and early prehistoric sample comparison, measurements “Dl” of the astragalus and “Bd” of the tibia are significantly different (Table 4.5). Likewise, measurements “Dvm” of the metacarpal, “Dm” of the astragalus, and “Dd” of the tibia are significantly different between the modern and late prehistoric sample (Table 4.4). Interestingly, Figure 4.3 suggest the significantly different measurements between the modern and early prehistoric sample correspond to the early prehistoric dimension measurement being smaller than the modern standard; and in the late prehistoric and modern comparison, the corresponding late prehistoric dimension measurements are larger than the modern standard. So while Figure 4.3 suggests that the modern sample is larger than the early prehistoric sample and smaller than the late prehistoric sample, student t tests comparing these samples suggest that the samples being compared are not significantly different in bone size when comparing the modern to both prehistoric samples. This is why the trend seen in Figure 4.3 is misleading.

Figure 4.4 is a better representation of the size trend between the prehistoric and modern samples. In this figure, the log10 values representing each dimension measurement mean are used to construct the box and whisker plot. The mean log10 value of each sample is indicated by the filled circle within each box plot and the modern mean value or standard, is represented by the vertical line. Based on where the mean values (filled circles) fall in reference to the modern standard line (vertical line running through each box plot), the early prehistoric sample mean's log10 value is larger than both the late prehistoric sample mean's log10 value and modern sample mean log10 value, and the late prehistoric sample value is smaller than the modern sample value (Early prehistoric > Late prehistoric < Modern; and, Early prehistoric > modern).

Discussion

As stated in Chapter Two, changes in mean body size may occur as a result of the interaction of several variables. Here, ecologically relevant net primary productivity (eNPP) and predation pressure (and its affect on population density) are the variables of interest when comparing size of modern white-tailed deer and prehistoric deer. Each variable and its potential influence on the lack of stunting of modern white-tailed deer in Missouri (compared to the late prehistoric sample) and the cause of stunting in the modern deer population (compared to the early prehistoric sample) will be discussed individually, starting with predation pressure.

Wolverton (2007) determined that predator eradication in central Missouri has not caused stunting of modern white-tailed deer relative to prehistoric deer. Sport hunting is currently the primary source of population control for deer nationwide (Wolverton 2007). As mentioned in Chapter Two, the number of hunters has remained unchanged or has decreased in recent history due to changes in social acceptance (Côté et al. 2004). Table 4.6 lists the recorded total deer harvests for hunting seasons in Missouri from 2009-2015. The number of deer harvested over the past 6 hunting seasons has fluctuated much like the acreage of agricultural crops within the state. Whether or not shifts in harvest pressure

(Allen and Wold 2009) and the reasons behind that a shift (e.g. trophy hunting) (Coltman et al. 2003) have any substantial impact on the body sizes of white-tailed deer in the state requires the construction and study of mortality profiles represented by deer harvests over consecutive years. As mentioned in the discussion of the prehistoric diminution event (~1300 B.P.), hunted populations tend to reflect mortality profiles in which individuals in old/senile annual cohorts are rare relative to their abundances in unhunted populations. The extent to which human harvesting influences the demography of Missouri deer population depends on the harvest rate, or how many animals in each annual cohort are killed each year. However, for hunted populations to remain stable, the recruitment (reproductive) rate needs to increase along with the mortality rate (Lyman 1987). Given that hunters tend to selectively remove larger reproductively active males and females from the population, smaller and younger individuals are more likely to pass their genes to future generations, potentially exacerbating the decrease in mean body size. So in the case of the modern diminution event, if the survivorship curve reflects an under-representation of senile individuals then the population may be over hunted (Lyman 1987). Mortality profiles of zooarchaeological deer assemblages will also need to be analyzed if a comparison similar to the one made here and that of Wolverton (2007) is to be used to study human predation pressure and its affects on deer body size. Nevertheless, such a study is beyond the scope of this research and so additional work will need to be done before predation pressure and its association with population densities can be evaluated as a possible factor influencing body size of Missouri white-tailed deer.

Table 4.4 Student *t* tests between the means of the modern sample and late prehistoric levels 1-2.

Element/Dimensions	t-statistic	p-value
Metacarpals		
Bp	1.537	0.936
Dp	-0.163	0.435
Bd	-0.991	0.164
Dvm	-2.462	<0.01
Metatarsals		
Bd	0.307	0.620
Astragali		
Dl	-1.759	0.041
GLl	-1.981	0.026
Glm	-1.099	0.138
Dm	-3.809	<0.01
Humeri		
Bd	0.516	0.695
HTC	0.962	0.827
Radii		
Dp	0.470	0.678
Bd	-1.467	0.079
Ulnae		
BPC	-0.637	0.265
Tibiae		
Bp	0.270	0.605
T3	0.061	0.524
Bd	0.994	0.835
Dd	-2.204	0.018

Table 4.5 Student *t* tests between the means of the modern sample and early prehistoric levels 3-6.

Element/Dimensions	t-statistic	p-value
Metacarpals		
Bp	1.816	0.963
Dp	0.491	0.687
Bd	-0.632	0.265
Dvm	-0.772	0.222
Metatarsals		
Bd	0.452	0.673
Dvm	-0.399	0.346
Astragali		
Dl	-2.093	0.020
GLl	-1.659	0.051
Glm	-1.92	0.029
Dm	-1.189	0.120
Humeri		
Dp	0.46	0.674
Bp	1.856	0.960
Bd	-0.99	0.165
HTC	-1.685	0.051
Radii		
BP	1.166	0.875
Dp	-0.433	0.334
Bd	-0.967	0.172
Ulnae		
BPC	-1.833	0.040
Femora		
Bp	-0.861	0.199
DC	-1.774	0.044
Bd	-1.137	0.134
Llc	-0.841	0.205
Tibiae		
Bp	-0.717	0.242
T3	0.610	0.725
Bd	-2.120	0.021
Dd	0.519	0.696

Figure 4.3 Ratio diagram of prehistoric dimension measurement means compared to the modern standard. Samples from provenience levels 1-2 are represented by filled squares and open circles represent samples from provenience levels 3-6.

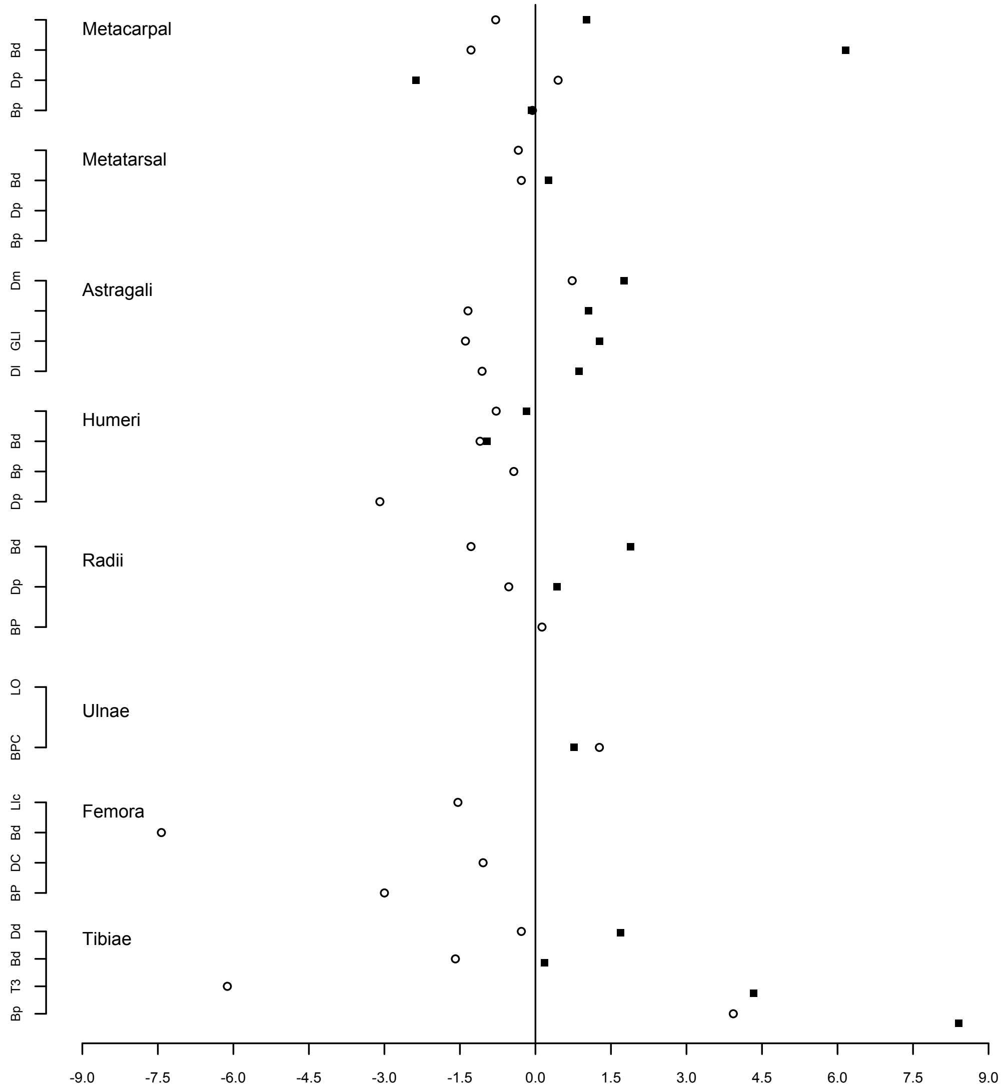


Figure 4.4 Box and Whisker plot comparing the log10 values of the means of the early prehistoric, late prehistoric, and modern sample. The sample means (filled circles) are illustrated so that their relationship to the modern standard mean log10 value (vertical line through all three boxes) is easily seen. Each box signifies the interquartile range of the sample, and the whiskers running horizontally through each box represents the sample's range.

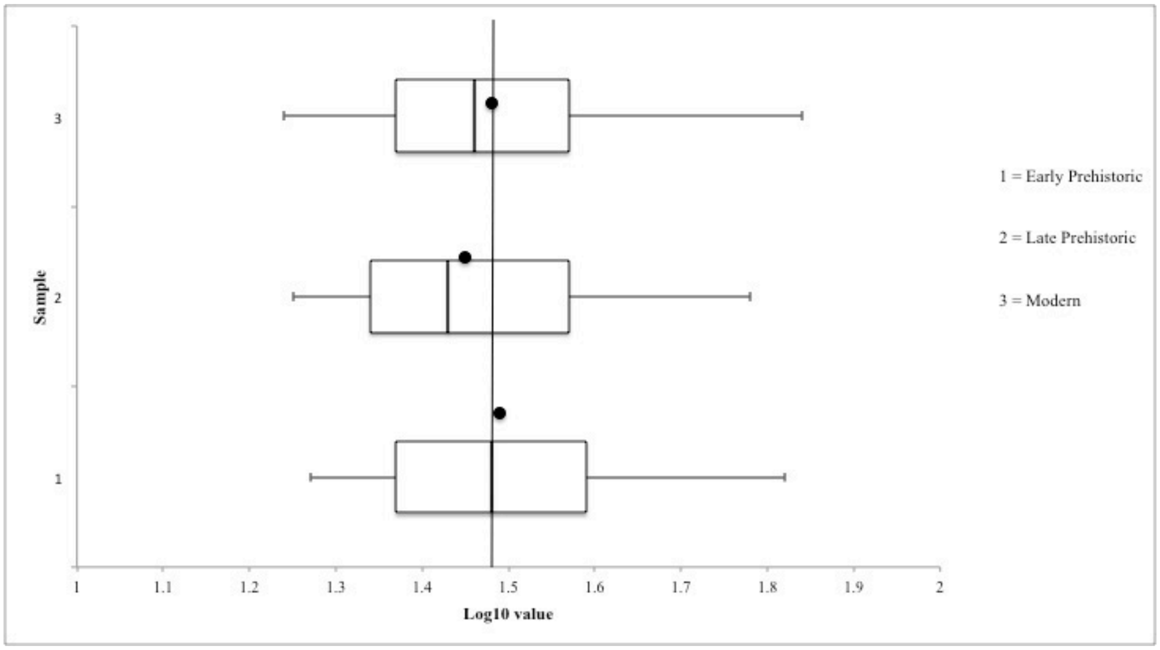


Table 4.6 Deer harvest data for hunting seasons.

	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Grand Total Deer Harvested Per Season	301,187	276,650	293,527	313,254	252,574	258,341

***Note:* Data from Missouri Department of Conservation (2015)

Recall that Table 2.1 lists crop yield data within Missouri over 30 years and that these data serve as a surrogate for eNPP. Over this 30-year interval, crop yields for wheat and sorghum decreased while the yields for corn and soybeans steadily increased or remained relatively stable. The lack of stunting within the modern sample compared to the late prehistoric sample is likely in response to the increase in eNPP from widespread agricultural practice in the Midwest. It is worth considering how agricultural practices have increased deer nutrition, and how this relates to increase or decrease in mean deer size. Nutrient requirements for deer, like many other ungulates, vary seasonally (Hewitt 2011). In concert with nutrient availability is a period of plant-growth dormancy in the winter (Hewitt 2011) and the potential for animal growth if the nutrients available during the growing season exceed what is required for bodily maintenance (Guthrie 1984). In this sense, three nutrient criteria influence the growth of ungulates: 1) the quality of nutrients available in the growing season, 2) the quantity of nutrients available during the growing season, and 3) the amount of time during which high quality nutrients are available during the growing season (Guthrie 1984; see also Huston and Wolverton 2009). Deer, being concentrate generalists, are capable of consuming a variety of plant life, up to 100 different species annually (Hewitt 2011). However, deer are also selective feeders in that they forage on resources that are of the highest quality first and resort to lower quality forage only after the high quality resources have been exhausted. Diets of deer include leaves and stems of woody plants, forbs (herbaceous, flowering plants), grasses, as well as both hard (i.e. nuts and pods) and soft (i.e. berries and fruits) masts (Hewitt 2011). Protein is the main nutrient on which forage quality is based and because dietary protein tends to decrease from spring to winter the extent to which deer rely on each food resource depends on when each is available during the growing season and its protein content (Hewitt 2011).

On average, a white-tailed deer's diet consists of 46% browse, 24% forbs, 11% mast, 8% grass, 4% agricultural crop (where available), 2% cactus, 2% fungi, and 3% other resources (Hewitt 2011). In the Midwest and Northwest regions of the United States, agricultural crops and grasses dominate deer diet during the summer and autumn, while reliance on browse and forbs is decreased (Hewitt 2011). However, high habitat quality, meaning a variety of food sources representing a wide range of age classes or successional stages, is crucial for productive deer herds because mature forests only produce a small amount of forage (Adams and Hamilton 2011). Early successional forests provide a large amount of forage and can support a larger number of deer than mature forests, despite mast, browse, and cover provided by mature canopies (Adams and Hamilton 2011). Interestingly, the United States Department of Agriculture (USDA) Forest Service (2008) suggests that 55.6 million hectares of forestland has been gained in the United States between the years 1980 and 2000; most of this was gained in the Midwest and western United States. This increase in forests may be problematic in terms of deer management because with a greater percentage of forests comes a lower percentage of early successional forestland (Adams and Hamilton 2011). The Missouri Cooperative Soil Survey (MCSS) (2015) characterizes central Missouri as consisting of the Central Mississippi Valley Wooded Slopes and Ozark Highlands resource areas. Within the Central Mississippi Valley Wooded Slopes ~40% of the area is cropland while 35% remains forested (MCSS 2015). In the Ozark Highlands forests and woodlands consist of nearly 70% of the total land while only 10% is cropland (MCSS 2015).

Given that forage quality in central Missouri has increased with the widespread practice of agriculture and the expansion of forests region-wide in the Midwest over the past 30 years producing additional browse and mast for deer, long-term studies on the affects of forage availability on current deer population body sizes within the state should be done. Documenting age classes in forested habitats and the habitat's deer population density, should also be undertaken before eNPP can be deemed a cause of the size trend evident in Figure 4.4. It is also important that the effects a warming climate have on eNPP be outlined, with particular focus on how anthropogenically caused climate warming may change that variable. This should be investigated because the quantity, quality, and availability of forage during the growing season are highly susceptible to changes in climatic conditions.

Recent research has shown that decreased body size may be a third universal response of animals to anthropogenically caused climate warming, alongside changes in phenology and the distribution of species (see references in Gardner et al. 2011). Because deer are phenotypically plastic and can live in various climatic conditions, anthropogenic climate change as a cause of decreasing plant productivity and stunting in Missouri white-tailed deer should be considered. Temperature and precipitation patterns in the United States project a warming trend of 1.5 to 2.0°C with a slight increase in precipitation over the next 30 years (Karl et al. 2009). Along with those increases are the number of days temperatures are predicted to be 5°C above the current climate norm and a decrease in frost days by 10% in the eastern United States. These will all have significant impacts on agricultural crops (Hatfield et al. 2011). In particular, increasing temperatures are often related to increases in weather fluctuations, meaning that both meteorological drought and high-precipitation events (those producing >5cm per 48 hour period) are of equal concern for crop production (Hatfield et al. 2011).

Whether or not a warming climate will be advantageous or deleterious for crops depends on the crop species since each has its own range of optimal temperatures. For maize, increasing temperatures shorten the life cycle and reproductive phase, leading to smaller corn grain yields. Muchow et al. (1990) found through simulation that maize yields may decrease 5 to 8% per 2°C temperature increase and over the next 30 years could decrease grain yields in the Midwest by 2 to 3%; these are now believed to be underestimations (Hatfield et al. 2011). Soybean crops are suggested to increase in the Midwest with warming temperatures because the current local temperatures are below the species' lower optimum (Grimm et al. 1994; Hatfield et al. 2011). However, for maize and soybean, an increase in temperature above 35°C and 30°C, respectively, decreases pollen viability (references in Hatfield et al. 2011). Nighttime temperature increases are of concern for wheat yields. If nighttime temperatures increase above 14°C-23°C there is a decrease in photosynthesis and yields (Hatfield et al. 2011). Lastly, sorghum yields are said to decline by 7.8% per 1°C temperature rise from 18.5 to 27.5°C (Chowdhury and Wardlaw 1978).

Hansen et al. (1997) state that the increase in forage through agricultural practices within central Missouri can support high deer population densities and when compared to the late prehistoric period this appears to be true. Yet within central Missouri, modern deer bone size is small relative to early prehistoric deer from the state (Figure 4.4). Whether or not the difference in size observed between the modern white-deer sample and the late prehistoric sample and the decrease in size between prehistoric samples (early prehistoric and late prehistoric samples) are related to a lack of available forage per individual within management units, or to population increases resulting from a decrease in predation pressure, has not been confidently determined here. Additional research focusing on how deer body size is manipulated by current predation pressure, eNPP, and climate change needs to be done in order for the cause of body size in modern Missouri deer to be rigorously identified.

Remains from Helmreich Shelter indicate a decrease in size of prehistoric deer between 1600-1300 B.P. Paleoenvironmental data suggest that climatic conditions may have been favorable for deer forage. Given the warming climate at this time, local fluctuations in temperature and moisture were likely common and could have caused short-term changes in primary productivity that led to the observed diminution in deer. To rule out prehistoric predation pressure as a potential cause for the prehistoric diminution in deer, additional investigation into the large carnivore prehistoric record in Missouri should be undertaken. And, analysis of deer demography through study of prehistoric deer mortality and survivorship is necessary.

To reiterate, the results in this chapter outline two episodes of white-tailed deer diminution: a prehistoric episode occurring between 1600-1300 B.P. (excavation level 2 and level 3), and a historic diminution episode occurring between the late prehistoric deer sample and the modern sample. Based on available information, I suggest that the prehistoric diminution episode was a response to fluctuating climatic conditions that may have caused any of the mentioned scenarios. The increase in bone size between late prehistory and modern times is likely due to an increased eNPP attributed to agricultural practices, while the historic diminution episode when compared to early prehistory is likely in response to modern management's focus on maximizing the number of white-tailed deer which has caused a lack of available forage per individual and the observed decrease in body size (Hewitt 2011; Strickland et al. 1996). Ultimately, further testing is needed to determine a direct cause for the prehistoric diminution as well as the modern diminution of Missouri deer.

CHAPTER 5: Summary and Implications

White-tailed deer management in Missouri is a delicate balance between keeping deer populations below both the ecological carrying capacity of the habitat and the social carrying capacity, the deer population density that is socially acceptable in a particular region or locality within current management units (MDC 2014). However, is this management plan 1) affective at maintaining desired population levels and 2) correct for maintaining healthy deer populations? It is interesting to consider Schmitz and Sinclair's (1997) suggestion that "deer overabundance is only of concern when populations approach environmental carrying capacity and potentially degrade habitat via over browsing" (quoted in Wolverton 2007:85). However, I argue that a decrease in mean body size is of concern and can only be mitigated through reevaluating current management goals.

To date, Missouri white-tailed deer management is determined on a unit basis where a unit consists of a single county or an aggregate of counties within urban areas of the state (MDC 2014). Recreational hunting is currently the only method of managing deer population densities. Current management objectives outline continued annual assessments and monitoring deer populations in management units, and advocate keeping hunter satisfaction and public safety concerns in mind (MDC 2014). In addition, high fences and food plots are used throughout Missouri as management tools but the ethics and effectiveness of each are questioned (Diefenbach and Shea 2011; Johnson and Dancak 1993). In light of management objectives in Missouri that are known to the public, I suggest that alternatives practices should be considered.

I propose that deer management open houses currently being held throughout the state should not just center around what deer hunters wish to change about current hunting regulations but should also engage the public's opinion on the current condition of Missouri deer herds. For example, would deer hunters be more interested in larger individual deer or larger deer herds? With larger individual deer the population density would need to be kept at a lower density, which would increase the amount of forage available to each deer and would produce larger individuals for hunting season. If larger deer herds are preferred by the public, then populations should be maintained so that the probability of a wildlife encounter for both enthusiasts and hunters is high, but at the cost of smaller adult deer. Despite the outcome, polling interest groups within the community is an excellent place to gather insight into how future management should change and should continue with deer size in mind.

Lastly, if current white-tailed deer populations are stunted due to overpopulation or if the number of deer harvested per season continues to decrease in relation to the annual decrease in deer hunters, alternative population control measures such as birth control or culling (Schröder et al. 2009) may need to be considered despite many ethical concerns associated with each method (see Rolston 1988). DeYoung (2011) suggests that managers tend to overlook the fact that deer populations that are kept near or are approaching the habitat's ecological carrying capacity are miserable and experience no population growth because of high mortality and low fecundity. Ethical debates aside, future management should focus on optimizing the health of deer populations and public satisfaction, and be based on scientific data collected from all avenues of knowledge that provide insight into the past, present, and future of both the species and its management. One such area of knowledge is paleozoology.

Unlike conservation biologists, paleozoologists thrive when working with processes that operate within geological time-scales and recognize when investigation into these time-depths is warranted. Biologists and wildlife managers study living populations and collect data that may enable them to manage species to the best of their ability within their current environment, without regard for how these organisms or systems operated in the past. Yet, many of the processes of interest for conservation do not operate within the time-scale of a single human lifespan, but within several if not tens or even hundreds of human generations. Most wildlife managers accept the notion that humans have been modifying their environments since prehistoric times and yet current investigation into human impacts on the environment only cover the historical record, which is often incomplete and does not offer a complete or thorough history of natural processes and the history of species that many management issues address. Often, paleozoological data can provide these details (Lyman and Cannon 2004). I agree with Lyman and Cannon (2004:11) that, “The pathway to useful synergy is indicated by the blinders of each [conservation biology and archaeology].” This simply means it is within the best interest of conservation biology and wildlife management to acquire data not only from our recorded history but also the evolutionary and ecological history of the species or ecosystems we seek to manage and conserve.

APPENDIX 1: Morphometric Data for Prehistoric White-tailed Deer

Data in this appendix relate to material covered in Chapter 3. All white-tailed deer specimens included in the analysis were recovered from archaeological excavations of Helmreich Shelter (234CP40) during 1957-1962 (Greer 1992). The author identified all faunal remains recovered from Helmreich Shelter alongside fellow graduate student Heather Craig but the author recorded all measurements listed. As stated in Chapter 3, all specimens were measured using a pair of steel digital calipers. Measurements listed for each skeletal element are the mean values calculated after three consecutive trials and whose means were combined and correspond to population mean values in Table 3.3. All appendix tables are in the same order in which skeletal specimens have been listed throughout this thesis: metacarpals (Table A1.1), metatarsals (Table A1.2), astragali (Table A1.3), humeri (Table A1.4), radii (Table A1.4), ulnae (Table A1.5), femora (Table A1.6), and tibiae (Table A1.7).

Table A.1.1 Metacarpals

Specimen	Bp	Dp	Bd	Dvm	Side	Excavation Level
47		31.65	19.24		L	2
57		33.21	23.02		L	n/a
2289	27.55	20.2			R	n/a
2290			30.69	20.43	L	n/a
2570			32.98	21.02	R	1-4
3727	27.87	20.93			R	8
3773			33.65	22.01	R	4
3824			26.7	19.64	R	2
3995	30.89				R	2
3997	26.84	19.93			R	2
3955			28.73	19.97	R	2
4279			36.43	23	L	4
4592			33.21	21.61	R	4
4686	27.14	19.3			L	4
5851			30.46	21.37	R	4
6019			28.15	18.95	R	5
6237	31.16	22.6			L	6
6800	29.77	22.16			R	1
7396			32.9	20.86	R	4
7440	29.7	21.22			L	3
8121			32.52	19.65	R	1-2
9002			34.67	23.47	L	3
9699			30.7	20.15	L	n/a
9741	30.73	22.52			L	n/a
10457	29.9	21.71			R	2
11347			29.16		L	5
11355			29.37	20.8	R	n/a
11356			30.35	21.82	R	n/a
11590			29.02	19.32	L	n/a
11853	27.88	20.61			R	n/a
11885			31.63	20.36	R	n/a

Table A1.2 Metatarsals

Specimen	Bd	Dvm	Side	Excavation Level
1357	31.26	22.41	R	3
4448	34.61	23.91	R	5
4591	31.62	22.12	L	4
4856	31.86		L	2
5647	32.37	22.82	R	2
6512/6513*	34.31	22.11	L	4
8608	32.45	21.23	R	6
9297	34.01	19.78	R	1-2
11186	32.54	23.55	R	3
11187	33.23	22.17	R	3

Table A1.3 Astragali

Specimen	Dl	GLl	Glm	Dm	Side	Excavation Level
1110	21.51	36.43	34.48	22.64	R	n/a
1277	25.19	44.79	40.88	25.82	R	5
1703	24.56	43.19	40.76	24.98	R	3
2240	23.5	40.45	38.53	24.34	R	6
2884	22.32	40.64	38.71	23.64	R	1-4
2904	22.31	40.09	36.89	24	L	n/a
2973	22	41.35	39.4	23.78	R	n/a
3067	22.25	39.14	36.74	22.93	L	n/a
3303	20.74	38.8	36.05	21.73	R	2
3549	20.24	37.13	35.4	21.17	L	1-2
3550	23.34	40.91	38.09	23.51	L	1-2
3958	23.58	41.33	39.0		L	2
4342	22.12	41.32	39.6	24.34	L	2
4543	22.56	38.25	35.53	21.12	L	1-2
4857	22.61	40.15	37.01	23.15	L	2
5561	21.89	38.83	36.87	23.83	R	7
5597	21.59	38.77	36.03	22.82	L	2
6652	21.74	40.33	39.37	23.16	L	2
6653	22.25	38.53	35.51	22.5	L	2
6917	23.98	42.05	39.56	23.25	R	4
7267	22.25		37.93	21.81	R	7
7398		37.82	36.24	22.23	L	4
7693	24.64	42.69	39.78	25.03	L	3
7817	22.73	39.71	37.11	21.5	L	5
7900	23.75	43.78	42.09	22.63	R	3

8026	22.57	43.44	39.6	23.31	L	3
8280	23.56	40.99	38.46	23.37	L	4
8302	22.05	37.96		20.77	L	6
8303	24.13	42.04	38.11	23.75	R	6
9077	21.7	37.61			R	1
9221	20.75	38.16	35.88	21.57	R	n/a
9286	21.75	38.84	36.7	24.08	R	1-2
9745	19.93	34.17	34.08	20.57	R	n/a
9780	21.97	40.91	37.79	22.98	R	n/a
10056	22.77	40.32	37.77	23.16	L	6
10116	25.05	44.62	41.42	25.74	R	1-2
10458	21.96	37.98		22.59	R	2
10502	21.55	38.42	35.54	22.03	R	1
10503	21.03	38.12	34.98	21.34	R	1
10663	22.26	40.24	37.41		L	1-2
10838	25.8	46.31	44.19	27.36	R	4
11182	24.59	42.64	39.2	23.8	R	3
11183	23.59	41.68	38.72	23.22	R	3
11583	20.97	35.93	37.33	21.95	L	n/a
11584	22.13	39.81	36.15	22.98	R	n/a
12034	22.02	38.91	36.4	22.27	L	n/a

Table A1.4 Humeri

Specimen	Dp	Bp	Bd	HTC	Side	Excavation Level
173			41.34	21.85	R	6
1393			41.89	24.22	R	3
2255			37.9	20.63	L	5
2802			37.97	20.5	L	n/a
3367			42.61	22.42	R	3
3822			39.05	22.03	L	2
6317			38.58	22.04	L	5
6437				19.95	L	2
7439			44.3	20.4	R	3
8023				23.35	L	3
9642				19.52	R	n/a
9643			39.1	22.37	R	n/a
10349	55.27	39.54			R	3
10929			42.74	22.15	R	2
11123			39.1	21.28	L	3
11124			40.98	21.43	L	3

11125			41.61	21.85	L	3
11126			43.07	21.95	L	3
11127			40.07	22.3	R	3
11129	66.31	52.88			R	3
11341			41.16	21.9	R	n/a
11744			41.1	21.44	R	n/a

Table A1.5 Radii

Specimen	BP	Dp	Bd	Side	Excavation Level
183	40.09	25.41		R	n/a
822	34.61	21.22		L	n/a
1211	32.36	21.17		R	6
1779			33.31	L	2
1780	38.24	22.7		L	2
2628	37.87	22.78		R	7
3369			34.16	L	3
3552	39.72	24.95		L	1-2
3823			34.14	L	2
3991		21.13		L	2
4541	40.57	24.39		R	1-2
4542			28.93	L	1-2
5327	39.31	22.91		L	n/a
5659	39.64			L	3
5660	39.72	22.84		R	3
5783	37.58	20.16		L	6
6315	40.16	23.91		R	5
6443			31.90	L	2
7117			36.22	R	4
7605	38.99	22.59		R	5
7723	39.33	25.03		L	5
7968			36.22	L	3
7969			37.06	R	3
8021	40.42	23.69		R	3
8025	39.69	23.89		L	3
8322	39.05	22.95		L	n/a
9363	33.29	19.66		L	3
9655			35.79	R	n/a
9929	36.41	23.53		R	4
10057			37.77	R	6
10119	33.97	20.69		R	1-2
10244	40.81	23.78		R	3

10988	37.95	24.57		L	3
11121	36.47	22.62		L	3
11528	36.8	22.99		L	n/a
12015	41.7			L	n/a

Table A1.6 Ulnae

Specimen	BPC	LO	Side	Excavation Level
174	22.26	59.32	L	n/a
1461	21.73		L	4
1740		51.16	L	3
3282	20.59	60.26	R	n/a
3394	22.67		R	2
3547	17		R	1-2
3825	22.22		R	2
3856	19.74		R	2
4125	19.35		R	4
4860	17.93		R	2
5273	21.73		R	3
5326	20.93		R	2
5528	22.39		L	1-2
5562	21.56		R	n/a
5570		43.92	R	1-2
6321	21.63		L	5
7045	18.5		L	5
8321	20.9		L	n/a
8380	20.12		R	4
8455	20.47		L	5
9010	20.32		R	3
9053	21.78		R	1
9054	21.35		R	1
10115	20.23		R	1-2
10461	21.22		R	2
11559	22.09		R	n/a
11700	22.39		L	n/a
11888	17.5		L	n/a
12007	19.44		R	n/a

Table A1.7 Femora

Specimen	Bp	DC	Bd	Dlc	Side	Excavation Level
500	65.81	27.18			R	4
1132	64.44	25.7			L	4
4278		26.43			L	4
5897	57.66	25.05			R	4
6316		27.37			R	5
6318				36.01	R	5
10760			48.57		L	4
11122	61.88	26.35			L	3
11184			53.31	34.62	R	3
11185		26.78			L	3

Table A1.7 Tibiae

Specimen	Bp	T3	Bd	Dd	Side	Excavation Level
54			28.24	35.07	R	n/a
120	51.6	28.63			R	4
157			38.13	28.01	L	1
182			34.68	27.06	R	n/a
532			34.99	24.71	R	4
1152			32.61	24.58	L	1
2174	60.67	36.15			L	2
2291			35.36	26.45	L	n/a
2420			38.69	28.05	L	6
3551			34.8	26.48	L	1-2
3829			34.37	24.9	L	2
4248			39.15	27.96	R	4
4338			35.4	25.61	L	2
5073			36.09	25.71	L	2
5749			34.39	25.41	L	2
7090			37.72	27.09	R	1
7441			37.88	28.6	L	3
7652	37.15	26.76			R	1
7765			37.28	26.74	R	5
8235	54.18	36.86			R	7
9298			36.92	26.06	L	1-2
9362			38.2	29.95	L	3
9763			37.4	27.9	R	n/a
9796			31.7	25.33	L	n/a

9930			37.43	26.93	L	3
9932			39.32	28.02	R	3
9955/9956*			37.81	28.31	R	n/a
10114			38.32	28.23	R	1-2
10350			37.31	30.84	L	3
10375			35.15	26.92	L	3
11188	55.18	55.19	34.86		L	3
11346			35.57	26.33	R	n/a

APPENDIX 2: Morphometric Data for Modern White-tailed Deer

Data in this appendix relate to material covered in Chapter 3. All white-tailed deer specimens included in the analysis were from skeletal collections housed at the University of Missouri, University of Kansas, and University of Wyoming. All specimens were measured using a pair of steel digital calipers. Measurements listed for each skeletal element are the mean values calculated after three consecutive trials and whose means were combined and correspond to population mean values in Table 3.2. All appendix tables are listed in the following order: University of Missouri (Table A2.1), University of Kansas (Table A2.2), and University of Wyoming (Table A2.3).

Table A2.1 University of Missouri

Specimen Metacarpals	Bp	Dp	Bd	Dvm	Side	County
1	28.27	22.1			R	Boone
2	26.27	18.47			R	Boone
3	28.5	20.83			R	Boone
4	28.1	19.33			R	Boone
5	27.23	19.73			R	Boone
6	31.9	21.6			R	Boone
7	27.7	19.73			R	Boone
8	31.07	24.67			R	Boone
9	31.87	22.83			R	Boone
10	29.53	21.57			R	Boone
11	28.37	19.67			R	Boone
12	24.9	19.73			R	Boone
13	31.27	22.67			R	Boone
14	26.7	20.33			R	Boone
15	24.17	17.4			R	Boone
16	29.3	21.1			R	Boone
17	25.67	19.03			R	Boone
18	28.77	20.7			R	Boone
19	29.3	21.2			R	Boone
20	27.0	19.6			R	Boone
21	28.0	21.13			R	Boone
22	29.97	21.37			R	Boone
23	30.5	23.33			R	Boone
24	26.53	19.37			R	Boone
25	26.7	20.57			R	Boone
26	24.53	17.67			R	Boone
27	27.57	20.6			R	Boone
28	27.0	23.5			R	Boone
29	29.3	23.47			R	Boone
30	30.57	22.97			R	Boone
31	30.6	22.87			R	Boone
32	30.57	21.7			R	Boone
33	31.7	23.33			R	Boone
71	32.57	24.3	37.1	22.47	R	Boone
75	32.63	23.17	33.97	21.4	R	Boone
76	30.3	22.4	31.53	21.8	R	Boone
77	31.73	22.03	31.7	20.83	R	Boone
78	29.5	21.3	29.3	20.33	R	Boone
79	34.27	24.13	33.83	22.8	R	Boone
80	30.17	22.53	33.63	21.63	R	Boone

81	31.9	23.57	32.9	22.2	R	Boone
82	30.33	22.03	30.9	19.8	R	Boone
86	30.8	21.27	33.9	21.47	R	Boone
87	27.7	20.63	28.3	20.1	R	Boone
88	28.17	21.63	29.17	20.77	R	Boone
90	29.27	21.2	31.0	20.97	R	Boone
91	27.93	19.93	29.8	20.07	R	Boone
92	28.67	20.33	28.37	20.13	R	Boone
93	29.77	22.1	30.8	21.77	R	Boone
94	31.7	23.27	33.1	21.8	R	Boone
95	30.17	21.83	31.5	20.7	R	Boone
99	27.07	19.37	27.67	18.73	R	Boone
780	28.43	19.83	28.43	20.47	R	Boone
787	31.90	24.73	35.73	22.73	R	Boone

Metatarsals

	Bp	Dp	Bd	Dvm	Side	County
27	27.13	27.5			R	Boone
118	27.5	28.57			R	Boone
119	26.27	27.23			R	Boone
120	30.4	29.07			R	Boone
121	27.43	28.8			R	Boone
122	24.93	28.03			R	Boone
123	33.57	29.07			R	Boone
124	26.2	27.53			R	Boone
125	28.03	30.73			R	Boone
126	29.67	29.47			R	Boone
127	27.87	28.47			R	Boone
128	27.13	28.0			R	Boone
129	27.7	28.1			R	Boone
131	27.4	29.5			R	Boone
132	28.9	30.37			R	Boone
133	26.33	29.57			R	Boone
134	29.5	28.23			R	Boone
135	26.43	29.7			R	Boone
136	29.63	30.63			R	Boone
137	30.77	32.77			R	Boone
138	29.17	30.03			R	Boone
139	26.87	28.3			R	Boone
140	26.3	27.3			R	Boone
141	26.6	27.37			R	Boone
142	26.23	28.03			R	Boone
143	24.63	25.13			R	Boone
144	26.63	28.5			R	Boone

145	24.77	25.67			R	Boone
146	24.53	23.3			R	Boone
147	25.27	26.57			R	Boone
148	24.57	27.27			R	Boone
149	23.9	25.9			R	Boone
191	29.03	28.67	32.27	22.87	R	Boone
192	29.67	23.73	34	22.1	R	Boone
193	32.13	33.57	36.17	23.4	R	Boone
194	29.37	30.2	35.1	22.5	R	Boone
195	29.57	29.8	33.33	23.73	R	Boone
196			34.63	22.97	R	Boone
197	24.43	26.2	30.83	20.7	R	Boone
198	26.33	27.87	28.73	21.63	R	Boone
199	27.37	29.2	31.1	22.13	R	Boone
200	26.0	27.8	30.77	21.53	R	Boone
201	27.4	26.2	30.63	22.1	R	Boone
202	26.5	28.5	30.9	20.9	R	Boone
203	29.17	29.93	32.83	22.33	R	Boone
204	29.27	30.27	34.9	21.93	R	Boone
205	28.37	28.8	34.97	22.4	R	Boone
206	28.27	28.83	30.5	20.57	R	Boone
207	29.23	31.7	34.3	23.87	R	Boone
208	29.5	29.0	37.8	22.93	R	Boone
780	27.27	29.37	30.5	22.1	R	Boone

Astragali

	Dl	GLl	Glm	Dm	Side	County
A1	23.3	41.1	38.9	25.77	R	Boone
A2	22.5	39.97	36.97	24.6	R	Boone
A3	21.1	38.87	36.13	23.07	R	Boone
A4	21.07	38.9	34.33	24.0	R	Boone
A5	21.37	38.77	37.27	23.1	R	Boone
A6	22.57	40.67	37.7	24.23	R	Boone
A7	22.6	40.83	37.8	26.37	R	Boone
A8	22.27	40.63	36.63	24.77	R	Boone
A9	23.63	42.5	40.87	25.27	R	Boone
A10	22.77	42.13	39.7	25.73	R	Boone
A11	24.27	44.13	41.27	25.33	R	Boone
A12	24.8	44.8	41.6	27.97	R	Boone
A13	23.27	40.77	38.4	25.83	R	Boone
A14	21.0	39.93	36.6	23.57	R	Boone
A15	23.8	41.5	39.53	24.73	R	Boone
A16	22.5	41.73	39.6	26.13	R	Boone
A17	23.73	41.67	39.63	25.03	R	Boone

A18	20.9	37.8	34.73	21.77	R	Boone
A19	21.2	39.83	37.37	23.73	R	Boone
A20	23.7	42.6	38.43	25.0	R	Boone
A21	23.2	42.57	38.97	26.53	R	Boone
A22	24.3	44.37	39.8	26.67	R	Boone
A23	22.33	40.07	37.9	26.23	R	Boone
A24	20.47	37.53	35.5	22.6	R	Boone
A25	21.87	39.3	36.57	24.9	R	Boone
A26	23.17	42.7	40.1	26.03	R	Boone
A27	21.77	39.4	35.83	25.27	R	Boone
A28	22.4	40.37	38.17	24.53	R	Boone
A29	21.6	40.7	39.27	23.77	R	Boone
A30	22.1	40.6	36.73	24.73	R	Boone
A31	22.9	42.7	39.67	26.43	R	Boone
A32	20.83	38.8	35.2	23.73	R	Boone
A33	21.8	40.87	39.37	25.77	R	Boone
A34	21.83	39.37	36.8	24.73	R	Boone
A35	23.2	41.4	36.93	25.1	R	Boone
A36	23.47	41.23	38.57	25.67	R	Boone
A37	21.5	38.5	35.23	23.97	R	Boone
A38	23.2	40.33	37.0	24.73	R	Boone
A39	23.5	41.53	38.43	25.1	R	Boone
A40	22.03	40.63	37.7	24.0	R	Boone
A41	22.123	38.6	36.3	24.87	R	Boone
A42	23.27	41.8	39.57	27.13	R	Boone
A43	22.6	39.87	37.2	224.83	R	Boone
A44	22.83	41.37	38.87	25.13	R	Boone
670	43.17	23.57	40.3	24.17	R	Boone

Humeri

	Dp	Bp	Bd	HTC	Side	County
27			38.83	21.17	R	
99			36.37	19.63	R	
780	61.73	49.87	42.53	21.23	R	

Radii

	BP	Dp	Bd	Side	County
27	36.33	22.17		R	Boone
99	34.17	20.67		R	Boone
780	37.57			R	Boone
787	42.47		39.57	R	Boone

Ulnae

	BPC	LO	Side	County
27	20.63		R	Boone
100	18.37		R	Boone

Femora

	Bp	DC	Bd	Llc	Side	County
780	57.9	26.03	57.43	31.33	R	Boone
787	69.37	28.0	60.5	36.57	R	Boone

Tibiae

	Bp	T3	Bd	Dd	Side	County
99			31.13	24.93	R	Boone
780			35.57	27.87	R	Boone

Table A2.2 University of Kansas

Specimen Metacarpals	Bp	Dp	Bd	Dvm	Side	County
12111	26.25	19.09	27.23	17.86	R	Leavenworth (Kansas)
143930	27.41	20.58			R	Franklin (Kansas)
146469	33.5	24.35			R	Leavenworth (Kansas)
152539	31.17	22.73			R	Franklin (Kansas)
152540	30.62	24.31	31.87	22.28	R	Mercer (Missouri)
152886	29.89	21.62	33.35	20.43	R	Adair (Missouri)
152887	31.26	22.52	34.06	22.5	R	Adair (Missouri)
161053	29.59	22.84	31.63	20.92	R	Adair (Missouri)

Metatarsals

	Bp	Dp	Bd	Dvm	Side	County
12111	26.25	19.09	27.23	17.86	R	Leavenworth (Kansas)
143930	27.41	20.58			R	Franklin (Kansas)
146469	33.5	24.35			R	Leavenworth (Kansas)
152539	31.17	22.73			R	Franklin (Kansas)
152540	30.62	24.31	31.87	22.28	R	Mercer (Missouri)
152886	29.89	21.62	33.35	20.43	R	Adair (Missouri)
152887	31.26	22.52	34.06	22.5	R	Adair (Missouri)
161053	29.59	22.84	31.63	20.92	R	Adair (Missouri)

Astragali

	Dl	GL1	Glm	Dm	Side	County
12111	19.12	33.59	30.89	21.96	R	Leavenworth (Kansas)
143930	22.1	40.8	38.83	21.68	R	Franklin (Kansas)
146469	24.83	43.57	41.36	25.36	R	Leavenworth (Kansas)

152539	21.64	40.48	37.73	21.79	R	Franklin (Kansas)
152540	23.42	41.93	39.05	24.37	R	Mercer (Missouri)
152886	22.5	44.02	40.9	24.28	R	Adair (Missouri)
152887	23.04	44.47	40.01	24.36	R	Adair (Missouri)
161053	22.16	40.8	38.5	24.25	R	Adair (Missouri)

Humeri

	Dp	Bp	Bd	HTC	Side	County
12111	46.06	34.75	19.01	58.07	R	Leavenworth (Kansas)
143930			37.34	20.44	R	Franklin (Kansas)
146469			41.76	23.76	R	Leavenworth (Kansas)
152539	60.39	43.26	41.56	22.05	R	Franklin (Kansas)
152540	59.52	46.67	43.31	21.92	R	Mercer (Missouri)
152886	56.91	38.11	42.22	22.12	R	Adair (Missouri)
152887	61.95	45.94	42.36	22.48	R	Adair (Missouri)
161053	58.07	44.08	41.17	21.33	R	Adair (Missouri)

Radii

	Bp	Dp	Bd	Side	County
12111	34.95		29.51	R	Leavenworth (Kansas)
143930	35.99	21.12		R	Franklin (Kansas)
146469	39.94	24.11		R	Leavenworth (Kansas)
152539	40.26	23.46	36.81	R	Franklin (Kansas)
152540	40.71		37.22	R	Mercer (Missouri)
152886	39.46		37.01	R	Adair (Missouri)
152887	41.0	22.98	40.9	R	Adair (Missouri)
161053	40.12		35.51	R	Adair (Missouri)

Ulnae

	BPC	LO	Side	County
12111		46.0	R	Leavenworth (Kansas)
143930	20.96		R	Franklin (Kansas)
146469	24.77		R	Leavenworth (Kansas)
152539	22.62	57.96	R	Franklin (Kansas)
152540		63.04	R	Mercer (Missouri)
152886		59.18	R	Adair (Missouri)
152887	22.43	63.85	R	Adair (Missouri)

161053		56.07	R	Adair (Missouri)	

Femora

	Bp	DC	Bd	Llc	Side	County
12111	50.13	21.62	38.88	29.97	R	Leavenworth (Kansas)
152539	59.39	26.19	45.43	35.77	R	Franklin (Kansas)
152540	58.76	28.06	44.95	36.94	R	Leavenworth (Kansas)
152886	60.35	26.17	40.9	36.0	R	Franklin (Kansas)
152887	62.84	28.26	44.43	37.67	R	Mercer (Missouri)
161053	58.87	27.09	41.84	33.94	R	Adair (Missouri)
Tibiae						Adair (Missouri)

	Bp	T3	Bd	Dd	Side	County
12111	50.13	21.62	38.88	29.97	R	Leavenworth (Kansas)
146469			36.99	31.32	R	Franklin (Kansas)
152539	59.39	26.19	45.43	35.77	R	Leavenworth (Kansas)
152540	58.76	28.06	44.95	36.94	R	Franklin (Kansas)
152886	60.35	26.17	40.9	36.0	R	Mercer (Missouri)
152887	62.84	28.26	44.43	37.67	R	Adair (Missouri)
161053	58.87	27.09	41.84	33.94	R	Adair (Missouri)

Table A2.3 University of Wyoming

Specimen

Metacarpals	Bp	Dp	Bd	Dvm	Side	Region
8160B	29.36	20.49	28.73	20.15	R	Black Hills
8242B	27.43	20.34	28.31	19.17	R	Black Hills
8244B	30.71	22.8	32.63	20.58	R	Black Hills
8245B	28.91	22.23	30.04	19.56	R	Black Hills
8273B	30.05	20.69	28.76	20.62	R	Black Hills
8495B	29.18	20.13	30.62	20.43	R	Black Hills
8562B	30.27	2.35			R	Black Hills
8570B	31.25	23.19	33.55	22.39	R	Black Hills
8624B	30.27	21.96	30.62	21.05	R	Black Hills
8754B	27.82	20.68	27.35	19.57	R	Black Hills
8795B	28.05	20.47	26.96	19.71	R	Black Hills
8868B	28.7	21.08	30.38	20.16	R	Black Hills

Metatarsals

	Bp	Dp	Bd	Dvm	Side	Region
8067B	25.16	29.41	33.17	21.94	R	Black Hills
8160B	27.43	29.67	31.46	22.19	R	Black Hills
8160B2	26.86	27.48	30.32	21.78	R	Black Hills
8242B	25.65	25.51	30.46	20.81	R	Black Hills
8244B	29.45	30.43	33.18	22.27	R	Black Hills
8273B			30.25	22.36	R	Black Hills
8495B	27.35	29.24	30.79	21.67	R	Black Hills
8562B	28.78	29.64			R	Black Hills
8570B	29.71	29.32	34.61	23.99	R	Black Hills
8624B	28.57	28.5	32.18	22.64	R	Black Hills
8754B	26.47	26.53	29.22	21.07	R	Black Hills
8795B	24.3	27.15	27.66	21.5	R	Black Hills
8868B	26.35	27.09	30.22	21.85	R	Black Hills
B0308	25.53	24.68	27.47	20.77	R	Black Hills

Astragali

	Dl	GLl	Glm	Dm	Side	Region
8067B	22.06	40.87	38.1	22.1	R	Black Hills
8160B	23.09	41.56	39.88	24.9	R	Black Hills
8242B	23.02	41.31	40.28	25.11	R	Black Hills
8244B	22.96	42.64	39.91	22.67	R	Black Hills
8245B	21.72	38.7	35.96	22	R	Black Hills
8495B	21.88	40.17	37.89	22.92	R	Black Hills
8562B	22.39	40.68	38.24	22.75	R	Black Hills
8642B	23.79	42.51	39.37	24.11	R	Black Hills
8754B	21.59	38.76	36.64	20.86	R	Black Hills
8868B	21.37	38.41	36.61	21.22	R	Black Hills
B0308	21.01	38.31	36.34	21.36	R	Black Hills

Humeri

	Dp	Bp	Bd	HTC	Side	Region
8067B			37.87	20.07	R	Black Hills
8160B	61.52	50.1	42.06	21.55	R	Black Hills
8242B	58.74	49.81	38.48	20.84	R	Black Hills
8244B	61.04	51.64	42.95	22.21	R	Black Hills
8245B			41.35	21.26	R	Black Hills

8273B	53.79	42.62	36.7	19.38	R	Black Hills
8495B	60.17	46.95	39.86	21.66	R	Black Hills
8562B			43.18	22.03	R	Black Hills
8624B	58.56	49.89	39.98	22.2	R	Black Hills
8754B	56.66	44.81	36.95	20.71	R	Black Hills
8795B	52.39	44.62	38.3	20.32	R	Black Hills
8868B	58.05	48.46	38.96	20.78	R	Black Hills
B0308	55.28	46.76	38.62	20.53	R	Black Hills

Radii

	Bp	Dp	Bd	Side	Region
8067B	37.83	21.14	34.55	R	Black Hills
8160B	40.83	23.35	35.83	R	Black Hills
8242B	35.58	19.77	31.48	R	Black Hills
8244B	39.55	24.28	35.76	R	Black Hills
8245B	38.45	22.31	34.38	R	Black Hills
8273B	38.42	22.04		R	Black Hills
8495B	37.15	22.35	35.22	R	Black Hills
8570B	39.19	23.44	37.28	R	Black Hills
8624B	37.74	23.43	32.79	R	Black Hills
8754B	35.52	22.13	31.79	R	Black Hills
8795B	36.81	20.77	31.95	R	Black Hills
8868B	37.34	22.09	34.12	R	Black Hills
B0308	37.35	23.04	33.45	R	Black Hills

Ulnae

	BPC	LO	Side	Region
8160B	21.81	57.01	R	Black Hills
8242B	19.95	48.8	R	Black Hills
8244B	25.13	62.08	R	Black Hills
8245B	22.1	58.41	R	Black Hills
8495B	21.61	58.85	R	Black Hills
8562B	21.67		R	Black Hills
8570B	23.01	56.93	R	Black Hills
8624B	21.78	57.56	R	Black Hills
8754B	21.68	49.22	R	Black Hills
8795B	20.15	48.3	R	Black Hills
8868B	22.92	55.42	R	Black Hills

B0308	19.85	54.35	R	Black Hills

Femora

	Bp	DC	Bd	Llc	Side	Region
8067B	60.08	25.07	38.03	33.65	R	Black Hills
8160B	60.5	24.98	43.91	34.29	R	Black Hills
8242B	58.3	23.67	38.66	30.45	R	Black Hills
8244B	64.86	25.31	44.01	34.23	R	Black Hills
8245B	59.94	24.72	44.11	34.3	R	Black Hills
8273B	61.71	25.13	41.21	32.7	R	Black Hills
8495B	59.37	24.43	44.67	34.15	R	Black Hills
8570B	63.43	25.68	45.45	34.07	R	Black Hills
8624B	60.28	26.52	43.17	35.0	R	Black Hills
8754B	53.28	23.18	37.35	32.28	R	Black Hills
8795B	53.53	24.2	36.26	32.17	R	Black Hills
8868B	57.58	25.48	42.39	32.31	R	Black Hills
B0308	58.0	23.0	40.06	31.69	R	Black Hills

Tibiae

	Bp	T3	Bd	Dd	Side	Region
8067B			34.45	26.52	R	Black Hills
8160B	60.08	38.44	36.03	28.1	R	Black Hills
8242B	55.97	38.0	34.23	26.86	R	Black Hills
8244B	60.99	38.31	38.16	28.17	R	Black Hills
8245B	55.63	33.85	35.95	26.38	R	Black Hills
8273B	554.18	33.03			R	Black Hills
8495B	57.32	35.61	35.84	26.48	R	Black Hills
8562B			36.02	28.26	R	Black Hills
8570B	60.09	37.07	35.15	27.8	R	Black Hills
8624B	58.32	33.58	36.38	27.49	R	Black Hills
8754B	53.69	32.8	33.18	24.71	R	Black Hills
8868B	55.49	33.64	35.07	25.19	R	Black Hills
B0308	53.58	33.02	35.01	25.12	R	Black Hills

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