

ZOOARCHAEOLOGICAL MEASURES OF RESOURCE INTENSIFICATION AND
DEPLETION: EXAMPLES FROM EASTERN NORTH AMERICA

Rexford C. Garniewicz

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Doctoral Committee

Patrick J. Munson

Della C. Cook

October 13, 2005

Greg A. Olyphant

Christopher S. Peebles

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Dedication

This dissertation is dedicated to William Richard Adams, whose devotion and interest in zooarchaeology served as a model for many students, including myself. Born in 1923, Dick began his lifelong interest in animal remains while a student at Indiana University, receiving his undergraduate degree in zoology and his graduate degree in anthropology. His master's thesis (Adams 1949) on animal remains from the Angel site is one of the first extensive faunal reports from the midwestern United States. Dick continued his association with Anthropology department from 1955 to 2002, tirelessly collecting and processing specimens. Over the course of his life he amassed one of the largest collections of comparative skeletons in a university setting.

Yet, it is not merely his accomplishments and dedication, but more his sense of humor and kind nature, which set him apart from many. That his students, and a long list of volunteers, would de-flesh and process carcasses that had passed their peak, stands as testament to his likeable personality. The road-kill cookouts he had at his house, and even 'chewing the fat' in his lab, built a strong sense of friendship among many students and faculty in the department.

Dick fully supported all of my work and gave me space and supplies for processing specimens in his lab asking nothing in return (except that one time I had to pick up a tapir from Detroit in my Chevy Nova). Without his assistance in providing me comparative specimens, facilities for processing new specimens, and the occasional help with specimen identification, I would not have been able to complete much of the work I have done during my time at IU. Dick Adams will always be remembered and appreciated by his many students.

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I would like to acknowledge all the assistance I have received from Patrick Munson over the years. He stimulated my ability to think critically and to come up with practical methodologies for resolving archaeological questions. His emphasis on actualistic studies was essential to my graduate career. During my work with him in the field I learned a great deal about archaeology, interpreting sedimentary sequences, and the value of coring. I appreciate his editing and will forever remember the proper use of the semicolon.

Christopher Peebles provided me with financial and collegial support during my tenure at the Glenn A. Black Laboratory of Archeology. By pulling together a group of specialists at the lab he created an environment where archaeological theory and method meshed. Opportunity to work independently on research and to run summer field projects advanced me professionally. Now that I am off on my own, I recognize how important this interaction was.

The other two members of my committee, Della Cook and Greg Olyphant were equally informing presences. Della, with her infinite knowledge about teeth (as well as other things), caused me to delve into examining the raccoon dentition. I have found that teeth are as interesting as they are complex and I will continue my studies well past this dissertation. Greg Olyphant provided me with the insight of a second discipline, including the proper ways of describing and interpreting soils in the field.

Outside of my committee, Mark Schurr, Bob McCullough, Cheryl Munson, Brian Redmond, Bret Ruby, Diane Warren and Steve Ball all assisted me in my development as an archaeologist and provided support at various stages of this dissertation. Finally, I would like to thank my wife, Amy Locklin, for her help, support, encouragement and understanding throughout the dissertation process.

Rexford C. Garniewicz

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Abstract:

The impact that increased human population size and agricultural intensification had on the prehistoric animal ecology of eastern North America is poorly understood. New methods for examining archaeologically recovered faunal remains permit a more detailed understanding of the interaction between humans and their environment. Techniques for the accurate estimation and comparison of age, size and sex parameters of prehistoric deer and raccoon populations are presented. Measurements include ageing by tooth eruption and wear, estimating deer weight based on osteological measurements of the astragalus, and determining raccoon sex based on canine tooth measurements. Combined examination of the age and size parameters of deer over time indicates that the population density and distribution of deer in the Late Prehistoric period was substantially impacted by human activity. This resource depletion is indicated by a decline in the presence of old individuals and an increase in body size in areas surrounding major Mississippian sites. Deer populations appear stable at distance from these sites and maintain the parameters of age and size seen in the Archaic period. An understanding of this variation over space and time is used to interpret the efficiency of various deer hunting techniques. Examination of the distribution of raccoon remains by sex at archaeological sites demonstrates targeted procurement by Late Prehistoric farmers. Intensified procurement of raccoon is revealed by an increased presence of males over time in archaeological samples, a good indication of deliberate trapping. Intensified procurement may relate to a crop protection effort; stable carbon isotope data from the Angel site suggest that raccoon and squirrel may have consumed sufficient quantities of maize to modify their $d^{13}C$ values

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Chapter 1

Introduction

Local increases in human population density are often associated with the intensified use and cultivation of certain plants. In prehistoric eastern North America, the effect of concentrated agricultural populations on hunting strategies and animal ecology is poorly understood. Views range from the proposal that depleted floodplain resources required annual hunting trips to the uplands to speculation that horticultural activity favored and attracted deer.

Broad scale studies tend to infer changes in population density from shifts in settlement systems or sociopolitical patterns. In most cases these shifts are also linked to significant changes in the subsistence economy. In eastern North America, large-scale and long-term population concentrations require the creation of surplus that is seen with the intensification of maize agriculture (Emerson et al. 2005). For the purposes of this study local population density is inferred from a general increase in site size and intensity of occupation, which appears to be correlated with the intensification of maize farming beginning in the Late Woodland and continuing through the Mississippian.

While several Late Woodland studies in the eastern United States employ resource depletion models (Woodrick 1981; Barfield and Barber 1992), others suggest a focal economy where abundant, high quality faunal resources were consistently available (Cleland 1976). Some Mississippian studies advocate a garden hunting model (Morse and Morse 1983; Muller 1997), which is distinct from both of the Late Woodland explanations.

Similar inconsistencies in interpreting the balance between human populations and animal resources are employed as causal explanations for animal domestication in the Old World. Therefore, zooarchaeological techniques for examining resource depletion have a wider significance. Successful methodology in North America may shed light on events leading up to animal domestication worldwide.

Previous approaches have not correctly identified the appropriate zooarchaeological measures to answer specific questions surrounding resource intensification and depletion. While approaches utilizing summary data on taxonomic diversity or relative abundance may be used to generate hypotheses, these are inadequate for providing the detail needed to examine the complex interaction between humans and the environment. Approaches which are so focused that they only examine a single variable, such as mortality profiles, are unlikely to succeed because there are a number of factors which can produce the observed variation.

The purpose of this dissertation is to collect and examine data using new methodologies to demonstrate changing patterns of animal exploitation through time. Examining the dynamics of animal populations by measuring combinations of variables such as mortality profiles, size estimates and sex distributions of key species is more likely to successfully discriminate the cause of observed variation.

Examination of a single species using several osteological measures in concert permits investigating faunal remains without the restrictions that frequently plague regional analyses. This approach may be applied to assemblages that could not be directly compared due to differences in taphonomy, environment, sample size, or intensity of site occupation. This approach is therefore proposed as a formal way to

examine changing patterns of faunal exploitation in eastern North America and to examine their impact on various species.

Chronology

In terms of broad-scale comparisons, this study divides the Holocene in eastern North America into three major subdivisions, Archaic, Woodland and Late Prehistoric. These subdivisions reflect major changes in the subsistence economy and settlement patterns of prehistoric Native Americans.

Archaic samples are taken to represent groups that are limited in overall population size and maintain residential mobility. Lifeways are primarily hunting and gathering. Toward the end of the Archaic, populations may have been involved in the planting of selected crops but the overall impact of this activity is very limited (Yarnell and Black 1985). Within this study, Archaic samples represent a baseline non-agricultural situation that may be compared to later developments.

Woodland populations exhibit various levels of horticultural activity. Even though the importance of domesticates in Early to Middle Woodland times is controversial (Fritz 1993:40), a combination of settlement patterns and botanical evidence suggests a geographically limited horticultural economy (Smith 1987, 1992). By early Late Woodland, large masses of carbonized seeds provide indisputable evidence for intensified plant utilization (O'Brien 1987:184). A mass of nearly 5 million seeds at the Newbridge site indicates a significant dietary staple (Asch and Asch 1981:287). Settlement patterns indicate increased residential stability and burial mound construction indicates increased territoriality (Charles 1985).

After 1200 ybp, stable carbon isotopes are probably the most accurate measure of maize cultivation. Studies of delta ^{13}C values in human bone collagen demonstrate a rapid expansion of corn production in the Late Woodland (Ambrose 1987). For the purposes of this study, Fort Ancient, Middle Mississippian and some protohistoric groups are considered relatively intensive maize agriculturalists. Although there is some variability in their overall consumption of maize (Schurr 1998), these cultures are combined within the Late Prehistoric heading because of the over-riding significance of their agricultural economy.

Classic Middle Mississippian examples are further subdivided from this group in levels of investigation because the impressive mound centers provide a clear example of intense and stable site occupation, which may be contrasted to contemporary outlying occupations. According to various estimates, large Mississippian sites such as Cahokia may have contained more than 10,000 people (Fowler 1974, Pauketat 1997). The presence of elite social strata (Steponaitis 1986) and the function of Mississippian chiefs in managing agricultural risk through control of prestige goods (Peebles and Kus 1977) indicate some substantial differences from other agricultural groups.

Within many large sites it is likely that maize itself is no longer the primary force in effecting centralization, but that storage, exchange and diversification take a leading role. Thus, while based within an economic system (intensive maize agriculture) they actually depend on an organizational form (chiefdom).

Pauketat (1991, 1994, 1997, 2002) places ideology in a primary role in the development of Cahokia leading to a so called “Big Bang” model that posited an internal mechanism for the rapid centralization of the political economy of the American Bottom.

Estimates of total population density in eastern North America are neither possible nor required for this investigation. Although general trends in decreased mobility and increased regional population size are associated with aggregation in resource-rich major river valleys (O'Brien 1987:181), local population density exhibits considerable fluctuation across time and space. Local population size may be reflected in vertical and horizontal site dimensions and the abundance of structures and storage pits. Unfortunately, duration of occupation and seasonality of site occupation may also influence these features.

Within this study subjectively differentiating broad types of sites, for example village, camp and rockshelter, by their site structure is sufficient. An upland Mississippian hunting camp may exhibit the same local population density as an Early Archaic site, thus they provide good comparable examples when considering the effect of climate vs. local population size. Although quantification of site size is difficult, these subjective measures appear to be effective and make sense for a comparative perspective.

Previous Approaches

Several approaches have been used to investigate prehistoric faunal exploitation outside of the customary site-specific faunal reports, taphonomic, and methodological studies. Some of these studies have focused on examining how archaeofaunas reflect local environments or long-term environmental change. Others have attempted to examine cultural patterns of behavior, including economic decision-making and various hunting strategies

Previous studies are important because they present hypotheses that can be tested with new methods. Examples of environmentally and culturally focused interpretations are examined briefly in the following section and provide the basis for more thorough investigations in the following chapters.

Archaeologists have long looked toward animal remains from archaeological sites as indications of paleoenvironments. Traditionally, species with narrow habitat requirements are used to interpret paleoenvironments and to track environmental continuity or change. These studies are usually descriptive in nature; however, some of the work by Styles (1986) is broader in scope.

Styles examines increasing productivity of aquatic habitats through time. Linking increased representation of aquatic species at archaeological sites to late Pleistocene and Holocene floodplain evolution provides a natural explanation for changing subsistence. This approach follows a longstanding recognition that riparian habitats are an important locus for population increase and culture change (Binford 1968) but places the focus of change on environmental characteristics rather than human behavior.

Increased utilization of fish is also tied to changes in technology as is demonstrated by Yerkes (1980, 1981a, 1981b). The investigation of zooarchaeological indicators for the methods and location of fish capture is taken to its apex in the work of Needs-Howarth (1999). She examines taxonomic abundance, age, size, and season of death of fish remains using a wide variety of techniques to test a number of models of prehistoric fishing. Her extensive investigation of Great Lakes fishing allows the discrimination of angling, spearing, netting and the use of weirs at a number of prehistoric sites. The use of zooarchaeological measures for detailed investigation of

prehistoric fish ecology in her dissertation provides a model for combining measures to investigate prehistoric deer and raccoon ecology in this dissertation.

Proceeding from the recognition that animal populations respond to changes in environment, even within the Holocene, studies of skeletal measurements of various mammals have been used to track environmental change (Purdue 1980). Early work focused on species such as rabbits and squirrels that have demonstrable north to south clinal variation. Purdue's keen interest in ecological parameters has extended into investigating clinal variation in deer size across time and space, associating this variation with changes in climate and regional ecology (Purdue 1991). His basic premise is that environmental variation affecting forage quality is the major control upon deer size. As a result, there is little consideration of the impact prehistoric human populations had on deer ecology.

Culture focused approaches may either examine how groups make rational choices about exploiting their environment, or examine the patterns of behavior they utilize in doing so. Stimulated by Caldwell's (1958) theory of primary forest efficiency, economic approaches have centered on predictions of optimal diet and their comparison to recovered faunal remains (Reidhead 1981; Keene 1981; Hewitt 1983). While optimal foraging models have proven effective in understanding decision making within a fixed environment, they have not been extensively applied to studies of long-term change. Part of this may relate to the choice of variables used in these types of studies. Most applications are heavily focused on theoretical modeling and do not investigate the interactive relationship between humans and their environment. As a result, very little

consideration is given either to the impact of populations on the local environment or to long-term environmental changes.

Various ways of procuring game, often combined within the sphere of hunting, are the most direct expression of the interaction between humans and wild animals. Specifically, these procurement strategies may include various forms of hunting (stalking, ambushing, driving) or different types of trapping (snares, deadfalls, pit traps). The former strategy has been a focus of several studies, but the latter is often disregarded.

A number of investigators have examined white-tailed deer mortality profiles and argued for selective hunting (Elder 1965; Cleland 1966; Smith 1975; Waselkov 1978). These approaches use various levels of ecological data or inference, some of it incorrect. Much of the resulting interpretation was tainted by Western views towards conservation and has now been discredited based on a thorough consideration of methodological and taphonomic factors (Munson 1991). It has been demonstrated that the underrepresentation of young individuals in archaeofaunas is mostly the result of age-mediated taphonomic factors, such as canid ravaging. Further elaboration on the mechanics of preferential destruction of ungulate mandibles is provided in Munson and Garniewicz (2003); however, neither of these last two critical publications provides a practical alternative for interpreting white-tailed deer mortality profiles. This leaves an extensive amount of data without any valid interpretation (see Chapter 3, Table 3.7). One of the major goals of this dissertation is to re-evaluate and interpret these data.

There has been some limited investigation of species other than deer. Of particular interest are studies of raccoon (Hamblin 1973, Smith 1975). Basing interpretations on the paucity of young individuals or the resulting abundance of adults,

both investigators have misinterpreted observed archaeological mortality profiles that differ from the expected distribution of living individuals. Their proposal for selective hunting of raccoon based on prime-dominated mortality profiles are untenable given what we now know about the preferential destruction of juvenile bone in archaeological contexts. Other methodological problems include the use of ageing criteria that are not replicable and the failure to examine non-Middle Mississippian samples for comparative purposes. Recent improvements in methodology and increased sample sizes now permit mortality profiles and other measures of raccoon populations to be interpreted (Garniewicz 2000).

Previous examinations of deer and raccoon hunting are flawed because they try to use mortality profiles to determine hunting strategies. Even without the problems associated with taphonomy, changes in mortality profiles may have multiple causal factors. Theoretical models suggest that both increased harvesting pressure and the effects of environmental stress will increase the percentage of juveniles in a population (Wolverton 2001:42). Thus mortality profiles alone provide insufficient information to discriminate between cultural and environmental factors.

Studies that have examined the interaction between culture and environment have been limited in chronological and geographic scope. Three important works have focused on animal utilization by Woodland or Mississippian societies (Theler 1987; Styles 1981; Smith 1975). Styles has also been the principle investigator of long-term trends in Midwestern faunal exploitation (Styles 1994; Styles et al. 1982; 1984).

Each of these studies has attempted to compare sites based on the entire range of fauna present. While this approach is understandable from a perspective of trying to

utilize all available information, it is problematic in that few site assemblages are directly comparable. Even minor variations in environment, seasonality, preservation or recovery may dramatically alter the overall composition of a faunal assemblage, particularly in relation to the abundance of small animal remains. Thus measures that are all inclusive, such as the Shannon-Weaver diversity index (Reitz and Wing 1999, Oetalaar 1990) or rarefaction analysis (Raup 1975, Styles 1981) are as likely to reflect random site-specific variation as they are to discriminate general patterns of behavior associated with resource depression or intensification.

From the current perspective, each of these cultural studies is methodologically limited. Due to requirements of assemblage comparison, the sites examined are restricted in temporal or geographic scope, which precludes broad-scale diachronic studies. Furthermore, the variety of methodologies does not permit the inclusion of new data to create a broader view; each study is independent and the results cannot be integrated. While understanding patterns of faunal exploitation by some Middle Mississippian populations is interesting and important, the ability to compare and contrast data to understand how exploitation changed from the Archaic and Woodland strategies would be truly informative.

Diachronic change:

Most attempts to look at diachronic change focus on specific sites (e.g. Jenkins 1993; Lippold 1971; Emerson 1979). These reports provide an interesting glimpse at change on a local level, but it is exceedingly difficult to evaluate whether these variations reflect broad scale trends. Site-specific studies are likely to exhibit problems involving

variation in context and size of samples as well as changes in density and duration of site occupation. The presumption that the immediate environment is a constant may also be problematic when considering long-term change.

By combining a number of sites within the lower Illinois River and central Mississippi River valleys, Styles (1994) has demonstrated long-term change in percentage values of broadly defined taxonomic groups. These trends are subjectively linked to environmental change as well as variation in human settlement and mobility strategies. Unfortunately, by compressing fauna into broad taxonomic groups, much of the detail and specificity about how people interact with their environment is lost.

Current diachronic studies may demonstrate the existence of resource depletion or intensification, but they do not indicate how specific animal populations were affected or how people changed their patterns of behavior as a result. Thus they provide us with an abstract measure rather than real detail on prehistoric life.

New directions

Approaches that have attempted to summarize subsistence, let alone examine change through time, become encumbered by both a large quantity of data and an uncertainty as to what these data mean. In addition to the presence of horticulture or agriculture, a large number of variables may affect a faunal assemblage. Taphonomy, site size and duration of occupation, as well as environmental variation on the local and regional levels, may affect faunal assemblages by changing the taxonomic diversity or the abundance and demography of certain species. While all of these factors may be recognized, it is not possible to control all of them following traditional methods of

analyses. Traditional studies focus on identifying all specimens within a sample and comparing the distribution of species in one sample to the distribution of species in another sample. Environmental approaches often focus on a very narrow type of data (e.g. deer size).

What is apparent in the current situation is that the way zooarchaeological data are used to test hypotheses is inadequate. Based on the same variation in mortality profiles, interpretations may range from scarcity models to abundance models, including both non-selective hunting and selective hunting of prime animals. Using the proportional representation of various taxa, for example, resultant interpretations of the data may range from an intrinsic response to environmental change to models of resource depletion. By using measures of size, it is possible to show a correlation with environmental change, but is that a valid explanation for the cause of change?

What previous investigators have failed to realize is that hypotheses focused on either environment or culture can be combined and tested by examining multiple lines of evidence relating to individual species. By combining analyses of mortality profiles with data on size or sex, the actual population characteristics of animal species may be reconstructed and tracked across time and space. Using multiple lines of evidence actually permits the discrimination of environmental change and variation caused by human influences. By combining ecological approaches and examinations of cultural activities such as hunting at a species level, it is possible to provide a view of the dynamic relationship between humans and their environment that is clearer than that which may be seen from a sheer mass of descriptive data.

The simplified approach used here focuses on key species and examines changes in their utilization and population characteristics through time. Such an approach results in a more in-depth study of some species, avoiding some of the pitfalls that plagued earlier investigations. Although not comprehensive of all species present in any assemblage, the resulting detail allows for a greater understanding of the interaction between prehistoric people and key species. This dissertation demonstrates that it is possible to extract the appropriate ecological and cultural data from zooarchaeological specimens and use them to examine long-term changes in animal populations and cultural behavior. It is also anticipated that this methodology may be applied to new geographic areas and novel species.

Overview

This study begins with an examination of techniques for investigating taxonomic diversity. Key concepts include the use of relative abundance measures rather than strict taxonomic diversity measures, the appropriate use of number of identified specimens (NISP) data, and the calculation of exploitation intensity values by using optimal foraging techniques.

At the most basic level of investigation it is possible to demonstrate that proportions of various taxa change through time. White-tailed deer and raccoon are identified as key species that exhibit inverse relative abundance values and may give different indications of resource intensification or depletion. Further calculations on the intensity of exploitation based on deer being the top ranked resource show increased

exploitation levels of several small- to medium-bodied species. This relationship has been clearly demonstrated by Styles (1981, 2000).

The decreased relative abundance of deer and the increase in intensity of raccoon exploitation suggest that these two key species are worthy of further investigation to understand how and why their exploitation changed through time. Previous models examining resource depletion have failed to recognize prey responses to resource depletion. In this study, changes in the population dynamics or behavior of prey species are examined in detail. In addition to a reduction in overall numbers, these populations may also exhibit a change in the distribution of individuals across the landscape, variation in the age or sex of individuals killed, and deviations in characteristics such as body size.

The third chapter begins the examination of white-tailed deer populations in greater detail, to distinguish between the effects of natural environmental change and the effects of human activity. Several authors suggest that changes in size or taxonomic diversity are related to natural environmental variation (Purdue 1991, Styles 1986). The other possibility is that the variation is due to changing patterns of human activity. Whether this anthropogenic change is the same as that proposed in previous studies of mortality profiles (i.e. Elder 1965, Waselkov 1978) will be examined.

As considered in Chapter 3, the ability to distinguish between environmental and cultural factors depends on combining multiple lines of evidence when analyzing faunal remains. While the number of individuals living to old age could be decreased by either environmental degradation or increased hunting intensity, it can be demonstrated that only the latter would result in an increase in body size. An approach utilizing both lines of evidence permits the rejection of one of the two otherwise logical explanations. The

data supplied in this chapter permit future work at any site to consider the remains of white-tailed deer in the context of human exploitation pressure.

The fourth chapter explores how the relationship between people and raccoons has changed through time. Previous approaches that used the same sample to examine raccoon mortality profiles produced conflicting results and interpretations. This appears to be largely the result of methodology that was not replicable. Thus, prior to the examination of additional samples a new methodology for ageing raccoons from dental wear is proposed. Although examining mortality profiles provides some insight, the key to studying raccoon populations turns out to be a simple dental measurement used to discriminate sex. Again, this methodology is easily applied to new samples that may then be combined with previous results.

The fifth chapter integrates information on these key species to explore the concept of "garden hunting" and the economics of deer hunting and raccoon trapping in Late Prehistory. Middle Mississippian techniques of deer hunting are suggested based on evidence of patch depletion surrounding major settlements. In the proximity of villages, solitary hunting was probably the most common practice; however, at distance from villages, in less heavily exploited patches, deer drives likely predominated. Efforts near major villages where deer were depleted focused on more intensive procurement of other species such as raccoons. This intensification is indicated by changes in the mode of procurement from hunting to trapping. Preliminary data on stable carbon isotopes from faunal remains support the additional hypothesis that intensified procurement of raccoon may have also been a directed crop-protection effort.

Chapter 2

Relative Abundance Measures and Exploitation Intensity of Key Species

Introduction

At the most basic level, the costs required to procure, process and utilize animal foods cannot exceed the value that they yield in fulfilling the variety of nutrients required for human existence. While many groups will violate this rule to procure particularly desirable delicacies, these are a minor component of their entire food economy and generally are of limited economic significance. Thus, given some cultural variability, people develop subsistence strategies that efficiently exploit animals in the surrounding environment and this is reflected in zooarchaeological remains.

While hunter-gatherers retain the ability to move to new environments where species abundance fits with their subsistence strategy, sedentary populations permanently alter their environment and subsistence strategies adjust as an expression of a bilateral interaction between culture and environment. This chapter begins the analysis of how culture and environment interact from the Archaic through the Late Prehistoric periods of eastern North America.

It is widely recognized that sedentism carries the risk of over-exploiting wild resources and this is inherently tied to debates about the origin of agriculture. Volumes have been written on the origins of agriculture and its extension into eastern North America, but relatively little of this work has examined the impact of the increased human population density upon the animal ecology of the same area.

Traditionally, to avoid exceeding the carrying capacity of their immediate environment, expanding populations without domestic stock are considered to have limited options. Theoretically hunters may deliberately adjust their activities to avoid killing animals when their populations become over-exploited; however, deliberate conservation involves making choices that result in significant short-term costs for the individuals involved. As a result, conservation ideals rarely act as a motivator for changing strategies of subsistence hunters (Winter 2002:14, Krech 1999), but strategies do change when populations of preferred species are depleted and game animals are encountered with decreasing frequency. Change occurs because people optimize their hunting efficiency by either switching to new prey species or shifting their activities to new locations.

When the exploitation of high ranked species becomes more difficult, animal exploitation is diversified to include a wider variety of animals and this ultimately involves seeking out lower-ranked species. This is the model of resource depletion that is predominantly interpreted at multicomponent sites. Whether the diversity takes the form of utilizing culturally less desirable sources of meat protein or using smaller animals that may involve more work in capture and processing, the overall result is the same. The proportion of highly ranked species declines and the taxonomic diversity of archaeological assemblages generally increases.

Sedentary populations may also use a pattern of logistic mobility by sending a segment of the population to utilize distant, less-heavily exploited areas. Logistic hunting may be followed by processing to remove skeletal elements and to repackage the hides, meat and fat of animals. This type of activity is frequently overlooked at single sites

because it may not be directly reflected in the faunal assemblage. Although the logistic model is not examined with relative abundance measures, it is considered in more detail in the concluding discussion on hunting.

Methodology

Measures of taxonomic diversity such as the Shannon-Weaver (Shannon-Wiener) index may be used to measure the heterogeneity of zooarchaeological samples (Reitz and Wing 1999:105). The more heterogeneous a sample, the greater the proportion of it is presumably composed of low ranked species. The Shannon-Weaver index is calculated according to the equation below:

$$H' = -\sum_{i=1}^s (p_i)(\log p_i)$$

Where:

H' = information content of the sample

p_i = the relative abundance of the i^{th} taxon within the sample

$\log p_i$ = the logarithm of p_i . This can be to the base 2, e, or 10.

s = the number of taxonomic categories

With this measure of diversity, samples with an even distribution of abundance between taxa have a higher diversity than samples with the same number of taxa but with disproportionately high abundances of a few taxa. More taxonomic categories lead to greater diversity values when samples show the same degree of equitability in abundance. Thus, this measure includes both the numbers of species and their relative abundance. Unfortunately it also requires that all species within a community are included in the sample and we know this isn't true in archaeological samples.

The number of species encountered in archaeological assemblages is dependent on the size of the sample. This premise in ecological and paleontological samples is the basis for rarefaction analysis, a measure of species richness. Recognizing that as sample size increases new rare species are added at a decreasing rate, a plot of the number of species against the number of specimens produces a logarithmic curve. This rarefaction curve is widely used by invertebrate paleontologists to correct for variations in species richness due to variation in sample sizes (Raup 1975, Foote 1992). Simply put, rarefaction, through a process of random sampling, reduces all samples to the same size as the smallest sample in the comparison. This allows statistically valid comparison, but at a loss of data. As a compensatory mechanism for comparing samples of varying sizes, rarefaction has also been applied to archaeological samples (Styles 1981:41-45).

In applying rarefaction, or the Shannon-Weaver index, to archaeological samples a significant problem arises. Zooarchaeologists have no real measure of the true individuals present in a sample. In contrast to botanists or zoologists who may count individuals, or in invertebrate paleontology where each specimen represents an individual, zooarchaeologists must estimate the number of individuals present.

Typically zooarchaeologists calculate the number of identified specimens (NISP) where each identifiable fragment of bone is given a count of one. Theoretically, a single individual may then result in hundreds of NISPs. By looking at individual elements, portions of elements, and sometimes age, sex and size criteria, a zooarchaeologist can also determine the minimum number of individuals (MNI) that would be required to produce the recovered sample. Although many people treat this as a true number of individuals, it certainly is not. Use of MNIs is further complicated by sample size

problems and is not an effective measure with small samples (Marshall and Pilgram 1993).

Grayson (1984:152) argues that diversity and heterogeneity indices may not be used on archaeological samples because of the inability to measure true individuals. While this may be true from a theoretical standpoint, in practice it may be possible to cautiously use NISP and MNI data in certain situations.

Given that zooarchaeologists are already working with somewhat questionable measures of individuals, heterogeneity indices might still work given: 1) standardized recovery techniques for all samples, 2) levels of taxonomic identification that are comparable between all analyses, and 3) samples that are unbiased by taphonomic factors. Unfortunately the resulting heterogeneity indices, even when calculated for separate taxa such as birds, reptiles, and fish, show such large variance that differences between sites of the same period are significantly greater than differences between major cultural periods. This problem has not prevented zooarchaeologists working in eastern North America (Oetelaar 1990) or the Old World (Stiner et al. 2000) from using heterogeneity indices.

That this methodology is used despite the recognition that samples fail to meet the prerequisite criteria for comparison and at best produce ambiguous results (Stiner et al. 2000:41) may relate to an ability to produce a simple number for an otherwise complex comparison. Experimentation by the author with these techniques on samples from eastern North America also failed to produce the desired results. Analysis of samples presented in Appendix 1 resulted in greater variability within any time period than between any time period. Problems with taphonomic effects, differential recovery,

environmental variation and differing levels of taxonomic identification appear to be of larger magnitude than any real variation in taxonomic diversity. The use of a single diversity index is judged by the author to be too general to apply to most samples studied.

Instead of measuring the general heterogeneity of samples, the author proposes using a sequence of three measures of increasing specificity to examine changes in species abundance through time. The most general of these is a relative abundance index of mammals based on size classes. This is followed by an examination of relative abundance of key species. Finally these values are converted to an index based on comparison with deer. This conversion, along with corrections for NISP variations, allow for comparisons of actual NISP values from archaeological assemblages to predicted NISP values based on optimal foraging theory.

Relative Abundance Index

An approach that utilizes relative abundance indexes was introduced by Bayham (1979) and has been elaborated on by Ugan and Bright (2001). The method is very basic, computing the ratio of large bodied animals to the sum of large-, medium- and small-bodied animals. This index, as it is used, implies that body size is a proxy measurement for prey rank. Following from this, values close to one in the index indicate relatively high foraging returns; values closer to zero indicate low returns for the amount of effort expended. Applications in the western United States have focused on mammalian species (Ugan and Bright 2001). Given the possibility of major environmental and taphonomic variability in the representation of fish and migratory waterfowl, the focus of work here follows the mammalian model.

The relative abundance index of size is calculated using the following criteria. Small mammals include all mammals up to rabbit size. Medium mammals continue up through medium-sized canids. Large mammals include all mammals wolf-sized or larger. Numerical values are calculated based on the number of identified specimens (NISP).

The relative abundance index of individual species to all mammals may be calculated by dividing the NISP of a species by the total NISP of all mammals. The results tend toward low fractional numbers for all species other than deer. The utility of these numbers is hindered in comparison to modern situations because of the difficulty in calculating the proportion of one species to the proportion of all mammals in a modern ecosystem that is not as clearly bounded as an archaeological faunal assemblage.

Given all practical measures of zooarchaeological and ethnographic data, as well as general agreement between archaeologists, zooarchaeologists and modern hunters, white-tailed deer are the number one ranked prey species in most of eastern North America. Based on the assumption that all populations focused a significant portion of their hunting efforts on the exploitation of white-tailed deer, they form a logical constant to use when comparing values of other species through time. By dividing all species' relative abundance values by the value for deer, results from prehistoric assemblages can be compared to known modern situations.

Optimal Modeling

A ranking of prey species may be produced by examining the intrinsic characteristics of individual species. This process introduces bias by the investigator;

however, the success of ranking may be evaluated by comparing the predicted values to the observed representation in archaeological samples. Through such comparisons specific criteria for ranking may also be evaluated.

Because people do not make choices solely based on the size of animals, the assumption that the relative abundance by size index is an adequate measure of rank may be questioned. Choice of individual prey species is more complex than this assumption; however, modifying the methodology to include all possible variables determining rank is impossible. Some modification to this measure is warranted and a determination was made that the fat content (and therefore caloric value) of various species is probably also significant (Speth and Spielman 1983). It is recognized that this approach using size and fat content does not take into account many of the non-size related costs associated with capture and processing that may vary from species to species.

While nutritional analysis of fat content is not available for all wild species, it is available for some of the most significant. Summary data based on the USDA National Nutrition Database (1999) are presented in Table 2.1. When ranked by amount of fat content per 100g of meat, some medium-sized mammals such as beaver, opossum and raccoon rate very high. One small mammal (muskrat) and a large mammal (bear) also rank in the highest group.

Unfortunately the USDA does not have nutritional data on all wild animals; thus, quantification of some significant species such as woodchuck that have high fat content is unavailable. Seasonal variation in fat content is also significant but not indicated in this table, nor can it be calculated for most mammalian remains recovered from archaeological contexts.

Table 2.1. USDA nutritional data on wild mammals, sorted by increasing fat content.

100g cooked meat	Energy (kcal)	Energy (kj)	Protein (g)	Fat (g)
Moose	134	561	29.3	1.0
Elk	146	611	30.2	1.9
White-tailed deer	158	661	30.2	3.2
Rabbit	173	724	33.0	3.5
Caribou	167	699	29.7	4.4
Squirrel	134	724	30.8	4.7
Beaver	212	887	34.8	7.0
Opossum	221	925	30.2	10.2
Muskrat	234	979	30.1	11.7
Bear	259	1084	32.4	13.4
Raccoon	255	1067	29.2	14.5

By assigning arbitrary values of one through three for large through small mammals and values of one through three for fat values of 15-10g, 10-5g and 5-0g of fat per 100 g sample of cooked meat, the combined effects of size and fat may be calculated. The results are presented in Table 2.2. Using this approach the group containing bear, opossum and raccoon ranks highest, followed by the group composed of white-tailed deer, muskrat, beaver and elk. The group containing rabbit and squirrel ranked lowest.

Table 2.2. Hypothetical ranking of common mammalian species based on size and fat content

Species	Size Rank	Fat Rank	Total Rank
Bear	1	1	2
Opossum	2	1	3
Raccoon	2	1	3
White-tailed deer	1	3	4
Muskrat	3	1	4
Beaver	2	2	4
Elk	1	3	4
Rabbit	3	3	6
Squirrel	3	3	6

While recognizing that the rank of species formulated from these limited data is subjective, the author believes that the grouping of high fat animals (raccoon, opossum, bear, muskrat, beaver) is of significant interest. The group of relatively low fat animals includes both large animals (elk, deer) that we know were highly ranked historically and prehistorically and small animals (rabbits and squirrel) of uncertain rank in prehistoric times.

As discussed previously, NISP is used for all calculation of relative abundance. Unfortunately it is not valid to compare NISP directly to the abundance of individual species (i.e. rank). These comparisons require other derived variables such as the minimum number of individuals (MNI) or meat weight (MW). The latter two techniques have been demonstrated to have some value in site-specific analyses with large sample sizes, but are not good techniques for producing the aggregate data required by this study.

The advantage of MNI and MW is that they allow important dietary reconstruction, but the disadvantage is that they over-estimate the importance of rare occurrences (i.e. when $NISP=MNI$). This over-estimate is related to problems of sample size and is particularly pronounced when MNIs for large mammals are close to NISPs for those mammals.

The relationship between NISP and MNI has been documented by Grayson (1978), Bobrowsky (1982), Marshall and Pilgram (1993) and Needs-Howarth (1995). The general conclusion of these works is that NISP is a more sensitive indicator for comparison between sites that may have varied sample sizes. Unfortunately, some value is lost in using NISP rather than MW. The relative number of bones that are identifiable

(or are commonly identified) varies by general size class and by species. Thus, NISP does not relate directly to actual or relative number of individuals of a species used by the inhabitants of a given site. Because more bones are identified at a specific level for larger animals, NISP comparisons under-represent smaller animals.

Tick Creek, a thoroughly analyzed and extremely large sample studied by Parmalee (1965), serves as an excellent model. At this site, a white-tailed deer NISP of 23,751 results in an MNI of 825, a ratio of 28.9 NISP/MNI for large mammals. In contrast, a raccoon NISP of 1350 results in an MNI of 312, a ratio of 4.3 NISP/MNI for medium mammals. Therefore, NISPs cannot be treated as representing individuals and there must be some correction factor to permit their use in subsistence models.

Recognizing this problem, Munson and Limp (n.d.) started work on a correction factor that may be used to convert between NISP data and MNIs. The rationale behind this factor was that, particularly with small samples and large animals, when one NISP creates one MNI the resultant calculations of meat weight are heavily skewed. More pertinent for this study is their observation that the ratio of NISP to MNI also varies by the size of the animal, and that smaller species have fewer identified specimens per individual. By using sites with relatively large samples they were able to demonstrate distinctive ratios of NISP to MNI for various species. Using NISPs >25 for small species and NISPs >100 for deer, the following correction factors in Table 2.3 were proposed. Sufficient NISP values are not present to predict a correction factor for bear or elk and it is presumed in this study that these factors are similar to deer. Sample sizes for other species such as opossum were also insufficient to calculate a correction factor; however,

in the case of opossum it is not possible to use a similar-sized animal since opossum elements are very distinctive.

Table 2.3. Correction factor (NISP/MNI) for converting NISP to estimated MNI, also used for converting modern yields of individual species to predicted NISP in archaeological assemblages (Munson and Limp n.d.).

Species	Correction factor	SD
Raccoon	5.3	1.07
White-tailed Deer	40.7	16.9
Muskrat	8.6	3.88
Beaver	15.1	2.57
Rabbit	8.9	2.78
Grey Squirrel	8.9	3.26
Fox Squirrel	7.1	1.72
Woodchuck	6.7	2.99

As originally devised, this correction factor was to be used for the comparison of sites with small samples to sites with large samples. By dividing NISP by this correction factor a proxy for MNI is produced that is less dependent on sample size. As used in this study, the correction factor has a greater significance in converting predicted yields of species in modern ecological settings (optimal foraging data) into predicted NISP values (expected representation in zooarchaeological assemblages). Multiplying the expected number of animals in an optimal foraging model (a number of individuals) by this correction factor gives the expected NISP at an archaeological site.

While recognizing that the abundance of species is likely to vary across space and time, general estimates of density and yield of selected species are calculated for the eastern United States following Smith (1975) and Reidhead (1981). As presented in Table 2.4, species such as deer and raccoon are expected to average about 40 individuals

per square mile. Other species such as bear may have considerably less dense populations (0.5 individuals per square mile), while species such as squirrel may have considerably more dense populations (320 individuals per square mile).

Potential offtake of species varies according to their reproductive strategies. Two types of reproductive strategies are defined based on variables present in the equation that defines carrying capacity. Within the equation, $dN / dt = rN \times (K - N) / K$, where:

- d - means a change in
- N - the number of individuals in a population
- t - a unit of time
- r - realized intrinsic rate of population growth
- K - carrying capacity,

the variable r is taken to represent species with relatively high intrinsic rates of population increase and the variable K is taken to represent species with relatively low intrinsic rates of population increase (Raven and Johnson 1995).

Some species have relatively high intrinsic rates of population increase. These r-selected species have high reproductive rates, mature rapidly and are generally short-lived. Although many individuals die before they reproduce, high reproductive rates make up for this mortality. Of particular concern to farmers, most pest species are r-selected. These small, rapid-maturing animals are difficult to extirpate even when this is the goal of harvesting strategies.

Other species may have slower reproductive rates and invest more care into their offspring. These K-selected species are more susceptible to over-harvesting, because the removal of adults from the population may outstrip the ability of the population to replace itself. These populations have adapted to live within the carrying capacity of their environment and depend on stable mortality rates

Even within a balanced ecosystem, r-selected species may have high offtake ratios, and in this study the ratios of several relatively r-selected species are set at 50 percent of the total population. As a result of their reproductive strategy, K-selected species such as deer and bear cannot maintain their population levels when more than 20 percent of the population is removed annually through hunting. With this very generalized model of a 50 percent yield for r-selected species and a 20 percent yield for K-selected species, Table 2.4 provides the number of individuals that may be harvested per square mile per year. These are “actual individuals” and may be converted to expected NISP in archaeological assemblages by multiplying with the correction factor presented in Table 2.3. This provides the predicted NISPs per square mile of territory.

Table 2.4. Optimal foraging data from modern environmental settings converted to expected NISP ratios. Density and potential annual yield from Smith (1975) and Reidhead (1981); correction factor from Munson and Limp (n.d); other variables calculated in this study.

Species	Density mi²	Potential annual yield	Predicted individuals	Correctio n factor	Predicted NISP	Ratio of predicted NISP to NISP deer
Raccoon	40	50%	20.0	5.3	106	0.33
Deer	40	20%	8.0	40.7	326	1.00
Bear	0.5	20%	0.1	40.7	4	0.01
Rabbit	140	50%	70.0	8.9	623	1.91
Squirrel	320	50%	160.0	8.0	1280	3.93

Finally, the predicted NISP may be converted to a value relative to the most highly ranked species. Based on the assumption that deer were always exploited at their maximum potential, all other values can be corrected by dividing by the predicted NISP of deer. The resulting expected NISP ratio that is presented in the last column of Table

2.4 may be compared to NISP ratios from archaeological sites that have been corrected by dividing by the values of deer. The closeness of the expected vs. the predicted value can be used to evaluate previously assigned rank based on archaeological measures of abundance.

Results

A sample of sites from eastern North America was selected based on several criteria, predominantly large sample sizes and comparability of taxonomic levels in the published raw data. These 19 sites are presented in Appendix 1. Mammals from all sites identified to genus level or better provide a sample size of more than 70,000 identified specimens. Because the goal is to utilize methodology that eliminates major variation caused by environment, taphonomy or levels of taxonomic identification, the results are considered representative of trends seen in the archaeofaunas of eastern North America even though the list of sites is neither exhaustive nor unbiased.

Samples are grouped by cultural chronology into Archaic, Woodland and Late Prehistoric samples. Given the data utilized at this stage of analysis, further chronological subdivisions were considered untenable. Species-specific data in following chapters will be the focus of more detailed chronological analysis. Relative abundance indices for the three size categories and three culture-chronological groups are presented in Table 2.5.

There will be little surprise amongst archaeologists that the relative abundance of large mammals decreases through time and that the relative abundance of both medium and small mammals increases. According to the assumptions outlined previously this

indicates a general decrease in foraging efficiency through time. As encounters with large mammals decrease, greater efforts must be focused on acquiring smaller species that likely result in lesser overall return rates. As an exercise, these calculations fit well with formal models of diet breadth, but the results give little detail on how people's subsistence choices change through time. For example, does foraging efficiency decrease due to increased hunting pressures that result from a long-term increase in human population density?

Table 2.5. Relative abundance indices of small, medium and large mammals through time in eastern North America

Taxon	Archaic	Woodland	Late Prehistoric
Large mammals	0.89	0.86	0.73
Medium mammals	0.08	0.10	0.18
Small mammals	0.03	0.04	0.09
Total NISP	14960	33592	22387

Tracking of individual mammalian species through time is more informative and may be linked to rank-based choices by prehistoric populations. When the relative abundance index by species is considered (Table 2.6) overall results are promising. Raccoon and opossum rank at very similar levels based on size and fat content and show similar proportional changes. They remain fairly stable through the Archaic and Woodland and both more than double in abundance in the Late Prehistoric. The range of opossum has increased in the Holocene so their change in abundance may have an alternate explanation (Guilday 1958). Black bear was exploited at very low numbers in the Archaic and Woodland and exhibits a six-fold increase in abundance in the Late Prehistoric. The results for muskrat, beaver and elk are ambiguous, and this may relate

more to environment and availability at the sites studied than to actual trends. White-tailed deer show a minor decline in abundance into the Woodland period and a larger decline into the Late Prehistoric. Rabbits (*Sylvilagus* and *Lepus*) and squirrels (*Sciurus* spp.) show very low levels of exploitation in the Archaic and Woodland and four- to seven-fold increases in the Late Prehistoric

Table 2.6. Relative abundance indices of various species through time based on data in Appendix 1.

Species	Archaic	Woodland	Late Prehistoric
Elk	0.010	0.008	0.017
White-tailed deer	0.874	0.846	0.690
Rabbit	0.011	0.009	0.042
Squirrel	0.009	0.006	0.051
Beaver	0.006	0.023	0.027
Opossum	0.002	0.002	0.007
Muskrat	0.000	0.018	0.004
Bear	0.001	0.004	0.024
Raccoon	0.032	0.029	0.073

While there is the possibility of a wide variety of food preferences, taboos, or ritual disposal of the remains of some species offsite, these effects are hopefully minor for the animals considered here. This caveat does not hold for the only domestic animal in precontact eastern North America, the dog. As Schwartz (1997) demonstrates, the cultural variability in the use and treatment of the dog makes it particularly unsuitable for an analysis of this type.

Opossum, muskrat, beaver and elk do show more erratic variation over time than other species examined. Likely, this results from these species not being ubiquitous in either their geographic or temporal distribution in the eastern United States. In the case

of the opossum, it has an expanding range through the Holocene (Guilday 1958). In the case of muskrat, beaver, and elk, they have habitat requirements which limit their range. Consequently, these are not good species for generalized studies of long-term change. The remaining species or taxonomic groups are fairly ubiquitous and provide good models for further study.

Of these species, those selected as good indicators include raccoon, black bear, white-tailed deer, rabbits and squirrels. Taking the relative abundance data for each species from Table 2.6 and correcting them using the relative abundance of deer (NISP species x/NISP deer) results in a ratio that may be compared to the ratios predicted from optimal foraging data in Table 2.4. Table 2.7 presents the corrected relative abundance of key species.

Table 2.7. Corrected NISP ratios of key species from Table 2.6 using relative abundance of deer as a correction factor.

Species	Hypothetical Rank	Archaic	Woodland	Late Prehistoric
Raccoon	1	0.036	0.034	0.105
Black bear	1	0.001	0.005	0.035
White-tailed deer	2	1.000	1.000	1.000
Rabbits	3	0.013	0.011	0.060
Squirrels	3	0.011	0.007	0.074

These results may be compared to expected NISP ratios based optimal foraging data (Table 2.4). By dividing the actual corrected NISP ratio by the expected optimal foraging NISP ratio, a variable is created that indicates intensity of exploitation ($E_i = \text{corrected NISP species } i / \text{predicted NISP species } i$). Results are presented in Table 2.8. Because data have been previously corrected based on the NISP of deer, the

exploitation of deer is forced by the model to be set at 1.0. The intensity of exploitation of other species may be compared to deer, though it should be mentioned that this comparison does not take into account the preferential survival of large mammal bones that is linked to variables such as bone density and size.

The following trends are apparent in Table 2.8. Deer with its assigned rank of 1 is constant. Bear and raccoon with their high fat rank are intensively exploited in the Late Prehistoric period; bear, with its large body size is represented at 3 times its predicted availability. Rabbit and squirrel show increased exploitation into the Late Prehistoric period compared to earlier samples, but the overall intensity of exploitation is still low compared to their potential.

Table 2.8 Intensity of exploitation [E_i =corrected NISP species i /predicted NISP species i], deer is theoretically set at a constant of 1.

Species	Hypothetical Rank	Archaic	Woodland	Late Prehistoric
Raccoon	1	0.111	0.104	0.323
Bear	1	0.081	0.407	2.849
Deer	2	1.000	1.000	1.000
Rabbit	3	0.007	0.006	0.031
Squirrel	3	0.003	0.002	0.019

The overall results suggest that ranking based on both fat content and size is valid. In the Late Prehistoric period the order of magnitude difference between large and medium high-fat species (0.11) is in accord with the difference between large and small low-fat species (0.03). Because raccoon, rabbit and squirrel elements are much less likely than bear or deer to survive taphonomic effects in archaeological assemblages, their real intensity of exploitation may be even higher than that indicated here.

Discussion:

In terms of uncorrected relative abundance, deer show the most significant overall decrease through time and this partially accounts for the corresponding increase in other species. Even at their lowest relative abundance in the Late Prehistoric they comprise 69 percent of the mammal remains by NISP in the assemblages studied. This certainly supports their continued ranking as the primary prey species in eastern North America. If deer relative abundance declines at archaeological sites through time yet they remain the number one ranked species, the decline should indicate a change in the number of deer available to human hunters. Deer as an example of resource depression is examined in detail in Chapter 3.

The author agrees with the primary placement of deer, yet recognizes that the rank of deer may vary seasonally. Deer are easily hunted in the fall when they are in rut. In season they provide an excellent source of protein and fat, while also providing secondary products such as antler and hides for the production of tools and clothing. However, out of season venison procurement priorities may change. These changes in rank are probably related to changes in the fat content of meat. Although an extreme case, Speth and Spielman (1983) document the protein poisoning associated with eating meat with no fat content.

The journals of Lewis and Clark discuss the lack of fat in deer and other cervids between February and May: "The deer are pore and their flesh by no means as good as that of the Elk which is also poore"(February 18, 1806). "...the Elk I killed this morning, thought it fat, but on examineation found it so lean that we took the tongue marrowbones

and skin only”(May 17, 1805). Lewis and Clark do not discard meat because it is unpalatable, but because consuming it will accelerate starvation.

The narrative of James Smith, who was taken captive and lived among the Caughnewaga, Wiandot and Ottawa in northern Ohio between 1755 and 1759, provides supportive information about the seasonality of hunting (Smith 1799). Based on his record of activities, deer hunting is most frequent between October and December, and bear hunting is most frequent between January and April. While this shift may partially be explained by the behavioral patterns of these two species, the fat content of bear meat is certainly significant during the late winter and early spring, a season typically marked by famine. Unfortunately the procurement of smaller species is not noted in enough detail to determine if other fatty species such as raccoon, woodchuck, and opossums were also sought after during this season.

Most if not all archaeologists and zooarchaeologists would probably rank raccoon as a moderately ranked meat source when compared to deer. This ranking undoubtedly reflects the modern perception that raccoon are a low ranked species and may take into account the relatively small body size of raccoon compared to deer and the amount of effort required to exploit the potential harvest of raccoons. It does not take into account the fact that by weight raccoon have more than four times the fat content of deer and nearly twice the caloric value (Table 2.1)

Noting that raccoon have the highest fat content of the game mammals examined, it is proposed that their ranking amongst prehistoric groups in the eastern United States may be higher than expected based on size alone. Calculations of hunting intensity suggest that raccoon are the most sought after mammal after deer in the Archaic and

Woodland and after deer and bear in the Late Prehistoric. Other factors relating to the conflict between raccoons and agriculturalists may also come into play and these are discussed in Chapter 4.

While deer and raccoon are discussed in more detail later in this dissertation, some other species, including bear, rabbit and squirrel are not. In the case of bear, significant samples did not exist to reconstruct population parameters; in the case of rabbit and squirrel, appropriate zooarchaeological measures were not identified. Therefore, it is appropriate to make a few comments on these species here.

Given the extraordinarily high value for exploitation intensity, bear may have been more common in areas surrounding Late Prehistoric sites than predicted by various models. With the optimal foraging models used here, an exploitation intensity of 2.85 would require an annual culling of 57 percent of the bear population. Because this would rapidly extirpate bear, either the optimal foraging data under-estimate the number of bear available, or prehistoric populations ranged further in the procurement of bear and were likely to transport skeletal elements back to their sites. Because bear are highly exploited relative to deer, deer may also have been less common than predicted by optimal foraging models.

While interpretation of bear remains at archaeological sites has been complicated by concerns related to ceremonialism and culturally biased disposal (Wallace, 1949; Ritchie, 1950), their proportional representation is probably also complicated by hunting technology. Bear were commonly hunted in the winter after going into hibernation because they are "very difficult to hunt when in full control of their senses" (Reidhead 1981:123). Dens were either discovered opportunistically during other winter activities

or by organized parties sent out to look for them. Bear were often driven out of their dens by the use of fire or smoke and shot with arrows upon their exit.

Ethnohistorically, the bow and arrow was the weapon of choice for hunting hibernating bear even after the introduction of firearms. As Perrot reports, the sound of guns was believed to awaken other hibernating bears, so they would exit their dens awake and angry when hunters attempted to smoke them out (Blair 1911:126). It is possible that the expansion in relative abundance of bear in the Late Prehistoric is due to a combination of effects that may include increased ranking of high fat meat, new hunting technology and increased archaeological visibility of late winter-spring site occupations. Exploitation in previous periods may have been resulted in ephemeral surface scatters at temporary camps; the presence of major villages with more significant occupations may increase the likelihood of preservation.

Two other taxonomic groups show both low fat values and small size (rabbits and squirrels), yet these groups also show increases in proportional representation through time. Overall, the intensity of exploitation of these taxa is still much lighter than that seen in raccoon. With these lean species, the author believes that the increases are due to intensified exploitation as a result of decreased availability of higher ranked species. Although not selected for fat, these taxa may have made a significant contribution of meat protein. It is also possible that increased representation of at least one of these species is related to garden hunting, a model proposed in Chapter 5.

The overall low numbers of these small species are undoubtedly related to taphonomic effects (Payne and Munson 1985). However, this does not diminish the ability to track changes in their intensity of their exploitation through time, because all

sites examined in eastern North America appear to be subjected to similar levels of canid ravaging. Thus, models that examine changes through time are less likely to reflect taphonomic biases than models that compare prehistoric situation to modern ones.

Conclusions

In combination, the data presented here suggest that changes in relative abundance through time are partially related to rank. Studies using size as a proxy for rank demonstrate a decrease in relative abundance of large mammals and an increase in relative abundance of medium and small mammals. At a general level this reflects a diversification of resource use that may be related to depression of large, highly ranked species. Other species-specific changes in relative abundance through time may relate to ranking variables other than size.

Studies examining both size and fat content as a measure of rank show that, when controlling for size, animals with a higher percentage of body fat are more heavily exploited in the Late Prehistoric period. Given the continued importance of oily/starchy seeds and particularly nuts even amongst intensive agriculturalists (Bush 2004) the importance of meat with high fat content should not be a surprise. Fat is an important ranking variable in the Late Prehistoric, though its importance may vary over time. As Classen (1985) demonstrates, a great deal of energy was expended processing mussels in the Late Archaic despite their low fat content. The abrupt termination of the shell mound culture helps demonstrate the possibility of a highly visible and dramatic change related

to food preferences. In the case of increased relative abundance of bear, additional factors such as changing procurement strategies may also play a role.

Variables, such as resilience to over-exploitation in certain species, may also play a significant role in changing relative abundance. It is argued in the following chapters that the relatively K-selected white-tailed deer is not resilient to over-exploitation, whereas the relatively r-selected raccoon is resilient. The significant zooarchaeological changes seen in these populations over time provide detailed evidence of the interaction between culture and environment.

Chapter 3

Prehistoric white-tailed deer exploitation

White-tailed Deer Biology

East of the Mississippi River, the white-tailed deer (*Odocoileus virginianus*) is divided into two subspecies: north of the Ohio River *O. v. borealis* occurs, and to the south *O. v. virginianus* predominates. White-tailed deer are a plastic species, and this separation reflects variation in the pelage color, external dimensions, cranial details, and antler tine-size and spread (Baker 1984:14). Of specific interest to this study are external dimensions and other size-related variables.

White-tailed deer fawns weight between 1.8 and 3.6 kilograms at birth. The maximum weight recorded for a dressed-out adult male is 183 kilograms (Minnesota) (Sauer 1984:80). Growth, like total weight depends on range; however, generally deer at 6 months have attained half their adult weight, with 18-month old individuals weighing 70% of an adult more than 30 months of age.

The weight of white-tailed deer exhibits clinal variation, with the heaviest deer living in northern latitudes and the lightest deer living in tropical or insular habitats. The variation in live weight for adult bucks ranges from means of 137 kilograms in Ontario to 23 kilograms in the Florida Keys; mature non-pregnant does weigh between 25% and 40% less than mature bucks (Baker 1984:16).

Prior to the work of Riney (1951) there is a lack of standard terminology for deer teeth; thus, some of the early literature can be confusing, relating to certain teeth as pincers, laterals and corners and referencing the first premolar (Severinghaus 1949:198).

Primitive placental mammalian dentition consists of three incisors, one canine, four premolars and three molars in each demi-mandible. In early artiodactyl evolution, the lower canine became incisiform, while the first premolar took on the form and function of the canine (Loomis 1925). Although some artiodactyls retain a canine-like first premolar (e.g. *Sus* spp.), deer only retain premolars two through four. See Figures 3.1 and 3.2 for current deer tooth terminology.

White-tailed deer fawns are born with four teeth and their remaining deciduous teeth erupt within several weeks. At six months the first molars are erupting and by twelve months they are in occlusion and the second molars are erupting. By 24 months all adult teeth are in place and functioning. Critical to ageing deer in this study are the characteristics of tooth-wear in deer exceeding 2 years. Details of tooth wear are summarized after Severinghaus (1949).

Figure 3.1. Deer mandible with deciduous dentition (6 months)

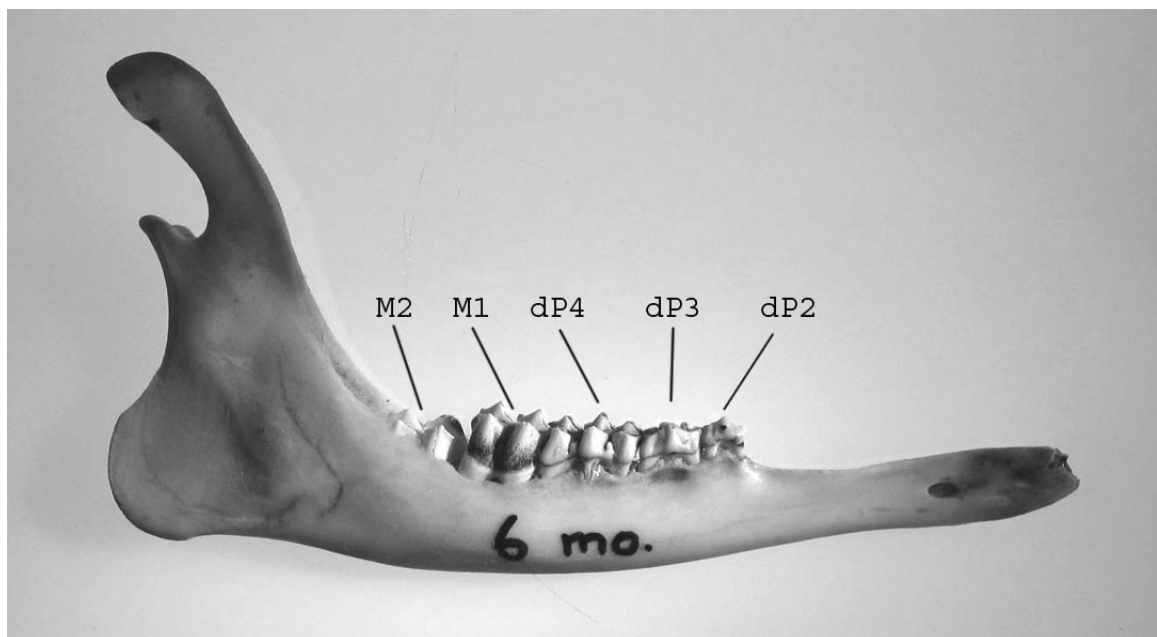


Figure 3.2. Deer mandible with adult dentition (30 months)

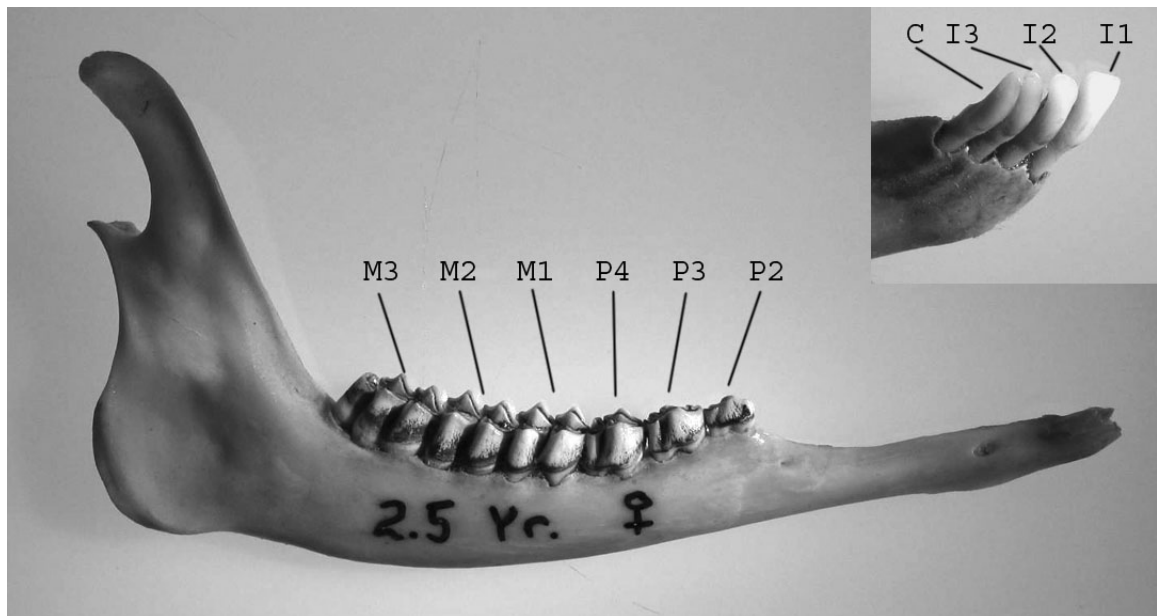


Table 3.1. Tooth eruption in the New York white-tailed deer (Severinghaus 1949). D indicates deciduous teeth, P indicates permanent teeth, () indicate erupting teeth. The lower canine tooth in deer is incisiform, resulting in the appearance of four incisors.

Age	<u>Incisors</u>			<u>Canine</u>	<u>Premolars</u>			<u>Molars</u>		
	1	2	3	1	2	3	4	1	2	3
1 to 3 weeks	(D)	(D)	(D)	(D)	(D)	(D)	(D)			
2 to 3 months	D	D	D	D	D	D	D	(P)		
6 months	P	D	D	D	D	D	D	(P)		
12 months	P	P	P	P	D	D	(P)	P	(P)	
18 months	P	P	P	P	P	(P)	P	P	P	P
24 months	P	P	P	P	P	P	P	P	P	P

Severinghaus records instances of deer living to between 14 and 16 years; however, all of these deer had been captive raised and been fed higher quality softer diets than wild deer. The loss of tooth height above the gum-line in 10 year-old individuals

under a normal diet regime is taken in this study to indicate that potential ecological longevity (PEL) of deer in the wild is 10 years.

Table 3.2. Descriptions of adult white-tailed deer tooth wear based on Severinghaus (1949)

- 2.5 Years - Lingual crests on the first molar sharp with enamel well above the narrow dentine. Wear on the posterior cusp of the third molar is slight.
- 3.5 Years - Lingual crests on the first molar blunt and dentine is wider than the enamel. The posterior cusp of the third molar is flattened by wear and exhibits a concave occlusal surface.
- 4.5 Years - The lingual crests of the first molar were almost worn away and the dentine is twice as wide as the enamel. The posterior cusp of the third molar is worn so that the occlusal surface slopes in the buccal direction.
- 5.5 Years - No lingual crests remain on first and second molars. The flat surface of the tooth slopes in the buccal direction, giving the horizontally rounded lingual edges the appearance of crests, but the original crests have worn away.
- 6.5 Years - At this stage only a small lingual crest remains on the third molar and the third and fourth premolars show heavy wear.
- 7.5 Years - The first molar is worn down to within 3mm of the gum line on the buccal side and within 5 mm on the lingual side; the second molar is worn almost smooth and the lingual crests are worn off the third molar.
- 8.5-9.5 Years - At this stage the infundibulum is worn away on all molars, and the dentine is thus joined. All cheek teeth are reduced to within 3 mm on the buccal side and 5 mm on the lingual side.
- 10.5 Years - Wear continues from the previous subclass, with teeth worn to the gum line. In some specimens dentine is worn through exposing the pulp cavity.

White-tailed deer have a compound stomach that permits them to utilize lower quality foods that are digested by microbial symbionts in the rumen and reticulum. Deer are not as effective as cattle at utilizing woody materials and have difficulty surviving on an exclusively woody browse (Verme and Ullrey 1984:111). Despite their classification as browsers, some have suggested that they could be considered true grazers, consuming grasses, sedges, fruits, nuts, forbs and mushrooms, as well as portions of shrubs and trees (Nagy et al. 1967).

Deer are selective feeders and will smell and taste food to discriminate plants and plant parts. As captive and wild individuals select different forage under the same conditions, it is likely that some preferences may be transmitted by imitation from one generation to the next. However these food choices are made, they are generally successful in terms of survival even under adverse conditions. During periods of scarcity, deer will utilize any food available. This often results in consumption of woody browse during the winter in northern climates. At the northern limits of their range and in overpopulated areas deer do die of winter starvation (Verme and Ullrey 1984:112-115).

Whether deer attain maximum body size is dependent on the availability of browse during their first two years of growth. At carrying capacity, deer population density is limited by the availability of food, and a segment of the population generally starves over the course of the winter. In most instances deer populations are not at carrying capacity, either because populations are controlled by natural predators (wolves, mountain lions, coyotes) or they are reduced in number by human hunting. In the few modern instances where natural predation and human hunting both have been eliminated, dense deer populations tend to out-compete other species for food. Deer in these dense populations are also in strict competition with each other for food and young individuals tend to be undernourished. As a result, average size of the deer in these populations is dramatically reduced, resulting in deer populations with diminutive individuals and low mean body weights.

The relationship between the number of deer and the available forage may be altered by a change in deer population density or an alteration in the quantity or quality of

available forage. Low numbers of deer relative to the food supply, and hence large individual size, may be the result of a reduction in population or an increase in available forage. A decrease in deer size may be the result of an increase in the number of deer or a decrease in available forage.

The George Reserve deer population in southern Michigan has been extensively studied since 1928. In regards to record buck production [antler weight is highly correlated with body weight according to the following formula: $\text{body weight (kg)} = -1695.5 + 28.8 * \text{antler weight (g)}$, $r^2 = 0.57$ (McCullough 1984)] no example demonstrates the deer density - size - age relationship in a clearer format. McCullough states:

Record bucks were produced not at high densities, which have the oldest individuals, but rather at the lowest densities. The largest buck ever taken and the next largest were taken in 1971 when the total buck harvest was 37.... The highest proportion of bucks weighing more than 90.5 kg was obtained at lowest densities.... This occurred despite these periods of heavy harvest having the youngest age structure in both the population and the kill. The record buck was five years old and the next largest was three years old. No buck taken in 1971-1975 or 1980-81 exceeded five years of age and most were yearlings, two and three-year-olds (McCullough 1984:234).

McCullough also demonstrates from a population of black-tailed deer in California that deer density is a far more important variable controlling productivity than all other variables combined (McCullough 1984:232). These other variables include predation by coyotes and other predators, poaching, drought and variation in mast crops. It is important to point out that the geographical area studied (Hopland Field Station) exhibits a substantial variation in climate, with mild wet winters and hot dry summers. These studies by McCullough demonstrate that two different species of deer from populations in

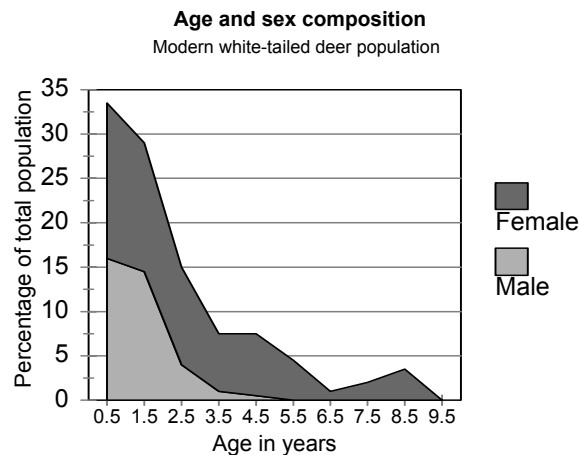
widely different ecological situations (Michigan, California) exhibit the same relationship between deer density and size.

Two examples of an opposing relationship between deer density and size are presented by Klein (1985). He notes that the response to hunting is opposite to the pattern of increased body size that has been observed after reduction of deer densities through hunting among North American deer (Klein 1970). Both of these examples occur outside the United States (roe deer in Denmark and red deer in New Zealand). Crucial to the case in New Zealand is that hunting was continuous (not seasonal) and therefore excluded deer from areas without sufficient escape cover and restricted the surviving deer to dense forests with heavy cover. It is very likely that what occurs in these situations is that while overall density decreases, the relative density in marginal environments (heavy cover) actually increases. In the New Zealand situation deer were reluctant to forage in open areas as a result of hunting pressure and their functional range was thus restricted.

Although wildlife biologists have noted that shifts in hunting strategies, trapping techniques and patterns of hunter choice may all affect mortality profiles, they do not do so in the way many archaeologists presume. Changed intensities of hunting do not change the relative representation of young age classes. In unregulated hunting the largest number of kills is always in the 0-1 year age class, followed by the 1-2 year age class, etc. in descending order. What changes in heavily hunted populations is not the large number of young but the small number of old individuals. In most modern “bucks only” hunting situations it is unusual for a male to live past 4 years of age. In the same population there are comparatively large numbers of females exceeding this age and

continuing to live up to 9+ years. This variation in mortality is best demonstrated in Figure 3.3, based on data from Dusek et al. (1983).

Figure 3.3. A stacked area graph showing the age and sex distribution of an actual modern white-tailed deer population. The female mortality curve is one only slightly affected by hunting (poaching) while the male mortality curve is strongly affected by hunting. Based on data from Dusek et al. (1989).

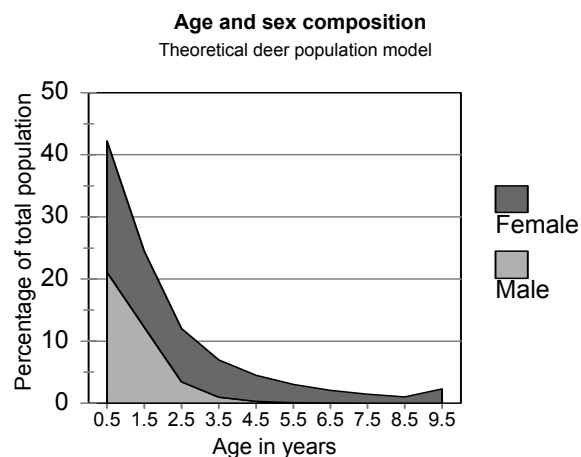


Although the selective hunting of prime individuals has been proposed as an explanation of prehistoric mortality profiles, this strategy would not noticeably affect the density of deer or their available forage. The only shift in mortality profiles that creates a shift in available forage is a reduction in deer density through intensive hunting (or trapping). There is dramatic evidence presented in numerous modern wildlife biology studies (frequently through the comparison of heavily hunted males to weakly hunted females) that hunting reduces the number of individuals living to old age.

Figures 3.3 and 3.4 demonstrate that increased hunting pressure results in a steepened mortality profiles. This is demonstrated by an actual study of deer subjected to different hunting regimes (Dusek et al. 1989) and by a theoretical model produced by

Eberhardt (1969). In his study annual survival rates of male and female fawns is 0.58; thereafter, female survival rate is 0.70 and male survival rate is 0.28 (survival rates calculated on the basis of actual survival of deer in Michigan's Lower Peninsula subjected to bucks-only hunting).

Figure 3.4. A stacked area graph showing the age and sex distribution of a theoretical white-tailed deer population where males are subjected to heavy hunting and females are not subject to hunting. Based on data from Eberhardt (1969) modified to cap life expectancy at 10 years.



Based on these observations from modern wildlife studies, all previous archaeological interpretations of deer hunting based on the age composition of deer kills are inherently flawed. The premise of this study is that prehistoric deer kills reflect the natural composition of deer populations and that variation in the number of young individuals reflects age-mediated taphonomic changes to the assemblage. The appropriate methodology for answering questions about changed intensities of hunting, as well as for investigating hunting strategies, would be to look at the relative representation

of older individuals and compare this to body size estimates. By combining these data it is possible to examine deer population density.

Methods

Given the above-observed variation in mortality profiles and size of modern white-tailed deer, specific measures were identified to track this variation in prehistoric populations. In attempting to unravel the relationship between prehistoric hunters and their prey, the most critical factor is deer population density. Although deer density cannot be directly measured for prehistoric cases it can be tracked by examining the relationship between deer mortality profiles and deer size.

Deer Mortality Profiles

A variety of techniques can be used to determine age of white-tailed deer. These include epiphyseal fusion (Purdue 1983b), cementum annuli (Gilbert 1966), crown height measurements (Walker 2000), and tooth eruption and wear (Severinghaus 1949). Each of these techniques has advantages and disadvantages. In small samples, the epiphyseal fusion technique frequently provides a larger number of specimens than dental or mandibular ageing; however, this technique cannot provide ages past 3 years, when fusion for all elements is complete. In samples with complete recovery, techniques that use individual teeth, such as cementum annuli studies and crown height measurements, are less biased against young individuals (Munson and Garniewicz 2003). Unfortunately annuli studies are destructive and can be difficult to apply to archaeological materials. Crown height measurements provide an objective technique for determining age;

however, some studies of known-age samples demonstrate accuracy that is no greater than that of traditional eruption and wear studies (Walker 2000). Interestingly, Severinghaus (1949) published detailed crown height measurements on his sample but found that wear stages were more accurate because of individual variation in tooth size.

In the present study deer are aged by tooth eruption and wear using the criteria described by Severinghaus (1949) in combination with a modern reference sample. At the start of this project the technique chosen for ageing deer was tooth eruption and wear. This technique allows for fairly rapid and accurate assessment of archaeological specimens, it is non-destructive, and it is the most widely used (and published) technique for ageing prehistoric material from eastern North America.

A separate taphonomic study conducted during this dissertation (Munson and Garniewicz 2003) indicated that mandibles exhibited substantially more destruction by various taphonomic forces when compared to individual teeth. Even considering this recent work on survivorship, if this study were repeated, I would still use tooth eruption and wear for a number of reasons. This technique permits the use of previously published data from sites where faunal materials are no longer available for research. Many of the large collections available for analysis were collected prior to the widespread use of 1/4 inch screening. Thus, the representation of individual teeth may be even more biased than that of the mandibles.

The study by Munson and Garniewicz defined ageable demi-mandibles as “fragments with any two or more teeth in place” (Munson and Garniewicz 2003:405). To the author’s knowledge, no other archaeological study of white-tailed deer mandibular ages identifies specimen completeness, making this variable difficult to control. Many

authors state that they used ‘relatively complete mandibles’; however, the exact meaning of this statement is unclear. When a sample of mandibles from Tick Creek rockshelter (Parmalee 1965:27) was reanalyzed, some of the specimens that had been aged by Parmalee contained no teeth at all. These were ageable based on the presence of tooth crypts indicating a certain stage of eruption and the rami of the mandibles themselves were nearly complete, they just didn’t have any teeth. Given the apparent variation in completeness of previously analyzed samples, the author decided to include all reliably ageable mandibles in the samples used in this study regardless of completeness. The relative completeness of each mandible studied is presented in Appendix 2 for future reference.

Replicability of ageing by tooth eruption and wear by experienced wildlife biologists has been shown to be less accurate than analysis of cementum annuli counts. A study by Hamlin et al. (2000) shows 42.9% accuracy based on eruption and wear and 85% accuracy based on cementum annuli when known age individuals were examined. Part of this variability is explained by the cementum annuli ages being performed by a single individual (Dr. Gary Matson) who has extensive experience and runs the only commercial wildlife ageing laboratory in the United States; this is compared to the results of six wildlife biologists, with comparatively less experience, ageing deer in the field under check-station conditions. Another serious problem may be that starting in the second edition of the Wildlife Techniques Manual (Mosby 1963) and continuing until 1994, tooth wear drawings are marked improperly (lingual and buccal crests are confused). This is critical in that Severinghaus uses the width of dentine vs. enamel on these crests to differentiate age classes. Using the Wildlife Techniques Manual rather

than Severinghaus' original 1949 publication would result in ageing 4 ½ year olds as 3 ½ year olds and ageing 3 ½ year olds as 2 ½ year olds. Finally, studies of deer in the field under check-station conditions would be expected to be less reliable than studies using the same ageing criteria for excised jaws (or archaeologically recovered mandibles) in a laboratory situation.

Most errors presented in Hamlin et al. (2000) for old individuals are misassignments by one or two years, so grouping data into larger than one-year age classes should eliminate some of the variability. Based on these data and associated problems in criteria and investigator variability there is a reasonable expectation that there will be some variation in how zooarchaeologists age mandibles by eruption and wear. These problems are further complicated by the fact that deer feeding on different quality browse and on varying soil types will also have different rates of tooth wear (Gilbert and Stolt 1970).

As indicated in the introduction, taphonomy is a significant problem in interpreting white-tailed deer mortality profiles. Although often ignored by modern researchers, the taphonomic problem has been recognized by some for more than a century. This taphonomic problem was first noted by Steenstrup (1855) who then conducted actualistic experiments, feeding bird bones to dogs and examining the results (Steenstrup 1862). This preferential destruction of bones was also noted at investigations of shell middens in the United States (Wyman 1868:577, Eaton 1898:147); the effect of canid ravaging on juvenile specimens is specifically mentioned by Morlot (1861:300).

This taphonomic problem is discussed in detail by Munson and Garniewicz (2003) and only the basic points will be covered here. Based on actualistic studies, canid

ravaging results in a dramatic lowering of the representation of young individuals.

Mandibles generally exhibit higher levels of destruction than individual teeth; however, survivorship of ageable mandibles approaches 100% by 18 months for raw specimens and 90% by 24 months for cooked specimens. Individual teeth from deer greater than 18 months of age appear to be relatively unaffected. Although various correction factors are possible, these depend on whether the specimens were raw or cooked and whether the investigators used individual teeth as well as relatively complete mandibular rami (2 or more teeth); these variables are unknown in most of the prehistoric samples considered.

Due to problems associated with the preservation of mandibles from young individuals this study considers only the relative representation of various adult age-classes. Although original data are presented with all age classes present, specimens under 24 months of age are eliminated from analyses that focus on older age classes. This not only eliminates taphonomic problems, but also shifts the focus to the age classes that are most severely affected by changes in the intensity of exploitation.

Some preliminary analyses examined deer aged three to six years and six to nine plus years. These results are presented briefly in Figure 3.6; however, the consideration of age classes shifted to 20-40%, 40-60% and 60-80% of potential ecological longevity (PEL) later in the study. These PEL categories provide a more standardized grouping of data that is comparable to other ongoing work. These three groups are essentially 2-4 year olds, 4-6 year olds and 6-8 year olds; thus this grouping effectively removes the taphonomically questionable individuals under 24 months of age and also eliminates the individuals who are older than 8 years. This old adult group may be important; however,

it is seriously affected by sample size problems since the number of individuals in these older age groups is such a small percentage of any real population.

Size estimates

The first attempt to look at relative size of deer by comparison of osteological measurements was by Guilday et al. (1962). They measured astragalus length of the sample from the Eschelman site and went on to state how interesting it would be if other researchers measured their samples for comparative purposes. To my knowledge not a single zooarchaeologist has ever mentioned or responded to Guilday et al.'s work. Emerson (1978), apparently independent of Guilday et al., also suggested that deer weight could be accurately predicted from the maximum length measurement of the astragalus.

Unfortunately, in the zooarchaeological literature from eastern North America, and contrary to European studies, osteological measurements on species other than domestic dogs are extremely rare. Only two investigators (Emerson 1980; 1978; Purdue 1991, 1989, 1987, 1986, 1983a) have calculated deer size from osteological measures. The original single measurement estimator as defined by Emerson (1978) has been redefined and refined by Purdue (1986).

Purdue (1986) considers a battery of six measurements taken with hand-held calipers to more accurately discriminate subtle differences in size and shape. Purdue took measurements to the nearest 0.01 mm; however, I was unable to attain replicability at this level of measurement with repeated trials and suspect that measurements to the nearest

0.1 mm are sufficient. This study employed the same 6 measurements used by Purdue (1986). These measurements are indicated in Figure 3.5.

Figure 3.5 Astragalus measurements

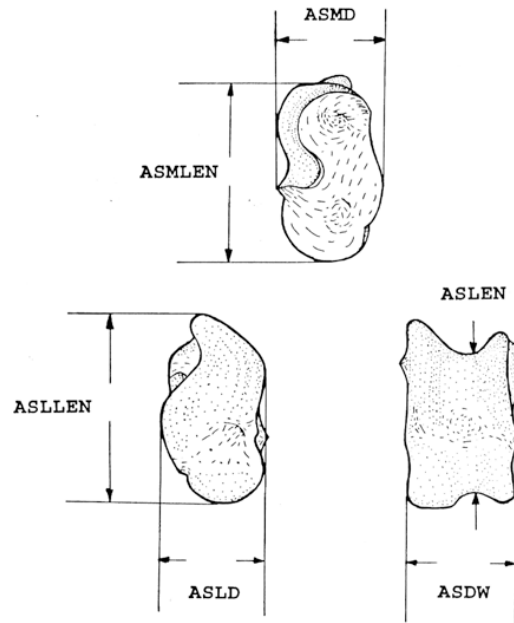


Table 3.3. Key to astragalus measurements

ASMD = Astragalus medial depth
 ASMLEN = Astragalus medial length
 ASLD = Astragalus lateral depth
 ASLLEN = Astragalus lateral length
 ASDW = Astragalus distal width
 ASLEN = Astragalus minimum length

Measurements taken according to Purdue can be converted for the purpose of comparison with Emerson's estimates. A regression of Purdue's astragalus lateral length against Emerson's maximum length reveals a high correlation ($r^2=.89$), with Emerson's maximum length equal to Purdue's lateral length times 0.941. Purdue's estimator is much more accurate and all future measurements should be taken according to his methodology (Purdue 1986).

When only 5 out of 6 measurements were possible the remaining value was estimated. I only performed this procedure when my sample size of complete specimens was less than 25. Purdue used a site-specific regression from the other two most highly-correlated values to estimate missing values; although, he specifically states "the astragalus differed between analytical units only by size, not by other proportions" (Purdue 1991:67). I found that astragalus proportions were constant and that site-specific regressions were imprecise when sample size was less than 25 specimens (i.e. when they were necessary) and therefore substituted a multiple linear regression (MLR) on my entire sample. This MLR resulted in the equations presented in Table 3.4 that were used to estimate the missing value from the remaining 5 values of each individual (all measurements in millimeters). It is recommended that future work use these equations for estimating missing values.

Table 3.4. Equations for estimating missing measurements.

$$\begin{aligned} \text{ASMD} &= -1.50 + 0.58 \text{ASLD} + 0.26 \text{ASDW} + 0.12 \text{ASMLLEN} \quad (r^2 = 0.72, \text{SE} = 0.76) \\ \text{ASMLLEN} &= 3.04 + 0.74 \text{ASLEN} + 0.47 \text{ASLD} \quad (r^2 = 0.71, \text{SE} = 1.14) \\ \text{ASLD} &= 1.97 + 0.28 \text{ASLLEN} + 0.20 \text{ASMD} + 0.18 \text{ASDW} \quad (r^2 = 0.84, \text{SE} = 0.45) \\ \text{ASLLEN} &= 2.92 + 0.63 \text{ASLEN} + 0.75 \text{ASLD} \quad (r^2 = 0.88, \text{SE} = 0.71) \\ \text{ASDW} &= 1.26 + 0.74 \text{ASLD} + 0.34 \text{ASMD} \quad (r^2 = 0.69, \text{SE} = 0.85) \\ \text{ASLEN} &= -0.75 + 0.59 \text{ASLLEN} + 0.25 \text{ASMLLEN} \quad (r^2 = 0.85, \text{SE} = 0.71) \end{aligned}$$

More accurate estimates of body weight are possible if the sex of the individual can be determined. Purdue (1986) transformed the measurements into z-scores considering each analytical unit separately. As a result, clinal variation in size (whether this variation is through space or time) does not affect site-specific sex determination. Positive z-scores were then attributed to males, negative z-scores to females. Purdue (1986) then provided a correction factor to eliminate the bias caused by miss-sexed individuals. This correction factor was derived from a sample of 397 deer from six modern populations where sex and body weight were independently known. With this correction factor, estimates of the means, standard deviations, and sample sizes on modern populations “compared favorably with their actual counterparts [population parameters] and, therefore, could be used with confidence” (Purdue 1986:69). Purdue’s correction factors are presented in Table 3.5.

Once the sex is determined the weights of adult deer in the late fall can be estimated by the following regressions:

$$\ln Bw_f = -4.62775 + (0.88870 * ASVO_f),$$

$$\ln Bw_m = -8.13984 + (1.26867 * ASVO_m)$$

Where Bw_f is live body weight in kg for females, Bw_m is live body weight in kg for males, $ASVO_f$ is astragalus volume for females and $ASVO_m$ is astragalus volume for males. Astragalus volume is calculated from caliper measurements using the following equation:

$$ASVO = (ASMD/2)*(ASMLEN/2)*ASDW*B.$$

Table 3.5. Purdue's regressions for converting apparent to corrected statistics.

	Sex	Statistic	Y-intercept	Slope	SE
ASMD	M	Mean	-1.24648	1.04243	0.13
		SD	-0.24752	1.37317	0.13
	F	Mean	-1.15033	1.06346	0.06
		SD	0.25138	0.93032	0.10
ASMLEN	M	Mean	-1.84986	1.03973	0.17
		SD	0.44023	0.83469	0.12
	F	Mean	-1.35830	1.04489	0.16
		SD	0.12806	1.09511	0.11
ASLLEN	M	Mean	-1.76992	1.03515	0.22
		SD	0.75732	0.67082	0.13
	F	Mean	-1.44287	1.04430	0.15
		SD	0.28686	0.93994	0.15
ASDW	M	Mean	-3.20911	1.11269	0.13
		SD	0.49871	0.74566	0.09
	F	Mean	-0.33910	1.02355	0.08
		SD	0.56172	0.61105	0.11
ASLD	M	Mean	-1.13295	1.04166	0.13
		SD	0.56650	0.49630	0.08
	F	Mean	-0.61865	1.03634	0.09
		SD	0.24165	0.84831	0.09
ASLEN	M	Mean	-1.82937	1.04583	0.14
		SD	0.72593	0.60713	0.11
	F	Mean	-1.17797	1.04630	0.10
		SD	0.11804	1.09953	0.08

The equations for the calculation of body weight and astragalus volume are presented by Purdue (1986:72) who determined them from known age and weight individuals in seven modern samples from the midwestern and southeastern U.S. (n=397). Early work by Purdue (1983a, 1991) used principle components analysis of all six measurements rather than body weight for comparative purposes. Based on my data both factor scores and estimated body weights were calculated. Factor scores were then

regressed on body weight and a significant correlation was found. This coefficient of determination was fairly high for males ($r^2 = .71$); however the value for females was lesser ($r^2 = .48$).

To investigate this relationship an analysis of variance (ANOVA) was run between analytical units and body weight. For males and females this proved significant at the $P < 0.01$ and $P < 0.001$ levels respectively. A separate ANOVA was run between the analytic units and all six astragalus measurements. All three of the measurements used to calculate weight were significant ($P < 0.05$); however, two of the remaining measurements were not. This suggests that the measurements that Purdue has chosen to use for calculating weight are well-chosen and that there is some unexplained variation that is represented by the other measurements. This variability also suggests that factor scores of astragalus measurements are *not* a good proxy for body weight.

The goal of Purdue's work was to demonstrate that deer size varied geographically and through time due to variation in environmental conditions, and unfortunately his data presentation is focused on this comparison. He often presents body weight data as factor scores and never presents body weight of males and females by mean and standard deviation. Mean body weights are readily calculated from Purdue's presentation of mean measurements; however, standard deviations of body weight cannot be calculated from the corrected standard deviations of mean measurements.

In the following analyses all comparisons are by body weight rather than using proxy factor scores. This technique provides data that are just as accurate, more appropriate and easily visualized (Factor score +1 or +2 vs. Female body weight of 56.1 kg or 60.2 kg). More importantly these body weight data can be compared across

independent studies in contrast to factor scores that are dependent of the specific array of sites analyzed by an investigator.

Data

This section sets out, in a systematic fashion, both the previously published data and the data generated for this study. Raw data relating to mortality profiles are presented first, followed by raw and corrected data relating to deer size. Statistical comparisons of individual and grouped data are presented in the results section that follows the presentation of data.

Mortality Profiles

Mortality profiles of white-tailed deer are generally presented in one-year increments, with the median for each age class used as a column heading. Thus, deer aged zero to one year are designated 0.5. The presentation of data in this section follows this format; when an original investigator lumped older age classes together (i.e. >7.5 years) the number of individuals in this group was evenly divided amongst the remaining year age classes. Due to the inclusion of some small samples that are useful when summing data by period, raw data are not converted to percentage values. Conversion to percentages would make variation due to small sample sizes less apparent.

Overall, 46 previously published samples of aged deer from archaeological sites in the eastern United States are presented and 8 additional samples of aged deer were generated for this study. All samples are referenced to an original publication in Table 3.4 unless they are newly analyzed samples designated 'This Study'. All samples

examined for this study have detailed analyses of teeth present and ages for each individual mandible in Appendix A. All mortality profiles are listed in Table 3.7 by their abbreviations presented in Table 3.6

Table 3.6 Sites used in the analysis of deer mortality profiles

<u>Abbreviation</u>	<u>Site Name</u>	<u>State</u>	<u>Reference</u>	<u>Culture Period</u>
RH2	Rockhouse Hollow	IN	This Study	Archaic
TC1	Tick Creek	MO	Parmalee 1965	Archaic
BR1	Brogley	WI	Emerson 1979	Archaic
PR1	Preston	WI	Theler 1987	L. Archaic
PR2	Preston	WI	Theler 1987	L. Archaic
CL	Claiborne	MS	Brent Smith 1974	L. Archaic
IK	Indian Knoll	KY	Skaggs 1934	L. Archaic
BR2	Brogley	WI	Emerson 1979	Woodland
TC3	Tick Creek	MO	Parmalee 1965	Woodland
AC	Apple Creek	IL	Parmalee, Paloumpis, and Wilson 1972	Woodland
MI1	Millville	WI	Theler and Pillaert 1983	M. Woodland
MA	Macoupin	IL	Hill 1970	M. Woodland
MI2	Millville	WI	Pillaert 1994	M. Woodland
PR3	Preston	WI	Theler 1987	M. Woodland
MI3	Millville	WI	Pillaert 1969	M. Woodland
CH	Chesser Cave	OH	Prufer 1975	L. Woodland
CO	Conners Midden	VA	Mc Ginnes and Reaves 1957	L. Woodland
MO	Moccasin Bluff	MI	Cleland 1966	L. Woodland
HF	Hales Ford	VA	Waselkov 1978	L. Woodland
BM	Belmont	VA	Waselkov 1978	L. Woodland
PH	Pine Hill	NY	Cottrell 1979	L. Woodland
PR4	Preston	WI	Theler 1987	L. Woodland
BF	Booth Farm	VA	Waselkov 1978	L. Woodland
GV	Graham Village	OH	Cleland and Kearney 1967	Fort Ancient
BL1	Blain Village	OH	Parmalee and Shane 1970	Fort Ancient
BL2	Blain Village	OH	This Study	Fort Ancient
PH	Philo II	OH	Shane and Barber 1976:4	Fort Ancient
BV	Bundy-Voyles	IN	Garniewicz 1997	Oliver
LI1	Lilbourn	MO	Smith 1975	Mississippian
RH1	Rockhouse Hollow	IN	This Study	Mississippian
SN	Snodgrass	MO	Smith 1975	Mississippian
CH	Chucalissa	TN	Smith 1975	Mississippian
LI2	Lilbourn	MO	Waselkov 1974	Mississippian
BA1	Banks	AR	Smith 1975	Mississippian
BA2	Banks	AR	This Study	Mississippian
OR	Orendorf, IL	IL	Emerson, 1981	Mississippian
TU	Turner	MO	Smith 1975	Mississippian
GO	Gooseneck	MO	Smith 1975	Mississippian
LG	Lake George	MI	Belmont 1983	Mississippian
AN	Angel	IN	This Study	Mississippian
CT	Chota-Tanasi	TN	Bogan 1976	Historic
OU1	Ouiatenon	IN	Martin 1986	Historic
SA	Gumbo Point	MO	Elder 1965	Historic
MU	Murphy	IN	This Study	Miss. C-W
BU	Buffalo	WV	Guilday 1971	Historic/F.A.
BR	Brown	MO	Elder 1965	Historic
UV	Utz Village	MO	Elder 1965	Historic
ES	Eschelman	PA	Guilday, Parmalee, and Tanner 1962	Historic
RH	Rhoads	IL	Parmalee and Klippel 1983	Historic
BE2	Bell	WI	This Study	Historic
SH	Shannon	VA	Barber and Baroody	Historic
OU2	Ouiatenon	IN	This Study	Historic
AR	Arnold Research Cave	MO	Elder 1965	Mixed
OB	Ozark Bluff	AR	Cleland 1965	Mixed

Table 3.7. Mortality profiles of white-tailed deer from eastern North America. Sites are referenced in Table 3.4, (N) represents the number of demi-mandibles aged and the designations 0.5 through 9.5 represent the mean of each one-year age class. Note: Original analyses of OR and BR2 combined age classes; these age classes were divided out, resulting in fractional representation in the older age classes

<u>Site</u>	<u>(N)</u>	<u>0.5</u>	<u>1.5</u>	<u>2.5</u>	<u>3.5</u>	<u>4.5</u>	<u>5.5</u>	<u>6.5</u>	<u>7.5</u>	<u>8.5</u>	<u>9.5</u>
RH2	(67)	8	14	12	12	10	3	4	1	0	3
TC1	(212)	35	55	34	25	10	11	13	11	11	7
BR1	(44)	13	7	8	10	3	3	0	0	0	0
PR1	(8)	0	0	1	2	4	0	1	0	0	0
TC2	(191)	43	36	26	25	17	10	12	7	6	9
PR2	(12)	1	1	1	1	1	2	2	2	1	0
CL	(11)	1	0	2	2	1	3	0	1	1	0
IK	(514)	30	60	126	125	65	46	39	10	6	7
BR2	(248)	37	42	64	52	19	17	4.25	4.25	4.25	4.25
TC3	(547)	100	126	88	58	35	39	32	40	13	16
AC	(58)	19	26	2	2	3	2	2	1	0	1
MI1	(20)	3	5	6	3	1	1	1	0	0	0
MA	(21)	2	8	3	3	4	1	0	0	0	0
MI2	(18)	2	10	7	3	1	1	1	0	0	0
PR3	(7)	3	2	0	0	0	1	0	0	1	0
MI3	(24)	2	10	6	3	1	1	1	0	0	0
CH	(33)	6	11	3	8	0	1	1	0	1	2
CO	(12)	3	3	2	0	1	2	1	0	0	0
MO	(56)	10	9	13	5	8	1	5	4	0	1
HF	(25)	8	3	4	3	3	1	1	1	1	0
BM	(17)	4	4	1	2	2	0	1	2	0	1
PH	(58)	3	7	14	9	5	10	7	3	0	0
PR4	(29)	8	4	2	3	4	2	3	1	2	0
BF	(29)	10	7	2	3	2	2	3	0	0	0
GV	(17)	0	4	7	4	1	1	0	0	0	0
BL1	(36)	8	11	2	5	5	2	1	2	0	0
BL2	(55)	9	21	8	7	3	6	0	1	0	0
PH	(20)	6	4	2	2	2	1	1	2	0	0
BV	(43)	7	13	6	8	5	0	2	1	1	0
LI1	(10)	1	2	2	2	1	1	1	0	0	0
RH1	(24)	3	1	10	3	2	2	1	2	0	0
SN	(130)	9	32	32	25	12	7	5	5	3	0
CH	(55)	6	9	11	9	8	6	3	2	1	0
LI2	(26)	4	4	7	4	2	2	1	1	1	0
BA1	(81)	17	14	13	13	10	7	4	3	1	0
BA2	(129)	18	41	27	21	8	6	7	1	0	0
OR	(64)	6	10	15	19	11	0.6	0.6	0.6	0.6	0.6
TU	(20)	0	3	7	5	3	1	0	1	0	0
GO	(8)	0	2	3	1	1	0	1	0	0	0
LG	(28)	9	6	6	2	2	1	1	0	1	0
CT	(73)	6	12	11	22	14	3	2	1	1	2
OU1	(15)	3	2	3	4	2	1	0	0	0	0
OU2	(35)	7	6	5	4	6	3	1	1	1	1
SA	(29)	1	5	13	5	3	1	1	0	0	0
MU	(27)	4	7	5	2	4	4	1	0	0	0
BU	(345)	74	53	25	56	41	41	31	7	10	7
BR	(153)	5	32	35	34	18	11	5	8	5	0
UV	(92)	7	17	20	7	12	11	10	2	1	5
ES	(182)	21	20	31	39	22	20	20	7	0	2
RH	(98)	19	24	17	20	8	3	3	4	0	0
BE2	(19)	4	1	4	7	1	1	1	0	0	0
SH	(30)	6	5	7	3	1	3	1	1	2	1
AR	(95)	4	23	17	10	10	9	12	8	1	1
OB	(94)	5	18	21	17	14	10	2	2	3	2
SB	(19)	2	5	5	1	2	1	1	0	1	1
JN	(15)	2	4	4	2	2	1	0	1	0	0
AN	(38)	4	7	8	5	5	2	3	2	1	1

Size estimates

Purdue presents descriptive statistics on the corrected measurements of astragali; however, these cannot be used to determine the standard deviations of estimated male and female body weights. Without original data available it is not possible to determine statistical significance on direct comparisons of size with previously published sites. However, mean weights of males and females can be calculated from these corrected measurements. The sites examined by Purdue and in this study are presented in Table 3.8 and the resulting corrected measurements are presented in Table 3.9. Mean weights calculated in this study are presented in Table 3.10, and calculated mean weights from corrected measurements are presented in Table 3.11.

For sites examined in this study estimated body weight is calculated for each specimen, so the mean and standard deviation of both male and female body weights may be calculated for each sample. Results are presented in Table 3.10. Since these calculations are not subject to the correction factors for the means of each individual measurement, the results are slightly different than the means in Table 3.11. The advantage of this method is that statistical comparisons of size may be made between individual samples.

Table 3.8. Sites used in the study of white-tailed deer size. Note, sites referenced “this study” have a site reference presented in Appendix 3.

<u>Site</u>	<u>Site name</u>	<u>State</u>	<u>Investigator</u>	<u>Reference</u>	<u>Culture Period</u>
AN	Angel	IN	Garniewicz	This Study	Mississippian
BA	Banks	AR	Garniewicz	Parmalee 1966	Mississippian
BE1	Bell	WI	Purdue	Parmalee 1963	Historic
BE2	Bell	WI	Garniewicz	This Study	Historic
BL	Blain	OH	Garniewicz	This Study	Fort Ancient
BR	Brown	MO	Purdue	Chapman 1982	Historic
CB	Crable	IL	Purdue	Illinois State Museum Site Files	Mississippian
IR	Crane/Loy/Macoupin	IL	Purdue	Illinois State Museum Site Files	Woodland
CR	Crawford Farm	IL	Purdue	Parmalee 1964	Historic
FC	Fort de Chartes	IL	Purdue	Parmalee and Bogan 1980a	Historic
SA	Gumbo Point/Plattner	MO	Purdue	Chapman 1959, Lewis 1979	Historic
HY	Hayes	MO	Purdue	Chapman 1982	Historic
K6	Koster Horizon 6	IL	Purdue	Brown and Vierra 1983	Archaic
K8	Koster Horizon 8	IL	Purdue	Brown and Vierra 1983	Archaic
K11	Koster Horizon 11	IL	Purdue	Brown and Vierra 1983	Archaic
MD1	Modoc 4-5k	IL	Purdue	Styles et al.1983	Archaic
MD2	Modoc 5-6k	IL	Purdue	Styles et al.1983	Archaic
MD3	Modoc 7-8k	IL	Purdue	Styles et al.1983	Archaic
MU	Murphy	IN	Garniewicz	This Study	Mississippian
NW	Noble-Weiting	IL	Purdue	Parmalee and Bogan 1980b	Mississippian
OR	Orendorf	IL	Purdue	Santure 1981	Mississippian
OU1	Ouiatenon	IN	Purdue	Noble 1983	Historic
OU2	Ouiatenon G	IN	Garniewicz	This Study	Historic
PB	Pabst	IL	Purdue	Lewis 1979	Archaic
RH	Rhoads	IL	Purdue	Parmalee and Klippel 1983	Historic
RH1	Rockhouse Hollow	IN	Garniewicz	This Study	Archaic
RH2	Rockhouse Hollow	IN	Garniewicz	This Study	Archaic
TC	Tick Creek	MO	Garniewicz	This Study	Archaic-Woodland
TW	Twenhafel 1-2k	IL	Purdue	Hofman 1980	Woodland
FC	Waterman	IL	Purdue	Parmalee and Bogan 1980a	Historic

Table 3.9. Descriptive statistics for corrected measurements of the astragalus of male white-tailed deer from all studied sites

<u>Site</u>	<u>(N)</u>	<u>Stat.</u>	<u>ASMD</u>	<u>ASMLEN</u>	<u>ASLLEN</u>	<u>ASDW</u>	<u>ASLD</u>	<u>ASLEN</u>
CB	(12)	X	25.68	40.87	43.79	28.41	24.41	35.14
		SD	1.01	1.15	1.50	1.21	0.91	1.12
IR	(32)	X	24.53	40.32	43.18	27.84	24.14	35.13
		SD	1.33	1.53	1.70	1.33	0.95	1.45
CR	(3)	X	26.49	42.91	46.47	29.59	25.84	37.41
		SD	1.61	1.90	1.84	1.83	0.98	1.81
FC	(12)	X	23.23	38.69	41.70	26.61	22.91	33.50
		SD	1.16	1.75	1.84	1.00	0.83	1.54
K6	(34)	X	24.02	38.86	41.88	26.81	23.53	33.85
		SD	1.24	1.66	1.70	1.18	0.95	1.31
K8	(5)	X	23.79	38.70	41.93	27.41	23.30	33.57
		SD	1.79	2.05	1.93	1.74	1.27	1.85
K11	(5)	X	24.67	39.64	42.65	26.32	23.68	34.52
		SD	1.56	2.24	1.85	1.18	0.76	1.71
MD1	(13)	X	22.88	38.65	41.27	25.84	22.50	33.50
		SD	1.03	1.48	1.51	1.16	0.88	1.21
MD2	(10)	X	23.06	37.88	40.94	26.29	22.61	33.20
		SD	1.02	1.65	1.56	1.25	0.90	1.53
MD3	(9)	X	23.73	38.76	41.13	26.25	22.80	33.60
		SD	1.24	1.32	1.26	1.14	1.02	1.24
NW	(24)	X	24.61	40.38	43.08	27.27	23.95	34.70
		SD	1.28	1.62	1.61	1.44	1.03	1.44
OR	(58)	X	24.97	40.77	43.41	28.06	24.05	35.49
		SD	1.48	1.86	1.78	1.82	1.06	1.62
PB	(14)	X	23.37	38.48	41.41	26.76	23.13	32.96
		SD	0.83	1.55	1.49	1.06	1.09	1.32
RH	(6)	X	24.32	40.84	43.43	27.54	23.93	35.52
		SD	0.48	0.99	1.06	1.23	0.94	1.32
TW	(18)	X	24.81	40.80	43.86	27.96	24.33	35.56
		SD	0.95	1.55	1.44	1.29	0.99	1.36
SA	(17)	X	24.88	40.87	43.85	27.68	24.21	35.47
		SD	1.92	1.87	1.93	1.34	1.09	1.69
HY	(20)	X	24.15	36.69	42.19	26.80	23.48	34.35
		SD	0.81	1.48	1.71	1.12	0.95	1.42
BR	(48)	X	24.03	39.74	42.53	26.45	23.35	34.59
		SD	1.28	1.56	1.55	1.27	0.91	1.37
FC	(12)	X	23.23	38.69	41.70	26.61	22.91	33.50
		SD	1.16	1.75	1.84	1.00	0.83	1.54
OU1	(15)	X	24.23	40.04	42.36	26.66	23.34	34.69
		SD	1.09	1.39	1.57	1.31	0.94	1.43
AN	(12)	X	23.90	39.60	41.92	27.08	23.04	34.29
		SD	1.00	1.44	1.60	1.16	0.88	1.24
OU2	(21)	X	24.06	39.42	42.28	26.56	23.35	34.23
		SD	1.15	1.33	1.61	1.30	0.95	1.40
RH1	(4)	X	22.71	37.76	40.62	21.88	22.20	32.71
		SD	0.54	1.15	1.33	1.15	0.83	1.41
RH2	(22)	X	23.86	39.25	41.69	26.21	23.20	33.82
		SD	1.26	1.63	1.77	1.15	0.93	1.56
BE	(5)	X	24.13	39.88	42.92	27.20	23.61	34.88
		SD	1.07	1.63	1.60	1.36	0.77	1.46
TC	(53)	X	23.63	38.62	41.26	26.09	22.89	33.32
		SD	1.11	1.33	1.62	1.25	0.90	1.33
BL	(27)	X	24.50	39.98	42.87	26.66	23.86	34.87
		SD	1.04	1.67	1.80	2.12	0.93	1.54
BA	(28)	X	24.01	39.79	42.95	27.03	23.85	34.62
		SD	1.13	1.36	1.56	1.26	0.93	1.50
MU	(12)	X	24.51	40.35	43.32	27.12	24.24	35.00
		SD	1.07	1.33	1.27	0.95	0.88	1.23

Table 3.10. Descriptive statistics for corrected measurements of the astragalus of female white-tailed deer from all studied sites

<u>Site</u>	<u>(N)</u>	<u>Stat.</u>	<u>ASMD</u>	<u>ASMLEN</u>	<u>ASLLEN</u>	<u>ASDW</u>	<u>ASLD</u>	<u>ASLEN</u>
CB	(14)	X	23.49	38.76	41.49	25.76	22.74	33.17
		SD	1.45	1.97	2.09	1.13	1.16	1.44
IR	(28)	X	23.23	38.01	40.42	25.81	22.74	33.01
		SD	1.22	1.99	1.70	1.01	1.10	1.55
CR	(9)	X	24.30	39.57	42.37	26.64	23.18	34.31
		SD	1.19	1.74	1.33	1.16	1.10	1.25
FC	(13)	X	22.68	37.28	40.05	25.02	22.26	32.28
		SD	0.84	1.97	1.73	1.09	0.73	1.42
K6	(35)	X	22.70	37.18	39.72	25.11	22.20	32.18
		SD	1.45	1.75	1.70	1.23	0.98	1.41
K8	(9)	X	21.74	36.19	38.12	24.69	21.32	31.18
		SD	1.35	1.05	1.33	0.98	0.92	1.11
K11	(6)	X	21.75	36.65	38.53	24.30	21.28	31.61
		SD	0.60	2.00	1.48	1.36	0.46	2.14
MD1	(16)	X	22.07	36.60	38.85	24.97	21.69	31.43
		SD	1.07	0.98	1.08	1.12	0.85	0.85
MD2	(15)	X	22.28	36.70	39.19	24.68	21.78	31.84
		SD	1.24	1.59	1.30	1.05	0.82	1.16
MD3	(7)	X	21.61	36.51	39.53	24.98	21.56	31.28
		SD	1.44	2.47	1.75	1.20	0.88	1.97
NW	(23)	X	23.59	38.25	40.82	25.46	22.83	32.95
		SD	1.47	2.02	1.76	1.32	1.09	1.84
OR	(68)	X	23.29	38.63	40.92	25.79	22.78	33.21
		SD	1.29	2.15	1.54	1.20	0.97	1.39
PB	(11)	X	22.40	36.05	38.44	24.69	21.98	30.91
		SD	1.17	1.40	1.56	1.74	0.79	1.28
RH	(6)	X	22.78	38.08	40.58	24.97	22.09	32.71
		SD	1.77	2.39	2.05	1.44	1.55	1.81
TW	(18)	X	23.50	38.59	41.14	26.16	22.90	33.51
		SD	1.23	1.73	1.71	1.09	0.92	1.36
SA	(19)	X	23.04	38.21	40.89	25.60	22.71	33.08
		SD	1.37	1.43	1.13	1.16	0.86	1.16
HY	(29)	X	22.93	37.74	40.56	25.32	22.44	32.61
		SD	1.39	1.71	1.41	1.13	0.91	1.17
BR	(47)	X	22.60	37.40	39.92	25.26	22.04	32.39
		SD	1.05	1.51	1.59	1.04	0.93	1.32
FC	(13)	X	22.68	37.28	40.05	25.02	22.26	32.28
		SD	0.84	1.97	1.73	1.09	0.73	1.42
OU1	(18)	X	22.96	37.63	40.42	25.25	22.44	32.35
		SD	1.21	1.54	1.56	1.10	1.04	1.31
AN	(15)	X	22.35	37.88	21.64	39.71	25.91	32.73
		SD	0.89	1.37	0.93	2.14	1.04	1.02
OU2	(20)	X	22.81	37.50	40.06	24.86	21.98	32.60
		SD	0.88	1.60	1.72	1.12	0.89	1.42
RH1	(7)	X	21.71	36.71	39.28	24.37	21.66	31.35
		SD	1.27	1.33	1.06	1.09	0.54	1.29
RH2	(19)	X	22.05	36.30	38.93	27.37	21.48	31.74
		SD	1.24	1.37	1.50	1.23	0.82	2.03
BE	(5)	X	23.20	38.30	40.72	26.39	22.41	33.32
		SD	1.25	0.86	1.59	1.58	1.16	0.91
TC	(47)	X	21.96	36.08	38.77	24.80	21.51	31.22
		SD	1.29	1.63	1.82	1.28	1.01	1.26
BL	(26)	X	22.62	37.18	39.97	25.30	22.14	32.47
		SD	1.00	1.02	1.23	1.20	0.82	1.10
BA	(32)	X	22.76	37.41	40.25	25.21	22.56	32.18
		SD	1.15	1.58	1.57	1.59	0.87	1.24
MU	(11)	X	22.71	37.92	40.56	25.61	22.51	33.22
		SD	1.02	1.27	1.35	1.04	0.79	1.22

Table 3.11. Deer body weight calculated from corr. measurements of the astragalus

Site	Males (N)	Males (kg)	Females (N)	Females (kg)
CB	(12)	102.0	(14)	60.4
IR	(32)	92.2	(28)	58.8
CR	(3)	118.8	(9)	65.3
FC	(12)	77.1	(13)	55.1
K6	(34)	81.6	(35)	55.2
K8	(5)	82.5	(9)	51.1
K11	(5)	84.6	(6)	50.9
MD1	(13)	72.7	(16)	52.8
MD2	(10)	73.2	(15)	52.8
MD3	(9)	78.0	(7)	51.7
NW	(24)	90.3	(23)	59.3
OR	(58)	96.6	(68)	59.8
PB	(14)	77.7	(11)	52.2
RH	(6)	91.4	(6)	56.2
TW	(18)	95.4	(18)	61.0
SA	(17)	94.8	(19)	58.3
HY	(20)	76.4	(29)	56.8
BR	(48)	82.6	(47)	55.5
FC	(12)	77.1	(13)	55.1
OU1	(15)	85.1	(18)	56.6
AN	(12)	84.2	(15)	56.8
OU2	(21)	82.3	(20)	55.3
RH1	(4)	72.5	(7)	51.0
RH2	(22)	79.7	(19)	56.8
BE	(5)	86.4	(5)	60.4
TC	(53)	76.6	(47)	51.6
BL	(27)	86.2	(26)	55.4
BA	(28)	85.0	(32)	55.8
MU	(12)	89.1	(11)	57.2

Table 3.10. Mean and standard deviations of body weight calculated in this study.

Site	Males (N)	Males (kg)	SD	Females (N)	Females (kg)	SD
AN	(12)	86.657	9.186	(15)	55.282	3.296
OU2	(21)	85.033	9.579	(20)	53.910	4.105
RH1	(4)	70.975	6.976	(7)	49.923	4.378
RH2	(26)	80.009	11.666	(15)	48.677	4.058
BE	(5)	89.059	12.394	(5)	58.749	6.102
TC	(53)	79.567	9.329	(47)	49.846	4.355
BL	(27)	88.746	12.189	(26)	63.928	3.598
BA	(28)	87.599	9.728	(32)	54.239	4.132
MU	(12)	91.475	7.383	(11)	55.638	3.825

Analysis of Mortality Profiles and Size

When all mortality profile data are grouped by major cultural group (Archaic, Woodland, Mississippian, Historic) and examined statistically, there are no significant differences in mortality profiles. The results of a Kolmogorov-Smirnov (K-S) Two Sample Test showing maximum differences for pairs of groups are presented below.

Table 3.13. Results of a K-S Two Sample Test between Culture Periods

	Archaic	Woodland	Mississippian
Woodland	0.429 p=0.35		
Mississippian	0.311 p=0.74	0.235 p=0.69	
Historic	0.354 p=0.62	0.682 p=0.68	0.250 p=0.69

Despite this poor statistical showing, there is an apparent trend in the composition of older age classes when the data are combined to create large sample sizes (Table 3.14). The Mississippian sample shows lesser representation in the older age classes compared to all other periods. This is particularly notable in the 9.5 year age-class, but the Mississippian sample has the lowest (or tied for lowest) percentages in the 5.5, 6.5, 7.5 and 8.5 year age classes as well.

Table 3.14. Representation of age classes by culture period (percentages)

	(N)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5
Archaic	(868)	10.1	15.8	21.2	20.4	10.8	7.8	6.8	2.9	2.2	2.0
Woodland	(1202)	18.3	23.0	18.1	13.1	7.4	6.8	5.3	4.7	1.9	2.1
Mississippian	(811)	13.7	23.6	21.1	16.9	10.5	6.1	4.0	2.9	1.2	0.2
Historic	(1071)	14.3	16.5	16.0	18.8	12.0	9.2	7.0	2.9	1.9	1.7

It is probable that the lack of statistical significance in this examination relates to the variability of mortality profiles between sites. This might be true because the sites considered are of various types (temporary camp, rockshelter, village) and the type of occupation may have a strong effect on the mortality profiles. Individual sites will be discussed in more depth in a following section. Although K-S tests are useful for comparing non-parametric data they are also more likely to not find significance (Type II errors) and are not powerful tests. The lack of significance is not altered by aggregating data into fewer age classes or by the removal of the younger or older age classes because K-S tests are strongest when data are not aggregated.

Visually, removal of the younger age classes assists in viewing the variation in older age classes. Two models are used, one which examines proportional representation of 3-6 and 6-9 year olds (Figure 3.6) and one which examines 2-4, 4-6, and 6-8 year olds, represented by 20-40, 40-60 and 60-80% Potential Ecological Longevity (PEL) (Figure 3.7).

When the representation of older age classes is examined, there is a slight but noticeable decrease in the percentage of individuals in the older age classes (6-9 years); the Mississippian sample is the only one where this value is less than 20% of adults 3-9 years. The Mississippian sample is also the only one where the percentage of individuals in the 60-80% PEL is less than 15% of adults in the 20-80% PEL group.

Figure 3.6. Relative representation of 3 to 6 and 6 to 9 year age-classes

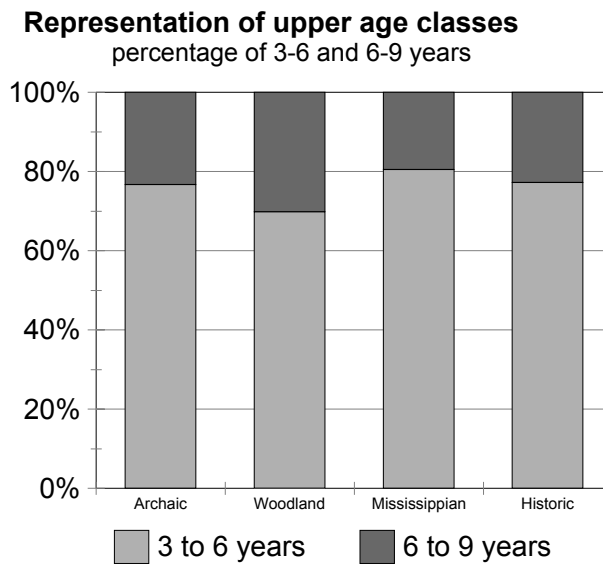
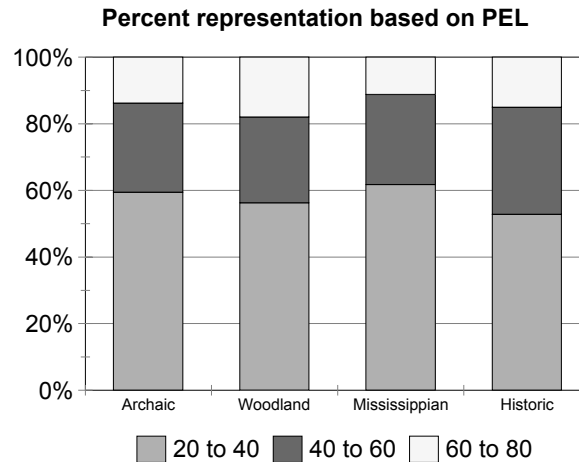


Figure 3.7. Relative representation of 20 to 40 percent, 40 to 60 percent, and 60 to 80 percent Potential Ecological Longevity (PEL).



Deer size based on astragalus measurements is summarized for the same major culture periods. Table 3.15 presents these results with meat weight of males and females in kilograms. The standard deviation is shown as SD and the number of sites in each

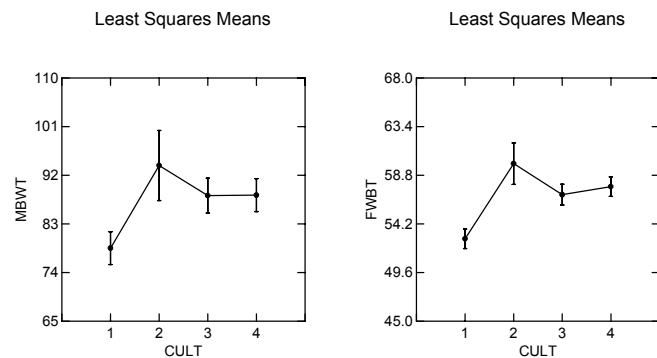
sample is indicated by (N). A statistical analysis of all samples grouped by major cultural period gives the following results.

Table 3.15. Mean weight of deer by culture period

	Sites (N)	Males (kg)	SD M	Females (kg)	SD F
Archaic	(10)	78.51	4.04	52.79	1.98
Woodland	(2)	93.80	2.26	59.90	1.96
Mississippian	(6)	88.24	8.81	56.96	3.04
Historic	(10)	88.32	12.90	57.70	3.30

In this case there is a statistically significant difference in the mean size of deer when grouped by major cultural period. When analyzing male body weight ($N=28$, r^2 0.261) the probability of this variation occurring by chance is 0.06. When analyzing female body weight ($N=28$, $r^2=0.459$) the probability of this variation occurring by chance is 0.002. Most of the significance is accounted for by the differences between Archaic and Mississippian or Historic samples. Due to only two Woodland samples being included in the analysis, the variance of this group is high and the large size exhibited in these samples may not be representative (See Figure 3.8).

Figure 3.8. Variance for male body weight (MBWT) and female body weight (FBWT) by culture period. Archaic=1, Woodland=2, Mississippian=3, Historic=4)



These results on age and size indicate that neither method provides stand-alone evidence for changes in deer exploitation. Data on mortality profiles are not statistically significant and data on size may be explained by environmental variation. As it turns out, the relationship between deer size and age at death is the key evidence for changes in exploitation.

Comparisons of deer age and size may be made at a broad summary level. When representation is calculated based on 10 kg intervals of deer male body weight, mortality profiles show a distinctive trend (Table 3.16, Figure 3.9). For samples with weight of 70 to 80 kg, 18.8 percent of adults fall in the 60-80% PEL category. For samples with weights of 80 to 90 kg, this number drops to 10.2%. For samples with weights greater than 90 kg the number of old individuals drops to 6.5%, only a third of what it was in samples with small deer.

Figure 3.9. Age classes with sites sorted by male body weight



Table 3.16. PEL age classes for sites sorted by male body weight

MBWT	(N) sites	20-40%	40-60%	60-80%
x<80	(5)	56.3	24.9	18.8
80<x<90	(10)	57.3	32.5	10.2
x>90	(3)	72.7	20.7	6.5

Broad summary data are unlikely to be a good indicator of what is happening at individual sites, but the variation in levels of deer exploitation at individual sites may also be examined with this age-size relationship.

When data are presented with a sort based on the mean size of male deer (Table 3.17) culture periods do not show any organizational pattern. Mortality profiles do show a distinctive pattern, with strong representation of the older age classes at the top of the table and strong representation of the younger age classes at the base of the table. Although not a perfect relationship, this is a statistically significant one.

Whole set correlation analysis (Cohen and Cohen 1983) is available on specialized statistical software (SYSTAT 10). This complex analysis of correlation allows the measurement of correlation between two sets of variables. It also produces a proxy for probability based on repeated sampling of the data.

A whole set correlation analysis of the mean size of males and females versus the percentage of individuals in the 20 to 40, 40 to 60 and 60 to 80 percent PEL groups indicates a moderate correlation between age and size which is statistically significant at a larger than normal 90% confidence interval ($r^2=0.536$ $P=0.098$). The strongest correlation is negative and it is between the percentage of individuals in the oldest age class and size. For males $r^2 = -0.664$ and for females $r^2 = -0.710$.

Table 3.17. Mortality profiles and size data for the 18 analytic units in this study aligned by site and sorted by male body weight. (deer body weight calculated from the corrected measurements of astragali)

Site	Males (kg)	Females (kg)	Site	Period	% 20-40 PEL	% 40-60 PEL	% 60-80 PEL
RH1	72.5	51.0	RH1	Miss	65.0	20.0	15.0
TC	76.6	51.6	TC1	Archaic	56.7	20.2	23.1
TC	76.6	51.6	TC3	Woodland	50.0	25.3	24.7
TC	76.6	51.6	TC2	Archaic/Woodland	52.6	27.8	19.6
RH2	79.7	56.8	RH2	Archaic	57.1	31.0	11.9
OU2	82.3	55.3	OU2	Historic	45.0	45.0	10.0
BR	82.6	55.5	BR	Historic	62.2	26.1	11.7
AN	84.2	56.8	AN	Miss	52.0	28.0	20.0
BA	85.0	55.8	BA1	Miss	52.0	34.0	14.0
BA	85.0	55.8	BA2	Miss	68.6	20.0	11.4
OU1	85.1	56.6	OU1	Historic	70.0	30.0	0.0
BL	86.2	55.4	BL2	Fort Ancient	60.0	36.0	4.0
BL	86.2	55.4	BL1	Fort Ancient	41.2	41.2	17.6
BE	86.4	60.4	BE2	Historic	78.6	14.3	7.1
MU	89.1	57.2	MU	Protohistoric	43.8	50.0	6.3
RH	91.4	56.2	RH	Historic	67.3	20.0	12.7
SA	94.8	58.3	SA	Historic	78.3	17.4	4.3
OR	96.6	59.8	OR	Miss	72.6	24.8	2.6

Several cases included above exhibit high percentages of old individuals that do not conform to the overlying pattern. These cases include Blain Village (BL1) and the Rhoads site (RH) both analyzed by Parmalee. The identification of these two cases as outliers, with large leverage on a linear regression model, led to closer scrutiny of Parmalee's mortality profiles. An independent detailed analysis of the Blain Village material by the author (BL2) prior to any analysis produced a mortality profile that differs from Parmalee's in having fewer old individuals, but fits the overall model quite well.

The Tick Creek sample and the Apple Creek sample, both of which have relatively large percentages of individuals in the older age class, were also analyzed by Parmalee. Unfortunately the Tick Creek Cave mandibles have lost their provenance information, but an expedient analysis of 191 unprovenienced materials by the author

(TC2) led to a profile that has relatively fewer individuals in the older age class when compared to Parmalee's TC1 and TC2.

The remaining profiles, which show a stronger patterning when compared to deer size, were analyzed by a variety of other investigators. This indicates an apparent situation in which Parmalee has overestimated ages relative to other researchers or other researchers have underestimated age relative to Parmalee. Because several studies show that tooth wear underestimates age relative to known age and cementum annuli ages, Parmalee's ages may be more accurate than those of other observers. When Parmalee's samples are divided out, his Mississippian and Historic samples show reduced percentages of older individuals when compared to his Archaic and Woodland samples. Even with these samples, a drop in percentages of individuals in older age classes is linked to an increase in deer size. Thus Parmalee's data still show the same directionality as other samples.

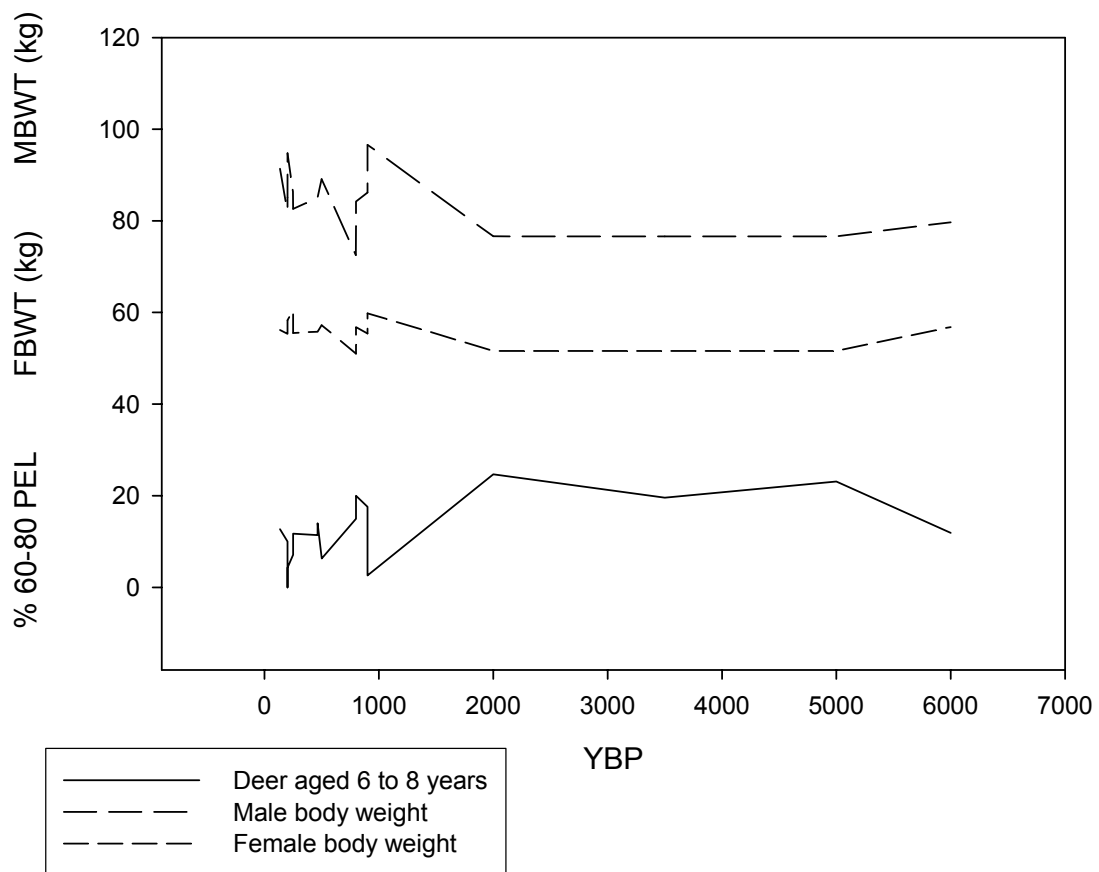
Statistically there is a significant relationship between age and size. Despite all variation due to differential application of ageing techniques by a variety of different investigators and variability in deer size due to geographic and environmental variation, the correlation between mortality profiles and size is still statistically significant at a 90% confidence interval ($r^2=0.563$ $P=0.098$).

Given this significant relationship between age and size, it is possible to examine the relationship between human and deer populations across long periods of time. Plotting sites based on the midpoint of date ranges, the male and female body weights as well as the percentage of individuals in the 60-80% PEL age class can be examined.

Figure 3.10 shows the unmistakable inverse relationship between deer age and size through time.

Figure 3.10. Relationship between white-tailed deer age and size through time

Relationship between white-tailed deer age and size over time



This figure demonstrates the relationships of deer age, size and culture period. Although there are relatively few samples, data in the Archaic and Woodland demonstrate a fairly stable population structure. There is a substantial drop in the number of old individuals (60-80 PEL) in some Mississippian samples *circa* 1200 YBP

and this is reflected in a corresponding rise in deer size. Representation of old individuals and deer size continues to fluctuate across the Mississippian and historic periods. Some contemporary samples show contrasting patterns (i.e. large deer and few old individuals or small deer and many old individuals); however, the inverse relationship between age and size remains constant.

In conditions where environmental change reduces the quality or quantity of browse, both the numbers of deer living to old age and their overall size should be reduced. Based on the fact that as a male deer ages it attains a greater body weight (with some seasonal fluctuation, female weight is stable for adults), the expected ecological relationship between age and size would be that if there were greater numbers of old individuals then the average weight of the population should be heavier. The exact opposite relationship is seen in these data; there is a negative correlation between older individuals and mean body weight, suggesting an anthropogenic cause.

The only possible explanation of these data is that the overriding factor regulating body weight is the density of deer populations. No other single factor can explain the decrease in old individuals and the increase in deer size. By reducing deer density through hunting, the numbers of individuals living to old age dramatically decrease. When deer population densities are low, young deer have access to high quality forage and tend to attain their maximum body weights. When culling of deer is low, populations are at or near carrying capacity, and deer are in competition for resources. Decreased access of young individuals to high-quality forage results in smaller deer and a decreased intensity of hunting results in older deer.

Given the variation seen in Late Prehistoric samples, a closer comparison between individual sites is warranted. As noted, Purdue's mean deer sizes cannot be compared statistically; however, for the data compiled in this study mean size may be compared directly between sites. Mean and standard deviations of white-tailed deer for this study are presented in Table 3.18.

Table 3.18. Mean and standard deviation of male and female body weight for sites in this study

Site	Males (N)	Males (kg)	SD	Females (N)	Females (kg)	SD
AN	(12)	86.657	9.186	(15)	55.282	3.296
OU2	(21)	85.033	9.579	(20)	53.91	4.105
RH1	(4)	70.975	6.976	(7)	49.923	4.378
RH2	(26)	80.009	11.666	(15)	48.677	4.058
BE	(5)	89.059	12.394	(5)	58.749	6.102
TC	(53)	79.567	9.329	(47)	49.846	4.355
BL	(27)	88.746	12.189	(26)	63.928	3.598
BA	(28)	87.599	9.728	(32)	54.239	4.132
MU	(12)	91.475	7.383	(11)	55.638	3.825

The best statistic for examining the differences between the means of any two of these samples is the Student's t-Test. Although it requires conditions of normal distribution and equal variance in the samples compared, it is robust to violations of either of these conditions. In the case of the data compared here, all samples have relatively normal distributions and similar variance.

For the comparisons there are seven samples where comparison gives us significant information. Historically we know that Fort Ouiatenon, a *circa* 1750 French fort, was heavily involved in the fur and hide trade, and thus it should provide an example of a deer population which has been modified by hunting pressures. Large Middle

Mississippian and Fort Ancient sites such as Angel, Banks, Murphy and Blain had relatively high human populations and intensive occupations. The prediction of this study would be that the deer populations they exploited would exhibit population densities similar to the deer surrounding Fort Ouiatenon.

In contrast, Archaic and Woodland material from the Rockhouse Hollow and Tick Creek rockshelters would not be expected to be heavily modified by hunting pressures, and thus should be significantly different than the preceding samples. The Mississippian occupation of Rockhouse Hollow appears to be a minor occupation, presumably a temporary hunting camp, and is expected to behave like both Tick Creek and the Archaic material from Rockhouse Hollow.

Student's t-Tests between samples indicate a number of significant differences. The Archaic and Woodland sample from Tick Creek and the Archaic and Mississippian samples from Rockhouse Hollow are significantly different from Angel, Banks, Blain, and Murphy. The mean weight for males at the Late Prehistoric sites ranged from 6.6 to 16.6 kg larger and differences in the mean weight of females ranged from 4.3 to 6.6 kg larger. Probabilities range from $P=0.000$ to 0.042 for females and $P=0.001$ to 0.070 for males. A single comparison, males from Angel vs. Archaic males from Rockhouse Hollow is above the 95 percent confidence interval and accounts for the $P=0.070$ value above. Due to the strong pattern of significant differences between these groups this difference is considered real by the author even though it is not within a strict 95 percent confidence interval. Both the Ouiatenon males and females show an approximately 5 kg larger mean weight when compared to the Archaic sample from Rockhouse Hollow. In the case of males the result is not statistically significant, but in females it is. $P=0.001$.

When compared to each other there is no significant difference between any of the Mississippian, Fort Ancient, or Historic samples from this study; however, there is only one pair of samples that are statistically identical: females from Blain and Ouaiatenon (difference in means, 0.02 kg; $P=0.988$). Likewise, there is no statistical difference between any of the samples from Rockhouse Hollow or Tick Creek. One sample in this group, females from the Mississippian sample at Rockhouse Hollow and the Archaic and Woodland sample from Tick Creek are statistically identical (difference in means 0.08 kg; $P=0.966$). Sample results are presented in Figures 3.11 and 3.12.

Figure 3.11. Distributions of statistically different body weights of both male (left chart) and female (right chart) deer in Mississippian samples from Angel (left plot) and Rockhouse Hollow (right plot)

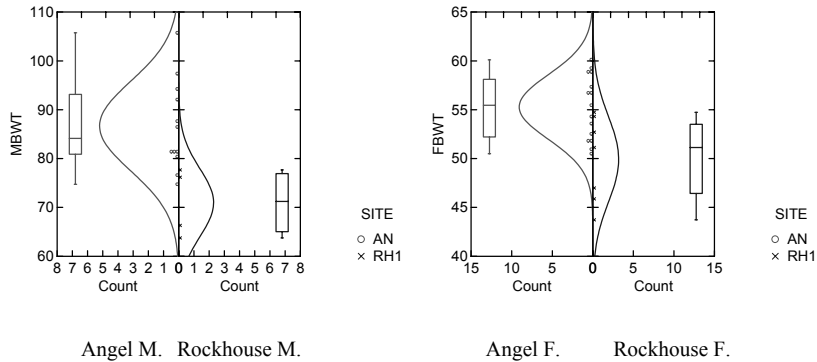
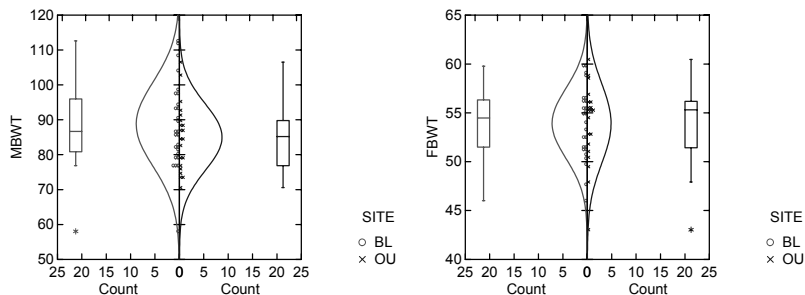


Figure 3.12. Distribution of similar male body weights (left chart) and statistically identical female body weights (right chart) at Blain (left plot) and Ouaiatenon (right plot).



Discussion of Results

Purdue argues that environment, particularly the availability of summer forage, is the main determinant in deer size (Purdue 1991). He argues that in the Midwest deer size peaks between one and two thousand years ago as a result of ameliorating climatic conditions which allowed deciduous forest to encroach on grasslands, increasing the availability of high quality summer forage (Purdue 1989, 1991). In contrast he sees the sizes of deer in the southeast as steadily decreasing through the past 4,400 years as the result of increased annual dryness, a paleoclimatic regime which inhibited the growth of summer forage (Purdue and Reitz 1993:293). An examination of the results from the current study (Figure 3.10) suggests that Purdue's preliminary results do not withstand comparison to a larger sample. Heavily hunted deer populations from early historic and protohistoric sites have average sizes of both males and females that are as large as the peaks seen in the Mississippian.

What are the alternate hypotheses for a change in deer size? Purdue cites other possibilities: "Bergmann's rule, fetal nutrition, seasonality of climate, and anthropogenic influences have all been proposed as possible explanations" (Purdue and Reitz 1993:294). The hypothesis presented here is that anthropogenic influences, i.e. the intensity of human hunting and the effect that this has on deer population density, have the largest effect on deer size. This is seen in modern wildlife studies cited at the beginning of this chapter and would appear to be the simplest explanation for variations in deer size across time and space.

Analyzing size alone, contemporary deer populations such as the Mississippian samples from Angel and Rockhouse Hollow exhibit statistically significant differences in mean weight. These sites are located less than 100 km apart and should be subject to the same range of environmental change. Thus these samples provide incontrovertible evidence of contemporaneous variation in deer size within a limited geographic area. The hypothesis that deer size is the result of deer population densities is therefore supported while Purdue's climatic model is significantly weakened. Further support for an anthropogenic hypothesis is provided by the covariation in male and female body weights and deer mortality profiles across the remaining sites.

Bell (1970) has shown that the distribution of patchy, high-quality forage makes it a cost-effective alternative for small-bodied animals with a limited rumen capacity (female deer); and that these individuals can afford the luxury of searching for high-quality food. In contrast, large individuals with plenty of rumen capacity tend to concentrate on forage of high fiber content and low digestibility (male deer). These individuals are not affected by forage quality, but rather by forage quantity.

When samples from the Rockhouse Hollow Archaic and Mississippian levels are compared, male deer from the Mississippian period are 9 kg smaller than male deer from the Archaic period. This difference has a probability of 0.073 of occurring by chance. Female deer from these two contexts show no significant difference, with a mean difference in weight of 1 kg and a probability of this occurring by chance of 0.538. This suggests the possibility that there was a reduction in the quantity of available forage affecting males more than females, and that in the Mississippian deer populations were more dense in the hinterlands than they were in the Archaic.

The variation in males and females probably relates to the example proposed by Klein (1985:15) of year-round hunting of introduced red deer in New Zealand. This continuous hunting not only resulted in a reduction of deer numbers, but also caused a redistribution of deer populations. In seeking refuge from hunting, deer became concentrated in dense forests with reduced forage availability. Although not examined by Klein, this situation should also result in a reduction in individual size.

Prehistorically, the area around Rockhouse Hollow continued to be heavily forested while the area around Angel was cleared for maize agriculture. It is a likely scenario that hunting pressures in the major river valleys pushed deer into *refugia* in the wooded uplands where reduced food quantity (i.e. a browse line) negatively affected males more than females. Any reduction in predator levels by Mississippian hunting would have further exacerbated the effect of this redistribution.

When the statistical relationship between age classes and deer size is combined with the data on size, there can be little doubt about the relationship of prehistoric hunting to deer population densities, size and mortality profiles. Only one site, Angel, shows higher than expected percentages of old individuals. Of all the possible explanations noted by Purdue and Reitz, including that of climate change, only an anthropogenic influence would result in the combined changes of size and mortality profiles of deer that are seen at archaeological sites in eastern North America. The strength and statistical validity of these age-size relationships permit further interpretations of deer hunting strategies in Chapter 5.

Chapter 4

Prehistoric Raccoon Exploitation

Introduction

Of mammalian remains found at archaeological sites in the eastern United States, raccoon is second in abundance to white-tailed deer. In the Late Prehistoric period exploitation of this species exhibits a substantial increase in intensity. Despite their importance in prehistoric diets, there is comparatively little analysis of age and sex structures of archaeological raccoon populations. The failure of zooarchaeologists to construct mortality curves may be due to problems in using the available dental wear-stages for this species (Grau et al. 1970). This may also explain the use of other ageing criteria by wildlife biologists. The sparse previously published data on this species are also in need of revised interpretation.

Based on a low representation of young individuals, Smith (1975:52) suggested that Middle Mississippian hunting pressure on raccoons was light. Since that time, a focus on the importance of taphonomy has suggested that low percentages of small species and under-representation of young individuals is more likely a reflection of poor bone preservation than of human activity (Payne and Munson 1985). As previously mentioned with deer, low numbers of young individuals in and of themselves provide an insufficient argument for low hunting pressures or any type of selective hunting.

Given their importance as a food source and their uncanny ability to adapt to anthropogenically modified habitats, it would indeed be surprising if raccoon populations did not respond to the intensified use and cultivation of certain plants. Since the

association of raccoons with corn (maize) fields is legendary, the intensity of exploitation that Smith (1975) proposes for the Mississippian is contrary to what would be expected.

Raccoon Biology and Ecology

The distribution of the raccoon covers the entire eastern United States as well as most of North America (Kaufmann 1982:567). It is an adaptable species but tends to remain fairly close to permanent water sources. Raccoons never den more than 400 meters from a water source and make little use of uplands that are more than 1.6 kilometers from floodplains (Hoffmeister 1989:283). Dens are most commonly hollow trees with large dry cavities; however, if suitable denning trees are absent, raccoons will use the burrows of other species, rock crevices or caves.

Raccoons are omnivorous and opportunistic. Invertebrate animal foods include crayfish, insects, mussels, snails and earthworms. Fleshy fruits and nuts (especially acorns) are important seasonal plant foods. Most significant, however, is their taste for maize. In some areas of their modern range maize is the most important item in their diet (Kaufman 1982:573). Based on a study of stomach contents, Mumford and Whittaker (1982:445) record maize as being the most important food by volume (28.1%) and frequency (34.1%) among Indiana raccoons. Although this proportion may be exaggerated by modern harvesting procedures, it strongly suggests that raccoons may have been a problem for prehistoric farmers.

Raccoons have a restricted mating season that results in a fixed birthing period. Across North America raccoons mate once a year between January and June. After a 60 to 73 day gestation period, between 3 and 7 (median 4) young are born. In central Illinois

and surrounding areas raccoons have a peak littering date of April 15th (Grau et al. 1970:365). The young can walk at 6 weeks and are weaned when they are between 2 and 3 months old.

Unfortunately there are no adequate modern survivorship curves for raccoon populations. Rabinowitz (1981) suggests an average longevity of 2.5 years and a maximum longevity of 7.2 years for a population in the Smoky Mountains. Popular sources suggest that raccoons in the wild may live to 10 years and that raccoons in captivity may live to 20 years. There are some mortality profiles of trapped samples, but these are not classified by dental wear and are presented in 1-year age categories (Lehman 1977; 1980). Some differential representation of young in mortality profiles has been demonstrated by Hasbrouck et al. (1992). They examined mortality profiles for hunted vs. trapped raccoon populations and determined that when harvests were low, trappers tend to take more birth year raccoons than hunters. With heavy exploitation this difference disappears.

More importantly, the probability of capture for males vs. females varies significantly when a raccoon population is subjected to trapping. Gehrt and Fritzell (1996) used radiotelemetry and live trapping to demonstrate that adult male raccoons were captured more frequently and that a higher proportion of the overall total of males was captured using traps. This live trap bias toward males was also demonstrated by Urban (1970).

In the Gehrt and Fritzell study, females always outnumbered males within the study area; however, males were always more likely to be captured in traps. The reason for this bias is that males have larger home ranges and tend to move about more than

females. As a result of their aggressive behavior, adult males are often under-represented in the surviving raccoon population (Hasbrouck et al. 1992:698). Since females form a greater proportion of the adult population, non-selective procurement of raccoons should result in a preponderance of females in the harvest profile.

Methods

Raccoon are among the easiest species to sex from archaeological remains. Grau et al. (1970) sampled 104 individuals of known sex and found that all of the male canines were thicker than 4 mm, whereas 93% of the female canines were thinner than 4 mm. Techniques for measuring raccoon mandibles and teeth are presented by Wright and Lundelius (1963).

Kennedy and Lindsay (1984) demonstrate that raccoon morphology (size) varies considerably across their geographic range. Ritke and Kennedy (1993) have further demonstrated geographic variation in the sexual dimorphism of raccoon canines. In combination this research suggests that while a cutoff point may work for a specific population it is not universally applicable across wide geographic ranges.

The most common techniques used by wildlife biologists to age raccoons are body weight, epiphyseal fusion of the radius and ulna, and the size and degree of ossification of the *os baculum* (Sanderson 1961). While epiphyseal fusion and the degree of ossification can be used on archaeological materials, their utility is limited to the younger age ranges and they are not useful in determining the relative ages of older adults. For reasons similar to those in white-tailed deer (Chapter 3) tooth eruption and

wear was the primary choice for ageing archaeological materials even though this is not a widely used technique for studying modern raccoon populations.

The deciduous dentition (0-3.5 months) could provide an important indication of summer occupation, a season which is difficult to identify archaeologically (Munson 1984). Techniques for ageing deciduous material are presented by Montgomery (1964). Unfortunately archaeological specimens with deciduous dentition are rare. Smith (1975) reports only one mandible out of 182 specimens and an earlier study by the author (Garniewicz 2000) identified only one out of 145 specimens.

Adult dentition begins erupting within 3.5 months of birth and tooth wear appears to be fairly regular in sequence despite probable variation in overall rates (Grau et al. 1970:369). Previous to the methodology presented by Garniewicz (2000), two methods were used to age raccoon mandibles.

Guilday et al. (1962:69) were the first to age raccoons based on tooth wear. In their zooarchaeological analysis of material from the Eschelman site they used four wear stages: Class 1 (no wear); Class 2 (moderate wear); Class 3 (heavy wear); and Class 4 (extreme wear, teeth flat). All age assignments were subjective and there is little hope for comparison and replicability of results between investigators.

More stringent criteria for ageing raccoons by dental wear, which included drawings of individual wear stages, were developed by Grau et al. (1970). In this study, natural wear stages are identified and their corresponding age range is established using individuals of known age. Although this technique provides age categories of unequal duration, it does identify realistic wear stages. The illustrations presented by Grau et al. (1970) proved difficult to use, but the verbal descriptions of each age class are of some

utility. They are summarized in Table 4.1. Though designed for studies of modern populations, the stages have been applied to archaeological material by Parmalee et al. (1972), Hamblin (1973), and Smith (1975). To the author's knowledge these stages have not been applied to modern raccoon populations other than during the original study.

Table 4.1. Wear stages proposed by Grau et al. (1970)

Class I	Little or no wear on any of the teeth
Class II	Wear begins on the buccal side of M1 and messial-buccal side of M2, but cones still present on both teeth.
Class III	The cone on the distal-buccal surface of M1 and the cones on the buccal surface of M2 are worn flat. The first appearance of wear on the premolars occurs at this time.
Class IV	M2 worn flat; M1, with the exception of two areas of enamel still present, is also worn flat. The distal-lingual cone of P4 is absent but the distal-buccal cone on P4 is present.
Class V	Both M1 and M2 are worn flat. The distal-buccal cone on P4 is absent.
General	Wear also accounted for a shortening of the crowns on the incisors and canines.

Problems with Previous Ageing Criteria

Three problems arise when using previous work based on the criteria outlined by Grau et al. (1970). First, there is no measure of specimen completeness; second, selection for relatively complete specimens results in a small sample size; and third, the results appear to be subject to a high degree of inter-observer error.

No mention of the completeness of the mandibular dentition is made by Parmalee et al. (1972) or Smith (1975). Hamblin, working with material from the Snodgrass site, states that only 34 out of 37 mandibles could be aged successfully because three mandibles contained no teeth (Hamblin 1973:40). This suggests that mandibles with a single tooth were included in the sample, with questionable mandibles being placed within minimum and maximum age-classes. A reduction to “relatively complete” mandibles reduces her sample size to 22 individuals.

The author was able to obtain consistent results between trials once he was experienced using the Grau system; however, the interpretation of written descriptions surely varies according to analyst. Hamblin (1973) and Smith (1975) both analyzed material from the Snodgrass site and produced very different mortality profiles (Table 4.2). Although variation in the size of their samples may be a problem, these trials fall on opposite ends of the spectrum of published data. The analysis by Hamblin has one of the lowest percentages of Class II, while the analysis by Smith has one of the highest. Although the differences are not statistically significant, the results of this comparison certainly raise questions about the replicability of results between observers.

Table 4.2. Raccoon age profiles from Snodgrass (percentage)

Author	(N)	Class I	Class II	Class III	Class IV	Class V
Hamblin	(22)	22.7	27.3	40.9	9.0	0.0
Smith	(53)	13.2	43.4	30.2	9.4	3.8

Results are from Hamblin (1973) and Smith (1975). Technique used is Grau et al. (1970)

The author had an assistant attempt to use the Grau et al. technique on one of the samples in this study. The results exhibit a similar degree of variation as seen in the analysis of material from Snodgrass and are shown in Table 4.3. We found that the largest discrepancies are probably due to difficulties in determining what Grau *et al.* (1970) intended by subjective phrases such as “little wear” or “worn flat” in their written descriptions. Again, while these results are not statistically different, they suggest that the results using Grau’s technique are not replicable between observers.

Table 4.3. Raccoon age profiles from Angel (percentage)

Researcher	N	Class I	Class II	Class III	Class IV	Class V
Garniewicz	49	16.3	49.0	16.3	12.2	6.1
Locklin	49	22.4	30.6	24.5	16.3	6.1

Results are based on a single trial by each investigator. Technique used is Grau et al. (1970).

New Ageing Criteria

Due to problems associated with fragmentary specimens and the replicability problems of the method outlined by Grau et al. (1970), a new series of mandibular wear stage drawings and descriptions were devised. Additional wear stages for isolated teeth allow for the expansion of sample size under carefully controlled conditions.

Most critical to ageing a mandible are the molariform teeth (P₄-M₂), which exhibit the most consistent wear. These teeth formed the focus of Grau’s methodology and fortunately they are also the most likely to remain in archaeologically recovered

mandibles. As a result, the following discussion and figures will focus on this portion of the dentition.

The methodology employed for ageing raccoons presented here includes techniques both for ageing relatively complete mandibles and for determining wear stages for individual teeth. The presence of at least two of the three molariform teeth is required for a mandible to be included in the sample. While this requirement reduces the size of the sample it also imposes uniformity on the samples to be compared. Wear stages of individual teeth within relatively complete mandibles were also recorded. The highest degree of correlation occurs between M_1 and the overall wear stage (90%). Wear on M_1 also appears to be the most regular and even, suggesting that attempts at determining age from isolated teeth should use the M_1 wear stages presented here.

Records for isolated teeth, particularly M_1 , provide a standard means for increasing sample sizes. Values for isolated teeth can be compared to values for relatively complete mandibles. If the distribution of these two data sets is similar their wear stages can be combined. Any serious variation between these two data sets may preclude combination of results and should be investigated further.

A line drawing of the lower right mandible of a young raccoon is presented in Figure 4.1. This figure presents the terminology that is used in the written descriptions of tooth wear (Table 4.4). Figure 4.2 presents five tooth wear stages. This figure includes drawings of early and late phases of wear within each stage (designated A and B). The gaps between early and late phases are large compared to the gaps between stages. Most mandibles examined clearly fall within early and late phases of one stage, thereby

reducing much of the inter-observer error that can occur when one tries to place specimens using a single drawing. Figure 4.3 presents 11 stages of wear for each tooth.

Table 4.4. Wear stages of raccoon mandibular dentition.

<p>General. The molariform teeth (M_2, M_1, P_4) have been selected as the teeth that are most regular in wear. Fortunately they are also commonly found in archaeologically recovered mandibles. Wear through the enamel (dentine exposure) is shown by shaded areas in Figure 4.2.</p>	
Stage 1:	In this stage there is “little or no wear on any of the teeth (Grau et al. 1970:368)”. Specifically, the stage begins with the eruption of adult dentition and the presence of a completely intact enamel surface. The stage continues until some dentine is visible on the cusp tips. At this early stage all of the visible dentine is roughly round in shape except on the hypoconid and entoconid of M_1 which may join to form an elongate dentine exposure.
Stage 2:	This stage begins with an elongation of the dentine visible at the surface. The triangular shape of dentine exposure at the metaconid and protoconid of M_1 indicates the beginning of wear stage 2. At the termination of this stage, all of the exposed enamel is irregular in shape. Wear may or may not occur on some cusps, noticeably the hypoconulid of M_2 due to the vagaries of occlusion. The distinctive character at the terminus of stage 2 is the conjoining of the entoconid, hypoconid and hypoconulid exposed dentine of M_1 .
Stage 3:	At the start of stage three there must be conjoining of more dentine than at the terminus of stage 2. This joining most often occurs at either the paraconid and metaconid of P_4 , or between the protoconid and metaconid or hypoconulid of M_1 . At the end of this stage, increasing wear on the 2 nd molar leads to conjoining of exposed dentine between the protoconid and metaconid.
Stage 4:	At the beginning of stage four there are two cusps that remain discrete. These are the hypoconid of M_2 and the protoconid of P_4 . At the end of this stage all of the diagramed cusps are joined; however, there is still irregular enamel showing on the occlusal surfaces of all three teeth.
Stage 5:	By stage five wear is extreme, at its start small areas of enamel may remain at the low points of the original molar surface. These are distinguished from the end of wear stage 4 by their small size. Often only one molar will have enamel remaining on its occlusal surface, thus simplifying its placement into stage 5. At the end of stage 5 areas of M_1 and M_2 will often be worn down to the root. Rarely the pulp cavity of M_1 will be exposed.

Figure 4.1. Morphology and terminology of raccoon teeth.

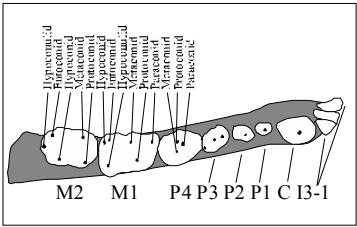


Figure 4.2. Raccoon mandibular wear stages

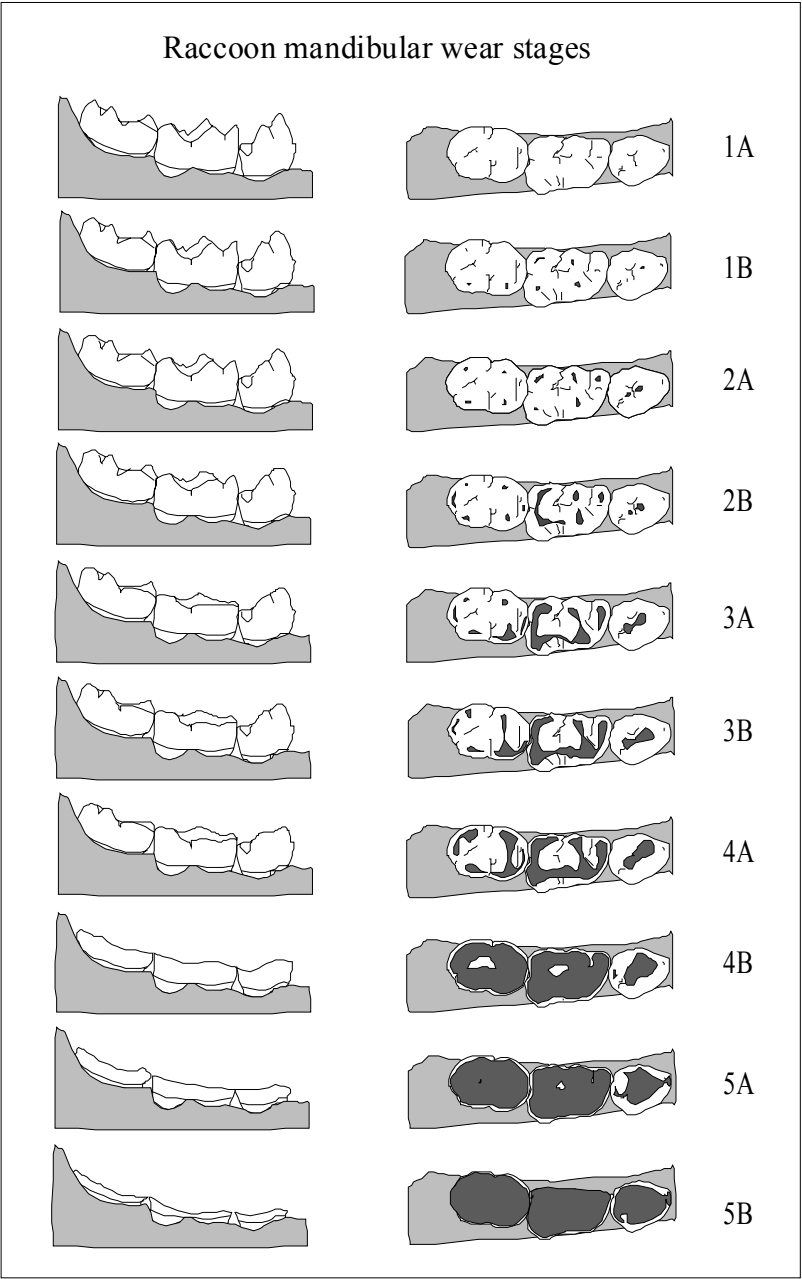
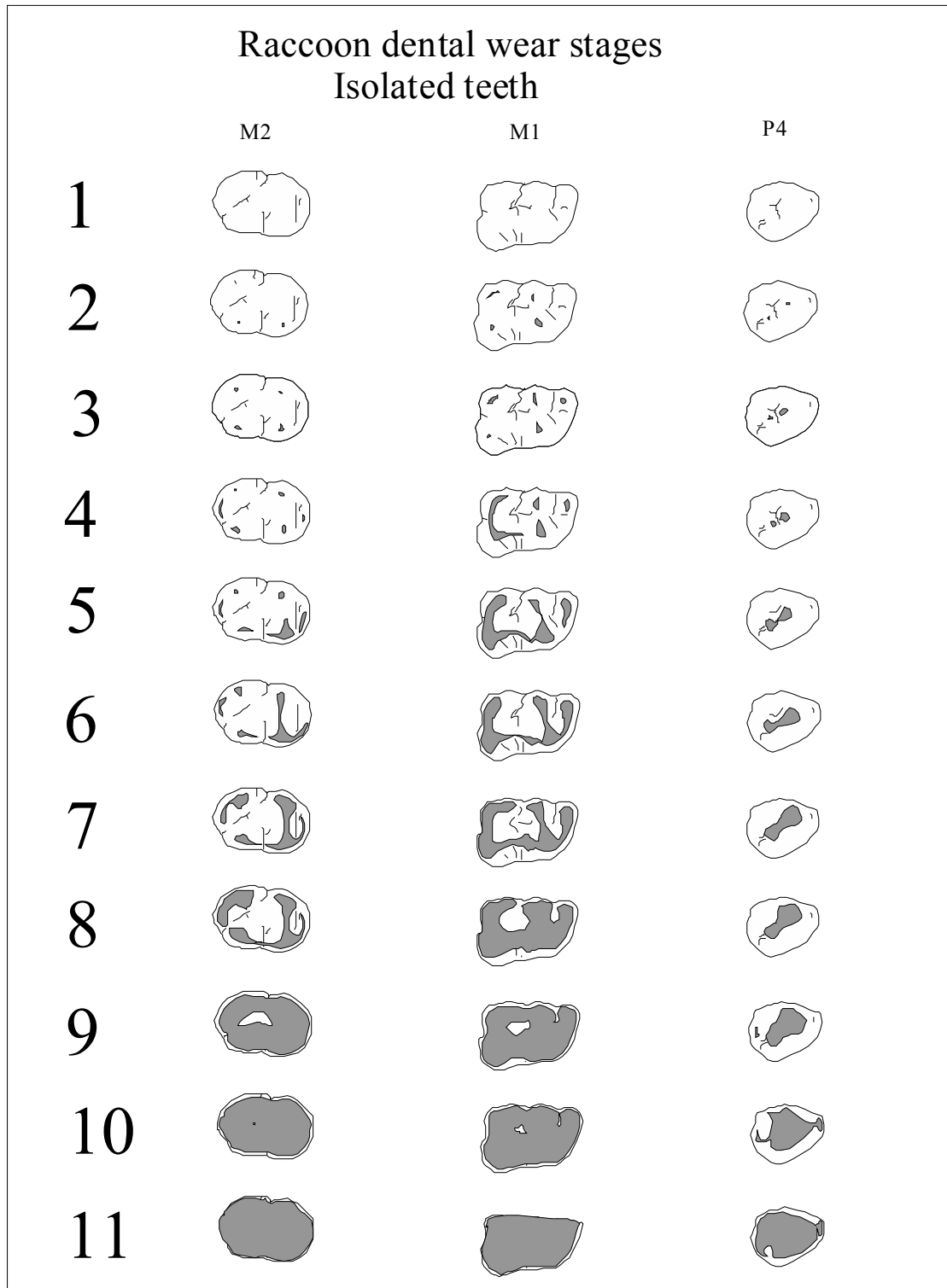


Figure 4.3. Raccoon dental wear stages: isolated teeth (Garniewicz 2000)



Replicability of new wear stages

Using the standards presented in this paper, three trials on separate days were done by each investigator for a sample of mandibles from Angel Mounds. Data are presented in Appendix 4. In all cases the age class assigned agreed in at least two out of the three trials and the final results reflect the predominant assignment. Summary results are presented in Table 4.5.

This new methodology appears to be fairly replicable. A second person untrained in faunal analysis and untrained by the author except for reading the wear stages presented in Garniewicz (2000) produced results that agreed with those by the author on 43 out of 49 specimens. The remaining 6 specimens were off by only one age class and the variation was not directional, some were over-estimates and others were under-estimates. Statistically, the results of these ranked non-parametric data can be evaluated with pairwise correlations between observations. The correlation is extremely high, with Spearman's $r_s = 0.956$.

Table 4.5. Raccoon age profiles from Angel (percentage)

Researcher	(N)	Class I	Class II	Class III	Class IV	Class V
Garniewicz	(49)	12.2	36.7	22.4	18.4	10.2
Locklin	(49)	18.4	30.6	18.4	22.4	10.2

Results are based on three trials by each investigator. Technique used is Garniewicz (2000). Spearman's $r_s=0.956$.

Every attempt was made to produce a replicable methodology with wear stages similar to those of Grau et al. (1970). Despite this attempt, any users of these new criteria should be wary of attributing age ranges to the wear stages, since the stages presented here have not been tested against samples of known age. Further, in establishing their correlation between wear stages and known age individuals, Grau et al. (1970) used raccoons raised in captivity. Variations in diet are likely to cause significant differences in the rate of dental attrition. This is particularly true of raccoons since they may have wide variations in the quantity of abrasive material in their diet.

With this caveat, it is important to relate the wear stages to approximate ages in months to demonstrate that the age classes are of unequal duration. Based on the data provided by Grau et al. (1970), Table 4.6 shows the relationship between the new wear stages and probable ages. Because the wear stages are of unequal duration there may appear to be a higher percentage of individuals in an age class as a result of the age class representing a wider section of the population. The frequency density correction factor in the third column can be multiplied by the number of individuals in an age class to equalize the age classes into 20% increments of lifespan. Lifespan is calculated at 120 months.

Table 4.6. Hypothetical relationship between wear-stages and age

	Months	Percent Lifespan	Frequency Density Correction Factor
Class I	0-14	11.6	1.72
Class II	15-38	19.2	1.04
Class III	39-57	15.0	1.33
Class IV	58-86	23.3	0.86
Class V	87-120	27.5	0.73

Mortality data

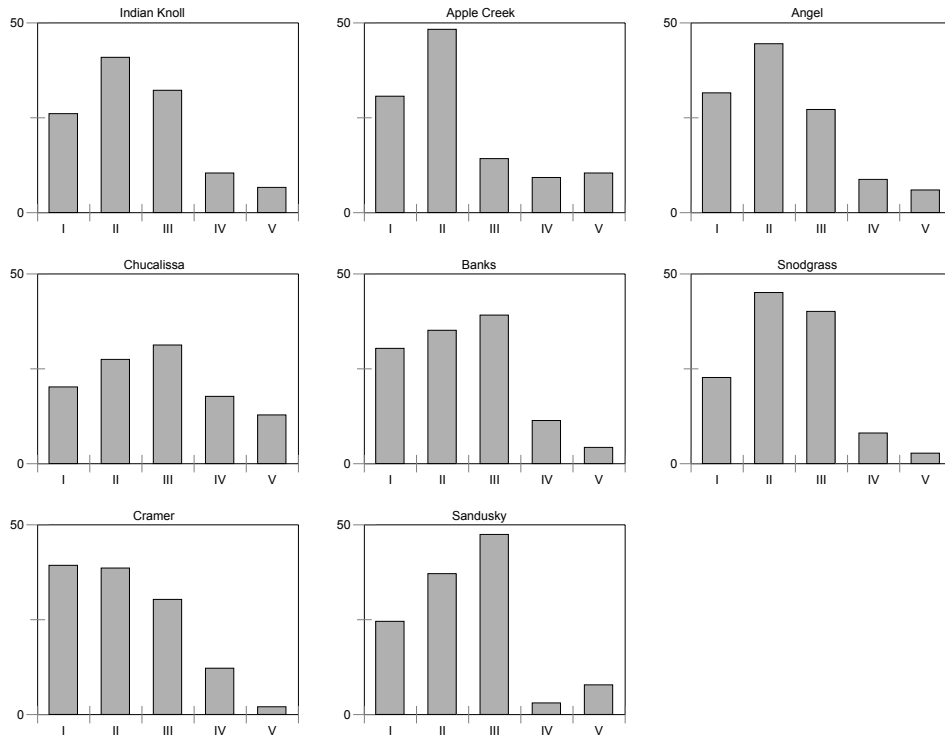
All data previously available to the author were published in Garniewicz (2000). These include sites with sample sizes under twenty and sites where the analysis did not follow the technique of Grau et al. This chapter focuses on samples with greater than 20 specimens. Previous work using the technique of Grau et al. (1970) has built up a data set of eight sites with sample sizes greater than 20 mandibles. Four of those sites were analyzed by the author during early stages of research (Garniewicz 2000). Due to intensive work on ageing raccoon mandibles using a new methodology, it is no longer possible to use Grau et al.'s stages without the imprint of this technique and further assessment following that technique was abandoned. Summary data on all of the sites analyzed using Grau et al.'s technique with sample sizes greater than 20 are presented in Table 4.7. These data, not using the new ageing technique proposed in this chapter, are included so that some previously examined sites may be included.

Table 4.7. Age classes of archaeological material using Grau et al. (1970). Raw data for sample sizes greater than 20.

Site	Reference	(N)	1	2	3	4	5
Indian Knoll	Garniewicz 2000	(33)	5	13	8	4	3
Apple Creek	Parmalee 1972	(28)	5	13	3	3	4
Angel	Garniewicz 2000	(49)	9	21	10	5	4
Chucalissa	Smith 1975	(34)	4	9	8	7	6
Banks	Smith 1975	(68)	12	23	20	9	4
Snodgrass	Smith 1975	(53)	7	23	16	5	2
Cramer	Garniewicz 2000	(35)	8	13	8	5	1
Sandusky	Garniewicz 2000	(28)	4	10	10	1	3

These results may be visualized more readily when they are converted to percentages and then adjusted by a frequency density correction. These adjustments are shown graphically in Figure 4.4.

Figure 4.4. Age classes of archaeological material using Grau et al. (1970) converted to percentages and adjusted with frequency density correction factor.



Work using the ageing techniques presented in this chapter has resulted in 5 mortality profiles with greater than 20 demi-mandibles and one mortality profile with less than 20 mandibles, which can be enlarged to a sample size of 20 by including ageable isolated teeth. These sites include one Late Archaic sample (Indian Knoll), a mixed Archaic and Woodland sample (Tick Creek), two Fort Ancient sites (Cramer Village and Sandusky Avenue), and two Middle Mississippian Sites (Angel and Murphy). The first

two samples are pre-maize, the Fort Ancient sites are swidden maize horticulturalist, and the Middle Mississippian sites are heavily maize dependent.

All of these mortality profiles have been compiled by a single experienced researcher, using a replicable technique. These data are presented in Table 4.8 and the results are shown graphically in Figure 4.5 converted to percentages and then adjusted by a frequency density correction factor.

Figure 4.5. Age classes of archaeological material using Garniewicz (2000); converted to percentages and adjusted for frequency density.

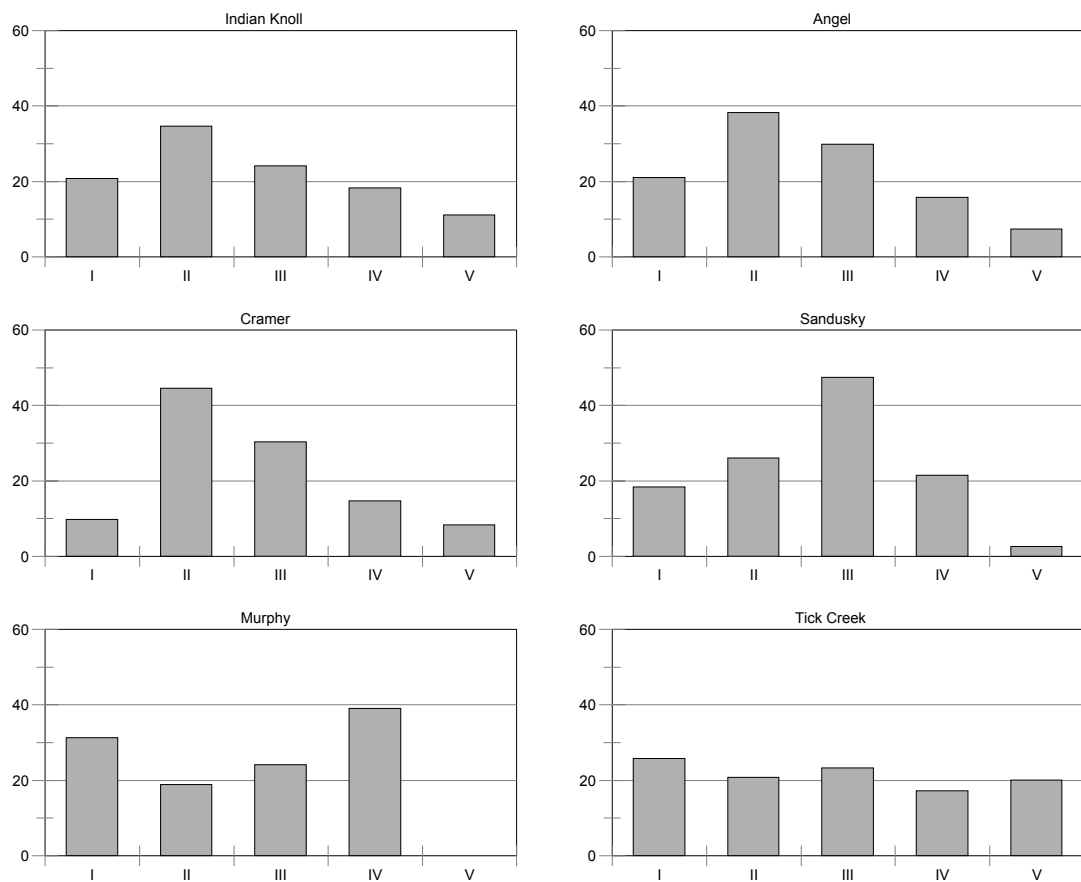


Table 4.8. Age classes of archaeological material using the methodology presented in Garniewicz (2000).

Site	Reference	N	1	2	3	4	5
Indian Knoll	Garniewicz 2000	33	4	11	6	7	5
Angel	Garniewicz 2000	49	6	18	11	9	5
Cramer	Garniewicz 2000	35	2	15	8	6	4
Sandusky	Garniewicz 2000	28	3	7	10	7	1
Murphy	This study mandibles	11	2	2	2	5	0
Murphy	This study teeth	20	5	4	4	6	1
Tick Creek	This study	40	6	8	7	8	11

Mortality analysis and discussion

Both statistical and ocular examination of the data on raccoon mortality profiles have failed to show any significant variation. While this was expected of the data based on Grau et al.'s technique, due to inter-observer error, it was anticipated that improved methodology applied to sites of various traditions would identify some variation in profiles. The absence of statistical significance holds true when the data are compared at the site level and when they are grouped by culture period. This failure to find significant difference remained even when age-classes were collapsed from five wear stages to two age groups (young and old adults).

The only visible trend seen in the data is that the first and sometimes second age classes are strongly under-represented when compared to modern populations. It is likely that taphonomic effects would override any over-representation of young individuals that may arise from trapping when compared to hunting.

The author is confident that this lack of significant variation is not due to the applicability of ageing raccoons by dental attrition, but rather from taphonomic effects

that reduce the representation of young individuals in these samples. Part of the problem may also relate to the fact that raccoons are r-selected and relatively few individuals ever make it to be old adults.

The new ageing methodology which shows early and late examples of wear within each stage is demonstrably more replicable than previous techniques which rely on matching archaeological examples to a single drawing and is proposed as a model for future dental wear studies.

Data on the distribution of raccoon by sex

The only other authors who have sexed archaeologically recovered raccoon canines are Hamblin (1973) and Smith (1975). Unfortunately raccoon canine width measurements are not included in their published reports, so clinal variation at previously studied sites cannot be controlled for. Both authors used a standard cutoff point of 4 mm. for separating males and females and this cutoff point is employed in the following analyses for purposes of comparability.

Based on the samples analyzed by the author, this cutoff point appears to be very effective in most samples examined. Raccoon sex distributions are presented in Table 4.9 using this cutoff point. Raccoon canine measurements for the four sites analyzed by the author are presented in Table 4.10. In a single instance, the Tick Creek sample, the 4.00 mm. cutoff point for males and females does not appear to follow the bimodal distribution of the data. Using z-scores to separate males and females results in a 4.03 cutoff point for males and females. Both of these results are presented in the table because this minor change in the cutoff point results in altering the sex identification of

four individuals and makes an observable change in the results. Using site-specific z-scores does not alter more than a single individual in any of the remaining samples.

Table 4.9. Sex distribution of archaeological material using canine width measurement of 4.0 mm as cutoff point.

Site	Culture period	Females (N)	Males (N)	Females (N)	Males (N)
Indian Knoll	Late Archaic	(10)	(8)	55.6	44.4
Cramer	Fort Ancient	(18)	(15)	54.5	45.5
Tick Creek	Archaic/Woodland ¹	(29)	(29)	50.0	50.0
Sandusky	Fort Ancient	(13)	(14)	48.1	51.9
Angel	Mississippian	(14)	(15)	48.3	51.7
Banks	Mississippian	(28)	(30)	48.3	51.7
Snodgrass	Mississippian	(10)	(13)	43.5	56.5
Tick Creek	Archaic/Woodland ²	(25)	(33)	43.1	56.9
Chuckalissa	Mississippian	(8)	(11)	42.1	57.9
Lilbourn	Mississippian	(6)	(8)	42.9	57.1
Turner	Mississippian	(3)	(4)	42.9	57.1
Murphy	Mississippian	(5)	(7)	41.7	58.3

¹ Tick Creek Sample using z-scores resulting in a 4.03 cutoff instead of 4.00 mm cutoff point

² Tick Creek sample using the standard 4.00 mm cutoff

Table 4.10. Width measurements of raccoon lower canines from archaeological sites.

Site	Width of lower canine in millimeters									(N)
	3.00 3.24	3.25 3.49	3.50 3.74	3.75 3.99	4.00 4.24	4.25 4.49	4.50 4.74	4.75 4.99	5.00 5.25	
Indian Knoll	1	5	5	3	2	8	3	2	0	(33)
Angel	0	5	3	2	4	2	1	1	0	(49)
Cramer	0	2	7	9	3	3	5	3	1	(35)
Sandusky	0	3	5	5	1	8	4	1	0	(28)
Murphy	1	0	1	3	2	2	1	2	0	(12)
Tick Creek	0	3	8	14	6	12	8	7	0	(58)

Sex analysis and discussion

As indicated by Grau et al. (1970) and Ritke and Kennedy (1993), raccoons have a bimodal distribution of canine width that is indicative of sex. An analysis of data from eleven sites indicates a distinct trend in the sex distribution of raccoon remains from archaeological contexts (Table 4.9). When sorted by the percentage of males vs. females ten of the eleven samples are also sorted by culture period, with the single exception being a mixed sample from Tick Creek.

Variation in canine width size is not statistically significant when analyzed across all sites or between individual sites. Even the two most dissimilar sites, Indian Knoll and Murphy, have a mean difference of less than 0.2 mm and no statistical difference ($P=0.314$). Part of the difficulty in attaining significant difference is that these comparisons are between bimodal distributions of continuous variables and are not suited to standard statistical tests. With this statistical caveat, the author believes that the results presented in Table 4.9 reflect a true variation in the pattern of exploitation seen over time. Failure to attain statistical significance may result from both the complexities of the data compared and the small sample sizes analyzed thus far.

When females outnumber males in a sample the distribution most closely resembles the natural sex structure of an adult raccoon population. This would indicate a non-selective method of raccoon procurement. When males outnumber females in a sample the procurement of raccoon must be employ a technique that is biased toward the number of males. Based on modern wildlife data, in hunting situations the number of females can be expected to exceed the number of males and in trapping situation the number of males can be expected to exceed the number of females.

Modern raccoon hunting is primarily conducted at night with the use of dogs to tree raccoons. Although Smith (1975:45) originally stated there was no ethnographic evidence that suggests aboriginal dogs were used for hunting in eastern North America, a more detailed review by Schwartz (1997) suggests that dogs had varied roles in hunting amongst hunter-gatherers across North America. Schwartz cites Howard (1965) on the use of dogs to hunt raccoons by the Ponca; however, there is no evidence of a similar use of dogs amongst eastern groups so we can presume that hunting at night would have been a relatively unproductive venture. Smith (1975:45) suggests two techniques that were probably used prehistorically. Raccoons were probably taken by the searching out of raccoon denning trees or the setting of traps along the margins of marshes, oxbow lakes, streams, etc.

Both of these techniques appear to have been in use in the Midwest in the last half of the eighteenth century. The captivity narrative (1755-1759) of Colonel James Smith who was taken captive and lived among the Caughnewaga, Wiandot and Ottawa in northern Ohio between 1755 and 1759 records both techniques. During the winter, Smith records taking raccoons out of hollow trees as an opportunistic activity, often on the return from failed deer hunts (Smith 1799:21). During maple sugar season he records making and attending traps for raccoons. His narrative follows.

”As the racoon is a kind of water animal that frequents the runs, or small water-courses, almost the whole night, we made our traps on the runs, by laying one small sapling on another and driving in posts to keep them from rolling. The upper sapling we raised about eighteen inches, and set so, that on the racoons touching a string, or a small piece of bark, the sapling would fall and kill it; and

lest the racoon should pass by, we laid brush on both sides of the run, only leaving the channel open.” (Smith 1799:52-53)

Of the eleven mentions of hunting raccoon, seven occur in October and November and probably relate to taking raccoons out of denning trees, four occur from January to April and probably relate to using deadfall traps.

The Late Archaic sample from Indian Knoll has the highest proportion of females. This may be due to the combined effect of fall-winter occupation and the predominant method of capture being non-selective. Juvenile mandibles of the white-tailed deer support the assumption that the site occupation was predominantly fall and winter. The proposed non-selective method of capture in this case is the removal of raccoons from denning trees in the winter when their denning holes are visible.

Tick Creek, which is a mixed Archaic and Woodland sample is anomalous using the 4mm criterion; however when adjusted for slightly larger female deer using either the bimodal distribution of widths or the z-scores of measurements, Tick Creek plots with 50% each of males and females. Parmalee (1965) does not discuss seasonality of the faunal remains from the rockshelter; however, he mentions mandibles from 24 deer aged less than six months; these would indicate June through November occupation at the shelter. Although most hunting activity was likely in the fall, spring or summer trapping of raccoon should not be discounted since there is some limited evidence of occupation during this period.

The two Fort Ancient sites examined showed mixed results. At the first site, Cramer village, females outnumber males probably due to the same non-selective procurement seen at Indian Knoll. At the second site, Sandusky Avenue, males

outnumber females, probably as a result of selective procurement. The Sandusky sample also includes one mandible with deciduous dentition that can be aged to between 78 and 106 days old at the time of death. The occurrence of a specimen that must have been taken during June or early July is also suggestive of trapping since it is difficult to locate denning trees during the summer and trapping is recorded ethnohistorically during this period.

In all seven Middle Mississippian samples males outnumber females. This distribution is much more typical of the trapped samples seen in modern wildlife biology studies. Even with small samples, the probability of all seven Middle Mississippian samples being biased towards males by chance is extremely low ($P=0.008$).

Despite the absence of significant differences in mortality profiles, the demonstrably strong trends in the sex distribution of raccoon at archaeological sites over time indicates a shift in procurement strategies. This shift from non-selective to selective procurement does not necessarily mean that one technology was completely replaced by another, but rather that the predominant mode of capture changes. This shift in hunting technique is discussed in detail in Chapter 5 and may relate to both changes in the seasonality and intensity of procurement.

Chapter 5

The Effects of Maize Agriculture on Prehistoric Hunting in Eastern North America

The data collected in this dissertation is focused on identifying population parameters of prehistoric animal populations using osteological measurements and specifically avoids using suppositions about prehistoric hunting techniques. Rather, these data are brought to bear on formulating suggestions as to how hunting patterns may have changed through time. Specifically addressed in the following section is how increased agricultural activity in eastern North America may have altered the procurement strategies of white-tailed deer and raccoon in very different ways.

Ethnohistoric data have been used to show that drives were a common form of capturing deer in the historic period (Webster 1979:817). Deer drives use either human beaters or lines of fire to drive deer toward an area where they are killed. Waselkov (1978:16-17) describes both of these techniques being used either to drive deer to water where they are dispatched from canoes or to drive them to clearings in the woods where they are killed by bow and arrow.

Often these drives were situated to take advantage of natural features to direct and isolate deer. In other cases intentional v-shaped funnel traps were created from brush. Samuel de Champlain witnessed an Iroquois deer drive into such a trap in late October 1615. He writes:

...we went to a spot some ten leagues away where our savages thought there were deer in great numbers. Some twenty-five savages...went into the woods near a little grove of firs where they made a triangular enclosure, closed on two sides, open on one. This enclosure was made of great wooden stakes eight or nine feet in height, joined close together, and

the length of each side was nearly fifteen hundred paces. At the extremity of this triangle there is a little enclosure, getting narrower the farther it goes, and partly covered with branches, with only one opening five feet wide, about the width of an average gate, by which the deer were to enter. They did so well that in less than ten days their enclosure was ready....When everything was completed, they set out half an hour before daybreak to go into the woods about half a league from their enclosure, keeping about eighty paces apart, each having two sticks which they strike together, walking slowly in that formation until they reach the enclosure. The deer, hearing this noise, flee before them until they reach the enclosure into which the savages force them to enter. Then the latter gradually coming together towards the opening of their triangle, they begin to shout and to imitate the cry of wolves, whereof there are many that devour deer. The deer, hearing this terrifying noise, are forced to enter the retreat by the small opening, whither they are very hotly pursued with arrows, and when they have entered, they are easily caught in this retreat, which is so well enclosed and barricaded that they can never get out of it. I assure you one takes eight days that we were there, they captured one hundred and twenty deer, with which they make good cheer, keeping the fat for the winter and using it as we do butter, and a little of the meat which they carry home for their feasts. They have other devices for catching deer, such as traps wherewith they cause the death of many (Champlain 1929[3]:82-85).

Stalking deer by wearing a decoy (antlered deerskin) is widely described in ethnographic accounts of deer hunts. The skill with which this deception was effected is revealed by John Lawson, who traveled extensively in the Carolinas in the early 1700s: "in these Habiliments (deerskin cape) an Indian will go as near a deer as he pleases, the exact Motions and Behaviour of a Deer being so well counterfeited by 'em, that several Times it hath been known for two Hunters to come up with a stalking head together, and unknown to each other, so that they have kill'd an Indian instead of a deer" (Lawson 1967:29).

Munson (1991) suggests that the novel appearance of this stalking technique to Europeans may result in an over-representation of this activity in the literature when compared to more familiar forms of hunting. Solitary hunting was also conducted by

luring with calls and antler rattling, baiting by cutting down white cedars, stalking without a decoy, stalking at night by canoe, snaring, and ambushing (McCabe and McCabe 1984; Munson 1991).

The only likely variation that different stalking techniques would contribute to a deer assemblage is an over-representation of males if decoys or lures were used to attract the aggressive male deer during the fall rut. Unfortunately the overall result of sex determination in prehistoric deer remains is unreliable for a number of reasons.

Two elements readily identify adult deer as male or female. The frontals with their antler attachments are the most obvious. Unfortunately the greatly increased strength of male frontals which result from antler growth and rutting activity makes them much more likely to be preserved in almost all assemblages (Loomis and Young 1912:23). The pelvis may also be used to determine sex. This method of determination requires excellent preservation of a bone that is inevitably destroyed by the processes of butchering, scavenging, burial or recovery. The relatively large males and relatively smaller females may be statistically separated based on osteological measurements (Purdue 1983a). This technique is problematic because the sexual dimorphism exhibited by deer is not great enough to create a bimodal size curve. Thus, using a discriminant function separates a unimodal curve into two sections. This technique presupposes a relatively even distribution of males and females so it would likely fail to identify samples that were predominantly male (Note: this is not a problem in using discriminant functions for subdividing raccoon samples because their distributions are demonstrably bimodal).

As a result of the difficulty in accurately determining the distribution of hunted animals by sex based on fragmentary archaeological materials it was decided that it was not possible to accurately discriminate between the various types of solitary hunting (stalking vs. still hunting). All varieties of solitary hunting may be contrasted to communal hunting, specifically deer drives, based on models of hunting efficiency.

Modern wildlife data demonstrate that the efficiency of drives, calculated as the number of deer captured per person per hour of work, is greatest when low numbers of people are involved and that efficiency is lowest when high numbers of people are involved (Wemmer and Stuwe 1985). Drives using between two and seven drivers resulted in returns of 2-10 deer per hour per driver. Drives using between 35 and 160 drivers returned between 0.11 and 0.54 deer per hour per driver, though part of this variation may be accounted for by variations in habitat structure. Deer drives are notoriously unsuccessful when deer are thinly scattered across the landscape and Wemmer and Stuwe only recommend drives for reducing dense populations of deer.

Waselkov (1978) proposes an evolution in hunting methods from stalking to drives based on the development of ranked societies. Smith (1980) also promotes drives originating in the Mississippian period as a result of increasing social complexity. These speculations are based equally on a misinterpretation of mortality profiles (Munson 1991) and a misunderstanding of the efficacy of drives.

An efficiency based model of hunting around major villages with depleted deer populations would suggest that the most effective way of procuring deer would have been using solitary hunting techniques. Because fewer than 10 individuals are required for a successful drive most Archaic populations, or even small family groups in the

Mississippian, would have contained the beaters required for a successful drive. Wemer and Stuwe further argue that large numbers of beaters make excessive noise and become increasingly difficult to organize (despite the social complexity of modern wildlife biologists). Stress creates unpredictable behavior in deer and drive methodology depends of predictable responses. When relatively small numbers of beaters are used the deer move steadily away. Thus, there are no requirements of social complexity that would exclude the use of drives in the Archaic or Woodland. As an efficient way of hunting, drive techniques were doubtlessly used in the Archaic and Woodland and may have continued into the Mississippian as a traditional form of hunting.

A possible problem in determining hunting techniques based on efficiency is that annual drives have historically served an integrative function for the group involved. Wasalkov (1978:25) provides an example where the Pamunkey Indians continued to hunt deer through drives from the early seventeenth century into the middle of the twentieth century in Virginia. Speck and Schaeffer (1950) speculate that this continuity affirmed the "Indianness" of the Pamunkey and that it was conducted as a matter of honor in fulfilling their 1677 treaty obligation with the General Assembly of Virginia.

Inherent in the application of these drives to the sparse and scattered deer population of Virginia in the 1930s and 1940s was failure from an economic standpoint. In 1938 and 1939 the Pamunkey killed two deer per year. In 1940 they killed a single deer. While one would suspect that these deer were both young and large, the effect of drives such as these in the overall subsistence strategy of a group would be considered insignificant.

Holland-Braund (1993:66) documents the decreased use of drives in hunting deer which paralleled decreasing deer populations in the Southeast. Deer mortality profiles and body-size estimates for Middle Mississippian deer are statistically indistinguishable from the heavily hunted examples from historic sites. The logical conclusion would be that at least around major sites the use of drives decreased in the Mississippian period.

Deer drives may have continued to be viable in two situations. One would be that they continue as in the case above for a non-subsistence function. This is not of concern here. The second situation is that deer in the Mississippian period are not evenly distributed across the landscape.

Hickerson (1965) and Watrall (1968) have proposed and documented the existence of a large contested area between the Chippewa and the Eastern Dakota in central Wisconsin. Hickerson predicted that the high deer density that characterized this transitional ecological zone with extensive forest-edge habitats led to conflicts between the Chippewa and Eastern Dakota. Deer were maintained in this area by the hostility-based exclusion of hunters, except for communal hunting undertaken by large parties prepared for conflict at any time (Hickerson 1963:43-45). Watrall (1968) documents the statistically significant difference in site density for this buffer zone when compared to neighboring regions during the Late Prehistoric and Protohistoric Periods (1200-800 AD). The buffer zone averages one site per 774 square miles and the surrounding areas average one site per 387 miles ($X^2=7.73$, $p=0.01$). Gramly (1977) suggests similar developments in the Northeast due to competition for deer hides.

It is then a reasonable expectation that buffer zones existed between Mississippian groups. The heavily defended Angel Site with its bastioned stockade wall provides

supportive evidence. I hypothesize that the Mississippian population which left faunal remains at the contemporary Rockhouse Hollow occupation was exploiting the dense population of deer which inhabited this *refugium*. These deer population parameters are supported by the small size and higher percentage of older age classes present at Rockhouse Hollow.

It is plausible that drives would have been used in this situation to exploit a dense population of deer in heavy cover. The possibility of conflict and the need to transport large quantities of meat back to a village site would also necessitate a fairly large group size. In all probability then the use of large numbers of beaters for drives in the Mississippian period would result from safety concerns related to increased interpersonal violence. Although related to ranked societies and social complexity, this does not appear to be what Waselkov and Smith were proposing.

Unfortunately due to the low percentage of Middle Mississippian sites in the uplands it was not possible to study another faunal sample from a similar situation. The difficulty of finding upland Mississippian sites may also provide support (albeit from negative evidence) of the possibility of a non- or seasonally-occupied buffer zone.

Although Muller (1986:223) has suggested that deer and other animals that exploit maize fields may have been taken as a result of field guarding in the Mississippian period, given our current understanding of deer population densities this seems an unlikely scenario. Since deer rapidly develop evasive tactics to avoid hunting, the procurement of deer from heavily hunted populations by guarding fields would be expected to be minimal.

At low deer population levels, raccoons, squirrels, crows and other birds rank as significant agricultural pests, and Marshall's argument (1987) for their increased exploitation parallel to agricultural development is sound. Neusius (1994) has demonstrated that garden hunting tends to be non-selective and should result in a diverse faunal assemblage. Deviations from the expected composition should be biased towards species that prefer garden habitats and/or are a significant threat to crops (Neusius 1996:276-277). These deviations may be identified by comparison to optimal resource utilization models or by comparison to pre-agricultural faunal samples.

As seen in Chapter 1, in the Late Prehistoric period raccoons show a strong increase in both their relative abundance and their level of exploitation based on optimal resource utilization models. This is in accord with their preference for garden habitats and their potential threat to agricultural crops. The changes seen in the population characteristics of this species through time are most likely related to garden hunting. Presumably their high fat content and corresponding caloric value create an added benefit.

Interpreting the hunting of raccoons by Middle Mississippian populations should consider the continuity of mortality profiles, the change in distribution by sex, and fit the economic model of Mississippians as agriculturalists.

Both authors previously studying the exploitation of raccoons by Middle Mississippian populations (Hamblin 1973; Smith 1975:42-52) erroneously interpret mortality profiles. Hamblin infers that the under-representation of young age classes is an indication of Mississippian hunters purposefully avoiding young animals so that they can reach their maximum weight at two years of age (Hamblin 1973:42). By allowing

these individuals to reproduce she also believes that this strategy ensures the propagation of the species. She also believes that the oldest individuals were avoided because of undesirable meat and pelt qualities. The naïve assumptions that cloud her interpretation are not in accord with Native American behavior in ethnohistoric accounts. Brightman (1987:123) has clearly demonstrated that there is a far greater body of evidence for extravagant exploitation amongst Native American groups than any conservation or intentional management of populations. This relates to both killing animals indiscriminately and in numbers beyond what can be reasonably utilized.

The prime-dominated model of raccoon hunting is also completely untenable given the impossibility of accurately ageing raccoons prior to killing them in a hunting situation and the impossibility of creating traps which selectively kill prime-aged individuals. Smith (1975:49) realizes this and states:

Deliberate sparing of young of the year raccoons by Middle Mississippi hunters is not a likely factor in low juvenile representation in raccoon kills: It would be quite difficult for Middle Mississippi hunters to identify juvenile raccoons older than seven months from older raccoons without resorting to close anatomical inspection.... The relatively high representation of the older age classes (animals five years or older) in the raccoon kills, especially at the Chucalissa site, suggests that the turnover rate of the raccoon populations was rather slow during the Mississippi period.

Neither of these studies examines non-Middle Mississippian raccoon samples and both are inherently flawed in their interpretation. Even if it was possible from a hunting perspective, it is beyond comprehension from an economic one that Middle Mississippian populations would allow young raccoons to continue depredating their maize crop for two years to maximize raccoon body weight. Mississippians were dependent on maize

productivity for survival and fattening raccoons is not an efficient use of agricultural crops.

The higher proportional presence of old individuals, like the under-representation of young is the result of age-correlated attrition of the more delicate juvenile mandibles. This taphonomic bias has been demonstrated to exist in the mandibles of larger ungulates (Munson 2000, Munson and Garniewicz 2003) and certainly exists in raccoons and other small mammals to an even greater degree (Payne and Munson 1985).

This study demonstrates that mortality profiles of raccoon, unlike those of deer, do not exhibit any variation through time. Therefore, interpretation of hunting patterns based on mortality profiles would be static. This view is in discord with other data that support a garden hunting model. An alternate explanation for mortality profiles of r-selected species is proposed.

Targeted hunting (or trapping) of raccoon should result in mortality profiles that parallel the live distribution of raccoon populations. This non-selective by age hunting of raccoons likely occurred throughout the entire prehistory of eastern North America. As a result, there is no significant difference between mortality profiles at any archaeological sites. Since raccoons have high reproductive rates (and correspondingly high mortality rates), increased levels of exploitation do not significantly alter the age structure of adults in the living population. Changes in the intensity of hunting may increase the proportions of young of the year; however, due to taphonomic problems with juvenile mandibles this is not possible to assess archaeologically.

Unlike deer populations, raccoon populations are resilient to over-exploitation and it is unlikely to have a significant impact on the age structure of living populations. With

r-selected species such as raccoon, young of the year make up approximately 50 percent of the total population; thus any variation in older age classes is swamped by the juvenile-adult difference.

While hunting raccoon results in a non-selective sampling of the population by sex, the population that is being sampled is naturally biased toward females. Trapping raccoon results in a procurement bias and assemblages that are male dominated. As demonstrated, raccoons exhibit a strong trend in the distribution of archaeological samples by sex. Archaic and Woodland samples are predominantly female biased and Middle Mississippian samples are all male biased. This differential representation by sex reflects a distinct change in procurement strategy of raccoon. Two techniques are recorded ethnohistorically; the removal of raccoons from denning trees, which results in a female biased sample, and the use of deadfall traps which results in a male biased sample.

The shift from hunting raccoons out of their dens in the Archaic to trapping at Middle Mississippian sites is an economically viable response to the problems associated with raccoons and maize agriculture. As documented in Chapter 4, the efficient removal of raccoons from their denning trees required the visibility provided by the fall loss of deciduous foliage. This strategy would only reduce raccoon populations after maize crops are harvested. Each remaining female gives birth to a litter about mid-April and all of these individuals are threats to both green and ripe maize in the field.

By additional trapping of raccoons in January through April and possibly continuing into the summer, the numbers of both old and young raccoons can be reduced, along with the corresponding loss of maize. This trapping activity is biased towards

males and results in the male-biased sex distributions of raccoon from Middle Mississippian sites.

Although not demonstrable by the data collected in this study, the increase in proportions of other small mammals (i.e. squirrels and rabbits) is probably also related to the resource depression of deer in the Late Prehistoric period. Unfortunately there are no identified skeletal characteristics that would permit the tracking of squirrel and rabbit population changes through time. Mortality profiles of these r-selected species are expected to respond like raccoon profiles and would provide little aid in understanding their populations. Probably the best and perhaps the only avenue for examining whether individual species are actually consuming maize is by looking at stable carbon isotopes in faunal remains.

Stable carbon isotopes

Stable carbon isotopes have been used extensively to examine the proportion of maize in human diets (Price 1989), but thus far have not been used to examine this same question with animal species. Presumably, if animals are a significant threat to crops, they may consume enough maize to alter the stable carbon isotope ratios in their bone collagen. The largest analyzed faunal sample consisted of 39 specimens of a range of species and was conducted to examine how consumption of various animals might be reflected in human isotope ratios (Katzenberg 1989).

Common native plants that use the C₃ pathway to fix carbon produce average $\delta^{13}\text{C}$ values of -26.5 ‰. Xeric environment grasses such as corn use the C₄ pathway to fix carbon and have average $\delta^{13}\text{C}$ values of -12.5 ‰. As the carbon in plants is

consumed and transferred to the bone collagen of the consumer, $\delta^{13}\text{C}$ values become enriched by approximately 5 ‰. By moving up an additional trophic level (herbivores consumed by carnivores) enrichment of another 1 ‰ can be expected (Chisholm 1989). Thus, C3 herbivores and carnivores should have values of -21.5 ‰ and -20.5 ‰ respectively and C4 herbivores and carnivores should have values of -7.5 ‰ and -6.5 ‰ respectively.

Enrichment of $\delta^{13}\text{C}$ may occur as the result of either an increase in trophic level or increased consumption of maize. Increased maize consumption does not increase the $\delta^{15}\text{N}$, whereas increased trophic levels results in an increase in $\delta^{15}\text{N}$. More complicated analysis may also include taking $\delta^{15}\text{N}$ isotope ratios.

A sample of 72 faunal specimens from the Angel site was analyzed by Dr. Mark Schurr at Notre Dame University. The results are presented in Appendix 5. Deer showed mean $\delta^{13}\text{C}$ values of -20.5 ‰, raccoon showed mean $\delta^{13}\text{C}$ values of -18.7 ‰, rabbit showed mean $\delta^{13}\text{C}$ values of -22.3 ‰ and squirrel showed mean $\delta^{13}\text{C}$ values of -18.5 ‰. These preliminary results suggest that deer and rabbit do not appear to be significant consumers of maize, but that raccoons and squirrels may be. Several dogs showed $\delta^{13}\text{C}$ values of approximately -10.6 ‰, indicating significant consumption of maize from either primary or secondary contexts.

Nitrogen isotope data were also determined for five specimens each of deer and raccoon. Deer nitrogen isotopes ranged from 3.99‰ to 5.31‰. Raccoon nitrogen isotope ratios ranged from 6.12‰ to 8.18‰. At a species level this seems to indicate that part of the increase in $\delta^{13}\text{C}$ may result from an increase in the trophic level or perhaps from consumption of aquatic resources. This does not seem to be the case at an individual

level, however, since the highest $\delta^{15}\text{N}$ value exhibits the lowest $\delta^{13}\text{C}$ value (possibly indicating a predominantly aquatic diet). The highest $\delta^{13}\text{C}$ values also have relatively low $\delta^{15}\text{N}$ values, possibly indicating limited maize consumption.

One possible avenue of exploration would be to look at stable carbon isotope ratios of fauna through time to examine if animal species truly are eating maize. As a result of observations here, further analysis of specimens from Indian Knoll (floodplain Archaic site) and Rockhouse Hollow (upland Archaic site) are underway so that variation in $\delta^{13}\text{C}$ through time may be examined.

The $\delta^{13}\text{C}$ enrichment for raccoon is only slightly higher than deer, indicating that this would be a relatively minor component in the overall raccoon diet. This is probably linked to the limited seasonal availability of maize to raccoons in contrast to the long-term availability of stored maize to humans (with $\delta^{13}\text{C}$ around -9‰). Based on modern behavioral models, squirrels may be more likely to depredate green and ripening maize and this may account for their high $\delta^{13}\text{C}$ values compared to rabbit.

Due to calibration problems with the mass spectrometer, these stable carbon isotope values are not accurate at the ppm level in these preliminary data, however work by Schurr and Garniewicz is ongoing to re-examine Mississippian samples from Angel and to compare them to Archaic samples from Indian Knoll and Rockhouse Hollow.

Chapter 6

Conclusions

Over the past several decades there has been a substantial evolution of zooarchaeological methodology and technique, beginning with the massive samples studied by Parmalee in the 1950s through the more complex studies of human ecology by Smith (1975) and Styles (2000). Regional studies suggest a number of possible explanations for changes in animal ecology and hunting strategies (Barfield and Barber 1992, Cleland 1976, Muller 1997) that have been evaluated in this study.

Previous approaches using a single measure such as taxonomic diversity or relative abundance provide a descriptive view of changes over time; however, they do not resolve the causal mechanisms for this change. Likewise, interpretations based solely on mortality profiles have failed to provide a unified conclusion. Because multiple factors may produce the variation seen in archaeological assemblages, the wide-ranging interpretations that result from examining single lines of evidence are not unexpected. More conclusive interpretations can be reached by utilizing multiple lines of evidence as is demonstrated by this dissertation.

Deer are the single most important game species in eastern North America, and, as a result they form a logical focus of analysis. As demonstrated by Styles (1981) deer remains at archaeological sites generally decrease in abundance over time. Purdue (1991) has independently shown that there are significant changes in white-tail deer body size over time. The research presented herein interprets how deer exploitation changed

over time based on the observed changes in relative abundance, body size, and mortality profiles.

Early in my studies of faunal remains I realized that deer bones from Mississippian archaeological sites were substantially larger than those of many modern comparative specimens. This observation led to more thorough research into variation in deer body size, which revealed that deer population density (as it affects access to high-quality forage) is the overriding factor in influencing deer size in most modern situations. Despite the recognition of this factor by virtually all wildlife biologists, there had been no application of this density-size relationship to the study of prehistoric remains. Would it be possible to use size as a measure of density and what other variables could be investigated to support this interpretation?

As I gathered modern comparative specimens as part of my research, it became clear that very few bucks in modern heavily-hunted situations are over 3 years of age while the less heavily hunted female deer may on occasion live up to 10 years of age. In these modern situations, with the effects of limited seasons, controls on the number of animals taken, trophy hunting, and the cultural desire to bag a big buck there is more variation by sex than would be expected in prehistoric situations. Yet, this provides an excellent model for survivorship in heavily hunted populations (modern males) versus lightly hunted populations (modern females). Thus, the second variable for investigating deer population dynamics was identified.

The fact that these variables, deer size and age at death, were both related to the density of deer is supported by modern wildlife studies. In regard to one of the most heavily studied deer populations, the George Reserve, McCullough writes “Record bucks

were produced not at high densities, which have the oldest individuals, but rather at the lowest densities [where there are very few old individuals] (1984:234).” Thus, in heavily hunted populations individual deer are large because deer densities are low relative to available forage and the population has few individuals living to old age because they are regularly culled. In less heavily hunted populations individual deer are smaller because densities are high relative to available forage and the population has more individuals living to old age.

In this study, a careful examination of 57 archaeological assemblages with white-tailed deer mortality profiles and 30 archaeological assemblages with calculated deer size also shows this relationship. In general, Archaic and Woodland sites have relatively small deer with a fair number of individuals living to old age. Most Mississippian, Protohistoric and Historic sites have relatively large deer where few individuals live to old age. This strongly supports a model where deer become a depleted resource as groups in eastern North America become dependent on agriculture and human population density increases. Yet this generalization obscures the most interesting finding of all.

This change in the deer age-size relationship seen over time is not continuous across the entire landscape. Rather, it is an artifact of the type of sites commonly chosen for investigation. Choosing sites with large well-preserved faunal assemblages results in a selection of Archaic rockshelters, Late Archaic shell middens and major Mississippian villages. The outlying Mississippian sites are overlooked in favor of their large counterparts. In order to avoid the problems associated with site types, a Mississippian rockshelter component was specifically targeted in this study.

The remains from Rockhouse Hollow (12 Pe 100) provide very specific data on how landscape use changes from the Archaic through the Mississippian. While Archaic deer from Rockhouse Hollow are relatively small and tend to be long lived, the Mississippian deer from Rockhouse Hollow are even smaller and have a greater proportion of old individuals than the Archaic sample. This is the exact opposite of what we see at contemporary major Mississippian villages, which contain larger, younger deer.

This finding contradicts previous models that correlate deer size to long-term environmental change. Instead, it suggests hunting pressures have substantially reduced deer populations that surround major Mississippian villages, but that deer in the hinterlands may be more densely populated and less heavily hunted than they were in the Archaic! This model supports the existence of a buffer zone between culture groups, where hunting was probably a high-risk activity of limited duration, likely undertaken in the fall or winter. These findings provide substantial support for the existence of buffer zones such as those proposed by Hickerson (1965), Watrall (1968) and Turner (1978).

This faunal evidence suggests that the requirements of increased human populations had a measurable impact on prehistoric deer populations. Overall, deer population densities decrease and the distribution of deer across the landscape appears to undergo reorganization. Densities of deer populations are lightest near major Late Prehistoric sites and are probably most dense in contested territories. As a result of patch depletion surrounding major sites, deer appear to form a smaller proportion of Late Prehistoric diets than they do during preceding periods.

As a result of cultural changes that impact deer populations, procurement strategies for deer also exhibit shifts from the Archaic to the Late Prehistoric. Deer

drives were likely used in the Archaic through Woodland, but probably decreased in number and efficiency near major settlements in the Late Prehistoric. The success of deer drives in the Late Prehistoric would be linked to high deer densities in contested territories which could only be exploited briefly and with large group sizes. In this particular situation large numbers of beaters in deer drives provide the additional benefit of security while within these zones.

As noted in Chapter 2, as the relative abundance of deer decreases, the abundance of small and medium mammals increases; however, an examination of relative abundance and fat content indicates a proportionally greater increase in mammals with a high fat content. Although the focus of the research presented here is on non-domesticated animals, Schwartz (1997:63) has linked increased consumption of dogs with a shift towards an agricultural way of life. Snyder (1991) has also demonstrated the nutritional importance of dogs as a food resource on the Plains, with the primary advantage of dogs being their high fat content. While outside the geographic area of concentration, the other significant sources of fat (ie preferred species) amongst Plains groups were raccoon and beaver (Snyder 1991:371).

This study independently identified raccoon as a key species, not just because of their high fat content, but also because of their penchant for maize and their ability to adapt to life in proximity to humans. Of all mammalian remains found at archaeological sites in the eastern United States, raccoon are second in abundance to white-tailed deer. As a result sample sizes are sufficient to examine their population parameters.

Although an investigation of raccoon mortality profiles proved not to be as successful as the examination of deer age at death, improved ageing methodology

demonstrates that these results are replicable. Varied representation of juveniles would have been the most likely indicator of changing procurement; however, this class was universally underrepresented due to taphonomic factors. The under-representation of older individuals in all samples is likely related to the naturally high reproductive and mortality rates of raccoon, not to human behavior.

Fortunately the distribution of raccoon remains by sex provided much more informative support to understanding their increase in relative abundance over time. Previous determinations of sex in raccoon remains had only examined Mississippian sites and had noted a predominance of males. This study examined Archaic, Woodland, Fort Ancient and Mississippian raccoon remains. While all Mississippian samples were male dominated, all Archaic and Woodland samples were female dominated. Fort Ancient sites were intermediate; with some being male dominated and others being female dominated.

The mechanism behind this shift is easily explained by understanding male vs. female raccoon behavior. Males tend to be more aggressive and less wary than females. As a result, they have both larger home ranges and higher mortality rates. Within a given area there are more females than males, and a random sampling of their population will result in a female dominated sample. Any capture technique that counts on raccoons making poor choices (re survival) is more likely to be biased towards males.

Archaic and Woodland procurement of raccoon therefore appears to be the result of a random sampling of the population. The most likely mechanism for this is the removal of raccoons from denning trees, one of the techniques documented as being in use at the time of contact. This strategy randomly samples the raccoons within a given

area and results in a female dominated assemblage. According to ethnohistoric accounts this technique is also opportunistic in that denning trees are observed in the course of other travels or activities, not deliberately sought out.

Late Prehistoric procurement of raccoons appears to differ from earlier techniques in being a targeted attempt to procure raccoons, most likely through trapping. Trapping of raccoons with either snares or deadfall traps is more likely to produce male dominated assemblages. This bias is well documented in modern wildlife studies and the most likely explanation for the male dominated assemblages observed in the Late Prehistoric. Since raccoon also increase in abundance at Late Prehistoric sites this shift in procurement strategies does not appear to impact their overall population structure, at least partially explaining the lack of observable variation in mortality profiles. The success of raccoon in this situation is an indication of their adaptability and perseverance, characteristics that likely led to their status as a pest species. Stable carbon isotope analysis by Schurr (this study) suggests that they may have been prehistoric crop-raiders.

While we see a shift in the predominant mode of raccoon procurement over time it is probable that at many prehistoric sites the recovered samples result from a combination of the opportunistic removal of raccoons from denning trees and deliberate trapping. Of particular interest is that the samples from Fort Ancient sites exhibit the only inconsistency in the sex bias of raccoon.

An examination of Oliver Phase, Fort Ancient, and Mississippian plant remains by Bush (2004) uses correspondence analysis to show distinct patterns of plant use between these groups. Fort Ancient sites form a very tight cluster with more balanced utilization of nuts and corn than other groups. While Bush notes that there is a lack of

agreement between her findings and stable carbon isotope data (Schurr 1998), with regards to the overall significance of maize, she makes an important point in regards to scheduling.

Central to the distinction of Oliver, Fort Ancient, and Mississippian plant use patterns may be a fall scheduling conflict between the use of nut resources and the demands of fall-maturing crops such as corns, beans and squash. As Bush aptly points out nut resources are also an important source of fat. “Nut resources were important to Oliver people. At most sites, hickory was favored over other nuts, probably for the ease with which oil could be extracted from the nuts (Talalay et al. 1984)” (Bush 2004:101).

If the nutshell/corn distinction does relate to a fall scheduling conflict, Bush proposes that some groups choose to process maize at that time while others focus on the mast crop, which may otherwise have been rapidly depleted by wildlife. In regards to raccoon procurement a decision may also have been made between investing time to protect maize fields from marauding raccoons vs. utilizing a host of potential wild resources and opportunistically procuring raccoons from their dens. The decisions regarding the importance of wild resources may thus extend well outside the season of harvest.

These decisions may also reflect the importance of total calories (agriculture) versus calories from fat (raccoon and nut resources). There is the additional possibility that while not a dietary necessity for certain Late Prehistoric groups, the raccoon was a highly valued food that could be targeted at the expense of more productive agricultural crops. If this was the case decisions regarding the hunting of raccoon (and perhaps

hunting in general) might be more open because populations are not dependent on corn agriculture for survival.

While I am skeptical of Classen's (1991) hypothesis that shell mounds were ceremonial constructs and that the meats were inconsequential, I would not be as hasty as she is to reject the hypothesis that the cessation of shellfishing 3000 years ago may be the result of a reallocation of women's labor from gathering shellfish to starchy seed horticulture. Instead I would argue that the scheduling of agricultural activities is even more complex than planting and harvesting and that garden hunting may have played a significant role in the reorganization of labor. Thus, the shift from opportunistic hunting of raccoon in the Archaic to deliberate trapping of raccoon in the Mississippian may reflect a more widespread change in the division of labor, where a greater percentage of overall food requirements, including meat protein, are the result of activities of women and children. Hunting of large animals with drives in the Mississippian may have ultimately had more significance for social rather than subsistence reasons.

To come full circle, as Reitz and Wing (1999) define zooarchaeology, it is a field of study that draws upon the knowledge of both biology (zoology) and anthropology (archaeology) and benefits both in return. The zooarchaeological models of resource intensification and depletion presented herein are proposed as species-specific studies tracking the interaction between humans and their environment as they affect key species. By examining prehistoric animal ecology, by simply being curious as to why Mississippian deer bones are larger than modern comparative specimens, we can gain valuable insight into patterns of human behavior that may otherwise have left little evidence in the archaeological record.

The work done in this dissertation would not be possible without the significant contributions of a number of other zooarchaeologists, Charles Cleland, Thomas Emerson, John Guilday, Paul Parmalee, Rick Purdue, Bruce Smith, Bonnie Styles, and many others. Like the work of my forebears, the methodology, data presentation and interpretation used in this study encourage continued additions of data and testing of the models presented herein. Future research will continue to shed more light on the dynamics of human-animal interactions as they have evolved in the Eastern Woodlands from the Archaic through the Late Prehistoric periods, continuing to unwind the complex relationship between prehistoric culture change and shifting animal population parameters.

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Appendix 1 Sites used for relative abundance study

Site	State	Reference	Culture	Didelphis virginianus	Ursus americanus	Procyon lotor	Mustela vision	Mustela frenata	Martes pennanti	Martes americana	Lutra canadensis	Mephitis mephitis	Mephitis negra	Spilogale putorius
Fairport Harbor	OH	Goslin (1943)	Fort Ancient	3	285	794	8					18		
Scaccia Site	NY	Guilday (1973)	Early Woodland		4	1								
Westheimer	NY	Guilday (1973)	Middle Woodland		20									
Sackett	NY	Ritchie (1973)	Late Woodland		14	1				1				
Nahrwold No. 1	NY	Guilday (1973)	Late Woodland		33					3				
Garoga Site	NY	Guilday (1973)	Protohistoric		201	5				1		2		
Chucalissa	TN	Parmalee (1960)	Mississippian	25	36	50	2					1	4	
Chucalissa	TN	Smith (1975)	Mississippian	56	13	183	7					2	18	
Chucalissa	TN	Smith (1975)	Mississippian			1								
Banks	AR	Smith (1975)	Mississippian	58	3	228	19					5	4	
Lilbourn	MO	Smith (1975)	Mississippian	2		57	9						2	
Lilbourn	MO	Smith (1975)	Mississippian	1		19								
Lilbourn	MO	Smith (1975)	Mississippian	1		83	3	1						
Turner	MO	Smith (1975)	Mississippian	4	2	36	1							
Snodgrass	MO	Smith (1975)	Mississippian	5		155	3						2	
Powers Fort	MO	Smith (1975)	Mississippian	4		13							5	
Gooseneck Site	MO	Smith (1975)	Mississippian	1		1								
Schultz	MI	Cleland (1966)	Early Woodland		2	1			1	1				
Schultz	MI	Cleland (1966)	Middle Woodland		8	6						4		
Schultz	MI	Cleland (1966)	Late Woodland		2	0								
Schultz	MI	Cleland (1966)	Woodland		35	35	4		7	3		10	2	
Juntunen	MI	Cleland (1966)	Woodland		7		1			1		11		
Moccasin Bluff	MI	Cleland (1966)	Woodland		4	18						2	2	
Tick Creek	MO	Parmalee (1965)	Archaic	36	11	440	2					9	145	4
Tick Creek	MO	Parmalee (1965)	Woodland	54	14	910	1					21	232	13
Raddatz	WI	Parmalee (1959)	Archaic			33		1	1	2				

Site	Taxidea taxus	Urocyon cinereo.	Vulpes fulva	Canis famil.	Canis lupus	Canis latrans	Canis sp.	Felis cougar	Felis concolor	Lynx rufus	Marmot a monax	Tamias striatus	Tamias. hudson.	Sperm. tridec.	Sciurus carolin.	Sciurus niger	Glauco. volans	Glauco. sabinus
Fairport Harbor		12		95				1		47	6	7			149	1		
Scaccia Site				2							8				6			
Westheimer		2			17		6			2								
Sackett		2		1	1					1	8	1			7			
Nahrwold No. 1		6		90	1					1	5	1						
Garoga Site		6	3	27	1						18	3	3		1			
Chucalissa				27	2				6	6					8	105		
Chucalissa				211	4				3	10	3				51	507		
Chucalissa				4											2	23		
Banks				95	1				1						20	18		
Lilbourn		3		1			10							1	23	86		
Lilbourn		1		2			2								13	8		
Lilbourn		5													72	29		
Turner		3		5							1				1	3		
Snodgrass		5		15											1	5		
Powers Fort		3		4												9		
Gooseneck Site		3													2	2		
Schultz				1														
Schultz				6							1							
Schultz				0														
Schultz				27							2							
Juntunen				196								26	2					
Moccasin Bluff			2	58	3					1	15				1			
Tick Creek		98		75	12				16	27	66	7			35	78	13	
Tick Creek	2	167		118	30	1			21	44	101	4			39	139	85	
Raddatz			2		33		20		1	2	33	55	27		25		26	1

Site	Castor canad.	Microtus penns.	Microtus ochrog.	Microtus sp	Clethr. gapperi	Blarina brevic.	Peromys cus sp.	Geomys bursar.	Neoto. florid.	Sigmodo hispidus	Oryzo. palustris	Synapt. cooperi	Ondatra zibethica	Erethiz. dorsat.	Sylvil. florid.	Sylvila. aquatic.	Sylvila. or Lepus	Sylvilag us sp.
Fairport Harbor	304	3												4	86	8		
Scaccia Site	2													1	1		1	
Westheimer	3													4				
Sackett														6	1			
Nahrwold No. 1	16	5					1							2	4			1
Garoga Site	208	1					16							6	1			
Chucalissa	11								2		6			1		87	19	4
Chucalissa	18								2	20	126			13		220	81	22
Chucalissa	1									1	5					5	2	
Banks	28										25			9		75	114	14
Lilbourn	2						2	1	1	19	75			35		63	46	22
Lilbourn	4										61			9		15	12	4
Lilbourn	3		3				16			37	122	9		7		9	78	
Turner	10							3						2		4	1	1
Snodgrass	4							19			1			3			1	1
Powers Fort	4							8								21	1	
Gooseneck Site	2													1			1	
Schultz	8													16				
Schultz	47													106				
Schultz	5													16				
Schultz	146			171			2					5	457					
Juntunen	245				5		23					4	1	10				
Moccasin Bluff	178												4	31	3			
Tick Creek	66							11	91				1		144			
Tick Creek	133			2			2	27	117			1		1	261			
Raddatz	20			5		1	4					2	3		24			

Site	Lepus americ.	Cervis canad.	Alces alces	Odocoileus virginianus	Rangifer tarandus	Cervidae	Scalopus aquatic.	Talpidae	Bat Sp.	Myotis sp.	Eptesicu s fuscus	Bison bison	Rattus norveg.	Unid. mammal	U. Small Mammal	U. Lg. Mammal
Fairport Harbor		324			1160											
Scaccia Site					313											
Westheimer			1		4567									2812		
Sackett					477											
Nahrwold No. 1	1	31			6227											
Garoga Site	1	44			1388											
Chucalissa					1803											
Chucalissa		1			3230		1								213	4515
Chucalissa					90		1								153	93
Banks					2832		25									
Lilbourn					504		1								431	694
Lilbourn					152										29	367
Lilbourn					335											
Turner					544		1								37	960
Snodgrass		1			3023		2								167	2047
Powers Fort					172										36	454
Gooseneck Site					224		2								35	720
Schultz					46											
Schultz		4			167											
Schultz		1			14											
Schultz		16			619											
Juntunen	37		10		4	8	13									
Moccasin Bluff		39			934			1								
Tick Creek		109			8683		2				4		3		1	
Tick Creek		176			15068		4		1		3	3	2		6	
Raddatz		34			4409		15			6	7					

Appendix 2

White-tailed deer Rockhouse Hollow Archaic (Kellar 1962)

Specimen #	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
1527-3490-1						1	1	1	1	L	2.5
1527-3490-2									1	L	1.5
1527-3512									1	R	4.5
1527-3525-1	1	1	1							R	0.5
1527-3525-2							1	1	1	R	0.5
1527-3525-3							1	1		R	1.5
1527-3544							1	1		L	5.5
1527-3573-1			1				1	1		L	1.5
1527-3573-2							1			R	1.5
1527-3573-3		1	1							L	1.5
1527-3575-1				1	1	1				R	3.5
1527-3575-2				1	1	1	1			L	3.5
1527-3611								1	1	R	2.5
1527-3621-1							1			L	1.5
1527-3621-2								1	1	L	2.5
1527-3621-3						1	1			L	3.5
1527-3720-1									1	R	1.5
1527-3720-2									1	L	4.5
1527-3737-1									1	R	4.5
1527-3737-2								1	1	L	6.5
1527-3737-3						1	1	1		L	2.5
1527-3737-4						1	1	1		L	2.5
1527-3867-1								1	1	L	1.5
1527-3867-2					1	1	1	1		L	0.5
1527-3894						1	1	1		L	3.5
1527-1214-1									1	R	1.5
1527-1214-2				1	1					R	4.5
1527-1243									1	R	3.5
1527-1624								1	1	L	1.5
1527-1625						1	1			L	5.5
1527-1657-1				1	1	1	1	1		L	4.5
1527-1657-2					1	1	1	1		L	3.5
1527-2102-1								1	1	R	2.5
1527-2102-2								1	1	R	3.5
1527-2070								1		R	3.5
1527-2168							1	1	1	L	1.5
1527-2115								1	1	L	5.5
1527-2200										L	0.5
1527-2199-1				1	1					L	3.5
1527-2199-2			1				1			L	0.5
1527-2673						1	1	1	1	L	6.5
1527-2187				1	1	1				R	9.5
1527-2673-2					1	1	1	1	1	L	9.5
1527-2684-1									1	R	3.5
1527-2684-2				1	1		1	1		R	4.5
1527-2684			1							R	0.5
1527-2689	1	1	1				1			L	0.5

Specimen #	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
1527-2753				1	1	1	1	1		R	2.5
1527-2707									1	R	2.5
1527-2710					1	1				R	9.5
1527-2753									1	L	2.5
1527-2738						1	1	1		R	6.5
1527-2772-1								1	1	L	2.5
1527-2772-2								1		L	3.5
1527-2806								1	1	R	2.5
1527-2801							1	1	1	R	1.5
1527-2777									1	R	0.5
1527-2812								1	1	R	4.5
1527-2829							1			R	1.5
1527-2880				1	1					R	6.5
1527-2882									1	R	3.5
1527-2876				1						R	1.5
1527-2926				1	1	1	1	1	1	R	7.5
1527-2936-1									1	R	2.5
1527-2936-2									1	R	4.5
1527-2936-3							1	1		R	4.5
1527-2936-4								1	1	L	4.5

White-tailed deer Rockhouse Hollow Mississippian (Kellar 1962)

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
1527-523-1						1	1	1		L	7.5
1527-523-2								1	1	R	3.5
1527-523-3				1	1	1	1			R	4.5
1527-612						1				L	2.5
1527-689					1					R	5.5
1527-778-1					1	1	1	1		R	6.5
1527-778-2				1	1	1				R	7.5
1527-778-3									1	R	4.5
1527-738					1	1	1	1		R	0.5
1527-730							1	1		L	5.5
1527-675							1	1		L	2.5
1527-901				1	1					R	2.5
1527-962			1				1	1		R	0.5
1527-1729					1					L	1.5
1527-2393						1				L	0.5
1527-3011							1	1		L	3.5
1527-3082					1	1	1			R	2.5
1527-3030									1	R	3.5
1527-3824-1					1	1				L	2.5
1527-3824-2						1	1			L	2.5
1527-3929-1									1	R	2.5
1527-3929-2									1	L	2.5
1527-3967							1			L	2.5
1527-3936									1	L	2.5

White-tailed deer Ouiatenon Historic (Martin 1986)

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
OUI-1					1	1	1	1	1	L	4.5
OUI-2	1	1	1				1	1		R	0.5
OUI-3						1	1	1	1	R	1.5
OUI-4				1	1	1	1	1	1	R	6.5
OUI-5									1	R	2.5
OUI-6					1	1	1	1	1	R	2.5
OUI-7					1	1	1	1	1	L	2.5
OUI-8	1	1	1				1	1	1	R	1.5
OUI-9				1	1	1	1	1	1	L	3.5
OUI-10							1	1		L	5.5
OUI-11	1	1	1				1	1		L	0.5
OUI-12							1	1	1	R	3.5
OUI-13						1	1	1	1	R	4.5
OUI-14							1	1	1	L	3.5
OUI-15	1	1	1				1			R	0.5
OUI-16											
OUI-17								1	1	R	4.5
OUI-18					1					L	4.5
OUI-19				1	1	1	1	1	1	L	7.5
OUI-20			1				1			L	0.5
OUI-21									1	R	2.5
OUI-22							1	1	1	L	5.5
OUI-23						1	1	1	1	R	3.5
OUI-24								1		R	2.5
OUI-25							1	1		L	1.5
OUI-26				1	1	1	1	1	1	L	4.5
OUI-27							1	1	1	R	8.5
OUI-28					1	1	1	1	1	R	1.5
OUI-29				1	1	1	1	1	1	R	5.5
OUI-30		1								R	0.5
OUI-31									1	L	1.5
OUI-32							1	1	1	R	9.5
OUI-33	1	1								L	0.5
OUI-34			1				1	1		R	1.5
OUI-35			1				1	1		L	0.5
OUI-36					1	1	1	1	1	L	4.5

White-tailed deer	Murphy			Mississippian				(Munson in press)			
Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
142.399.2									1	R	4.5
142.1.2					1	1				R	5.5
142.200.2						1				L	1.5
142.6.3			1							R	1.5
142.12.3							1			R	2.5
142.295.2				1	1	1	1			L	4.5
142.295.2			1							L	1.5
142.22.3			1							L	0.5
142.429.2	1	1	1							R	0.5
142.229.3	1	1								R	5.5
142.206.2					1	1	1	1	1	L	4.5
142.211.15			1							R	0.5
142.382.2						1	1			L	3.5
142.382.2			1							R	1.5
141.2968.1								1	1	R	5.5
141.2945.2					1	1				R	4.5
141.2958.3	1	1	1			1	1			R	0.5
141.2894.2					1	1	1	1	1	R	3.5
141.2896.3							1	1		L	2.5
141.2905.1					1	1	1	1	1	L	2.5
141.2908.2						1	1	1		L	1.5
141.2910.1									1	R	6.5
141.2916.1							1	1		R	1.5
141.2935.1				1	1	1				L	1.5
215.80.1.1								1	1	L	5.5
215.80.1.1							1	1		L	2.5
261.145					1	1				R	2.5

White-tailed deer Banks Mississippian (Smith 1975)

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
9-29		1	1				1			L	0.5
9-29			1				1			R	0.5
9-29					1	1	1	1		R	5.5
9-29				1	1	1	1	1	1	L	3.5
10-29									1	L	2.5
10-29	1	1								R	1.5
10-29		1	1							R	0.5
10-29							1	1		R	
10-29							1	1	1	L	2.5
10-29							1	1	1	L	1.5
10-29								1	1	R	3.5
10-29							1		1	R	1.5
10-29								1		L	1.5
10-29						1	1	1		R	4.5
10-29	1	1	1			1				L	0.5
10-29				1	1	1				R	6.5
10-29							1	1		L	2.5
10-29							1	1	1	L	1.5
10-29							1			L	4.5
10-29								1		L	2.5
10-29				1	1	1	1	1	1	L	5.5
10-29					1	1	1	1	1	L	6.5
10-29							1	1	1	L	4.5
10-29							1	1	1	R	1.5
10-29					1	1	1	1	1	L	3.5
10-29				1			1	1		R	1.5
10-29									1	L	1.5
10-29									1	L	2.5
10-29									1	L	0.5
10-29				1						R	1.5
10-29					1		1	1	1	L	5.5
10-29							1	1	1	R	1.5
10-29									1	R	6.5
10-29			1			1	1			R	0.5
10-29					1	1	1			L	2.5
10-29			1	1						L	5.5
10-29								1		L	1.5
10-29					1		1			R	5.5
10-29						1	1			L	3.5
10-29									1	L	1.5
10-29						1	1	1		R	3.5
10-29			1				1	1		L	0.5
10-29							1	1	1	L	2.5
10-29									1	L	2.5
10-29							1	1		L	6.5
10-29								1		L	2.5
10-29									1	L	2.5
10-29									1	R	6.5
10-29									1	L	1.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
10-29									1	L	1.5
10-29									1	L	1.5
10-29									1	L	2.5
10-29			1							L	1.5
10-29			1							R	1.5
8-29		1	1				1	1	1	R	0.5
None							1	1		L	2.5
None		1	1				1	1	1	L	1.5
None	1	1	1				1	1	1	L	1.5
None								1	1	L	2.5
None							1	1		R	3.5
None	1	1	1				1			L	1.5
None	1	1	1				1	1		L	0.5
None	1	1	1							L	1.5
None						1	1	1		R	2.5
None				1	1					L	2.5
None					1	1	1	1	1	L	3.5
None				1	1					R	3.5
None				1	1		1	1	1	R	1.5
7-29							1	1	1	R	1.5
None				1	1	1	1	1	1	L	2.5
None					1	1	1	1	1		1.5
None								1	1		1.5
None		1	1				1	1		L	0.5
None	1	1	1				1			R	1.5
None	1	1	1				1			R	0.5
None						1	1	1	1	R	3.5
None						1	1	1	1	R	3.5
None						1	1			L	2.5
None							1	1	1	R	3.5
None				1			1	1	1	L	1.5
None							1	1	1	R	3.5
None						1	1			R	2.5
None									1	L	3.5
None				1	1	1	1	1	1	R	1.5
None							1	1	1	R	1.5
None				1	1	1	1			L	4.5
None					1	1	1	1			3.5
None					1	1	1	1		R	6.5
None									1	R	4.5
None							1			L	1.5
None		1	1							L	0.5
None				1	1	1	1	1		R	7.5
None	1	1	1				1			R	0.5
None					1	1				L	2.5
None	1	1	1				1			L	0.5
None			1				1	1	1	L	1.5
None				1	1	1	1	1	1	R	3.5
None									1	R	1.5
None							1		1	R	1.5
None						1	1	1		L	3.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
None		1	1				1			R	0.5
None		1	1							L	0.5
None				1	1	1	1			R	3.5
None									1	L	3.5
None									1	R	4.5
None	1	1	1							R	1.5
None				1	1		1	1		L	1.5
None					1	1	1			L	2.5
None					1	1	1	1	1	R	3.5
None	1	1	1							R	1.5
None		1	1							L	0.5
None				1	1	1				R	4.5
None						1	1	1	1	R	5.5
None								1		R	2.5
None	1	1	1				1			L	0.5
None					1	1	1	1	1	L	6.5
None	1	1	1				1		1	L	1.5
None					1	1	1	1		L	3.5
None						1	1	1		L	3.5
None	1	1	1				1	1			0.5
None						1	1	1	1	R	3.5
None							1	1		R	2.5
None							1	1	1	R	1.5
None					1	1	1		1	R	2.5
None				1	1	1	1	1	1	L	2.5
None									1	R	4.5
None				1	1	1	1	1	1	L	2.5
None							1	1	1	L	2.5
None				1	1	1	1	1	1	R	2.5
None			1							L	1.5
None			1							L	1.5
None									1	R	1.5

White-tailed deer	Indian Knoll			Late Archaic				(Skaggs 1943)				
Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age	
1		1	1							L	0.5	
2		1	1							L	1.5	
3	1	1	1				1			L	0.5	
4			1				1			R	0.5	
5		1	1							R	0.5	
6		1	1							L	0.5	
7		1	1				1			L	1.5	
8			1							L	0.5	
9		1	1							L	1.5	
10			1				1			L	1.5	
11	1	1	1							R	0.5	
12		1	1							R	0.5	
13		1	1							L	0.5	
14	1	1	1							L	1.5	
15		1	1				1			R	1.5	
16	1	1	1							R	0.5	
17	1	1	1				1			R	0.5	
18			1				1			L	0.5	
19		1	1							R	0.5	
20	1	1	1							L	0.5	
21		1	1				1			L	0.5	
22			1				1	1		L	1.5	
23		1	1							L	0.5	
24		1	1							R	0.5	
25			1							L	0.5	
26			1		1		1			R	1.5	
27			1							R	1.5	
28		1	1							L	1.5	
29			1				1			R	1.5	
30	1	1	1							R	1.5	
31	1	1	1							R	0.5	
32	1	1	1							R	1.5	
33	1	1	1							L	1.5	
34			1					1		R	0.5	
35			1				1			L	1.5	
36			1				1	1		L	0.5	
37		1	1							R	0.5	
38		1	1				1	1	1	L	1.5	
39		1	1				1			L	1.5	
40		1	1				1			L	1.5	
41		1	1				1	1		L	1.5	
42		1	1				1			L	1.5	
43		1	1				1			L	0.5	
44		1	1				1	1		R	1.5	
45		1	1				1			L	1.5	
46		1	1				1			L	0.5	
47	1	1	1							L	0.5	
48	1	1	1							R	0.5	
49			1	1	1	1	1	1		R	1.5	
50			1			1	1	1		R	1.5	

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
51	1	1	1				1			R	1.5
52		1	1				1			R	1.5
53		1	1				1	1		R	0.5
54			1				1	1		R	1.5
55		1	1				1	1		R	1.5
56			1				1	1		R	0.5
57					1	1	1	1		L	1.5
58					1	1	1			R	1.5
59							1	1		L	1.5
60		1				1	1	1		L	1.5
61					1		1	1		R	1.5
62					1		1			L	1.5
63					1	1	1			R	1.5
64					1					R	1.5
65				1						L	1.5
66				1						R	1.5
67		1								R	1.5
68		1				1				L	1.5
69		1	1							R	1.5
70			1							R	0.5
71				1	1	1	1	1	1	L	6.5
72				1	1	1	1	1	1	L	2.5
73				1	1	1	1	1	1	L	3.5
74				1	1	1	1	1	1	L	2.5
75				1	1	1	1	1	1	R	3.5
76				1	1	1	1	1	1	R	6.5
77				1	1	1	1	1	1	L	5.5
78				1	1	1	1	1	1	L	4.5
79				1	1	1	1	1	1	R	7.5
80					1	1	1	1	1	L	3.5
81					1	1	1	1	1	R	2.5
82					1	1	1	1	1	L	2.5
83				1	1	1	1	1	1	L	3.5
84				1	1	1	1	1	1	R	2.5
85				1	1	1	1	1	1	R	3.5
86				1	1	1	1	1	1	R	6.5
87				1	1	1	1	1	1	R	3.5
88				1	1	1	1	1	1	R	2.5
89				1	1	1	1	1	1	R	2.5
90				1	1	1	1	1	1	R	3.5
91				1	1	1	1	1	1	R	2.5
92				1	1	1	1	1	1	R	5.5
93				1	1	1	1	1	1	R	3.5
94				1	1	1	1	1	1	R	8.5
95					1	1	1	1	1	L	6.5
96				1	1	1	1	1		L	5.5
97					1	1	1	1		L	2.5
98					1	1	1	1		L	5.5
99					1	1	1	1		L	2.5
100				1	1	1	1	1	1	L	5.5
101					1	1	1	1		L	4.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
102				1	1	1	1	1		L	2.5
103					1	1	1	1		L	3.5
104					1	1	1	1		L	3.5
105					1	1	1	1		L	3.5
106				1	1	1	1	1		L	2.5
107					1	1	1	1	1	L	5.5
108				1	1	1	1	1		L	2.5
109				1	1	1	1	1		L	5.5
110					1	1	1	1		L	5.5
111					1	1	1	1		L	2.5
112				1	1	1	1	1		L	2.5
113					1	1	1	1		L	2.5
114					1	1	1	1		L	3.5
115					1	1	1	1		L	6.5
116				1	1	1	1	1		L	3.5
117					1	1	1	1	1	L	3.5
118				1	1	1	1	1		L	5.5
119				1	1	1	1	1		L	2.5
120					1	1	1	1	1	L	2.5
121							1	1	1	R	3.5
122								1	1	L	3.5
123								1	1	R	3.5
124								1	1	L	1.5
125								1	1	L	3.5
126								1	1	L	4.5
127								1	1	L	1.5
128								1	1	R	3.5
129								1	1	L	3.5
130								1	1	R	6.5
131								1	1	L	1.5
132								1	1	L	4.5
133								1	1	R	4.5
134							1	1	1	R	2.5
135								1	1	L	6.5
136								1	1	R	4.5
137								1	1	L	5.5
138								1	1	R	1.5
139								1	1	R	2.5
140								1	1	R	2.5
141								1	1	L	1.5
142								1	1	R	3.5
143							1	1	1	L	7.5
144								1	1	R	2.5
145								1	1	R	2.5
146								1	1	R	2.5
147								1	1	L	3.5
148								1	1	L	1.5
149								1	1	R	2.5
150								1	1	L	2.5
151								1	1	R	5.5
152							1	1	1	R	1.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
153								1	1	L	3.5
154								1	1	L	3.5
155								1	1	L	5.5
156								1	1	R	2.5
157								1	1	L	4.5
158								1	1	R	3.5
159								1	1	R	3.5
160								1	1	R	1.5
161							1	1	1	L	3.5
162								1	1	L	5.5
163								1	1	R	6.5
164								1	1	R	2.5
165							1	1	1	R	1.5
166								1	1	L	5.5
167								1	1	L	2.5
168								1	1	R	1.5
169								1	1	L	2.5
170								1	1	L	4.5
171								1	1	R	3.5
172								1	1	L	3.5
173								1	1	R	2.5
174								1	1	L	2.5
175								1	1	R	3.5
176								1	1	L	4.5
177								1	1	R	4.5
178								1	1	R	2.5
179								1	1	R	3.5
180								1	1	L	3.5
181								1	1	R	5.5
182								1	1	R	6.5
183								1	1	R	3.5
184								1	1	L	3.5
185								1	1	R	4.5
186								1	1	L	2.5
187								1	1	R	5.5
188								1	1	L	7.5
189								1	1	R	2.5
190								1	1	R	3.5
191							1	1	1	L	1.5
192								1	1	L	4.5
193								1	1	L	2.5
194								1	1	L	2.5
195								1	1	L	2.5
196								1	1	L	4.5
197								1	1	L	3.5
198								1	1	R	2.5
199								1	1	R	3.5
200								1	1	R	4.5
201								1	1	R	3.5
202								1	1	R	4.5
203								1	1	R	3.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
204								1	1	R	1.5
205								1	1	R	3.5
206								1	1	L	3.5
207						1	1	1	1	L	5.5
208								1	1	R	1.5
209								1	1	L	6.5
210							1	1	1	L	2.5
211								1	1	L	2.5
212									1	R	6.5
213								1	1	R	4.5
214								1	1	L	1.5
215								1	1	L	6.5
216								1	1	R	2.5
217								1	1	L	3.5
218								1	1	L	2.5
219								1	1	R	4.5
220								1	1	R	3.5
221								1	1	R	1.5
222								1	1	R	2.5
223									1	L	5.5
224									1	R	3.5
225									1	R	2.5
226									1	R	3.5
227									1	L	2.5
228									1	R	2.5
229									1	L	2.5
230									1	R	3.5
231									1	R	5.5
232									1	L	3.5
233									1	L	3.5
234									1	L	2.5
235									1	L	3.5
236									1	R	6.5
237									1	L	2.5
238								1	1	L	1.5
239									1	R	3.5
240									1	R	4.5
241									1	L	5.5
242								1	1	R	2.5
243									1	R	3.5
244									1	L	3.5
245									1	L	6.5
246									1	R	3.5
247									1	L	2.5
248									1	L	2.5
249					1	1	1	1		R	4.5
250					1	1	1	1		R	3.5
251					1	1	1	1		L	6.5
252					1	1	1	1		R	2.5
253				1	1	1	1			L	3.5
254					1	1	1	1		R	2.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
255					1	1	1	1		R	6.5
256				1	1	1	1	1		R	2.5
257					1	1	1	1		R	4.5
258				1	1	1	1	1		R	3.5
259				1	1	1	1	1		R	6.5
260				1	1	1	1	1		R	2.5
261					1	1	1	1		R	2.5
262				1	1	1	1	1		R	3.5
263				1	1	1	1	1		R	3.5
264				1	1	1	1	1		R	3.5
265				1	1	1	1	1	1	R	3.5
266				1	1	1	1	1		R	2.5
267				1	1	1	1			L	3.5
268				1	1	1	1			L	5.5
269				1	1	1	1	1		R	5.5
270				1	1	1	1			L	3.5
271					1	1	1	1		R	4.5
272					1	1	1	1	1	R	3.5
273					1	1	1	1		L	2.5
274				1	1	1	1	1		L	3.5
275					1	1	1			L	3.5
276					1	1	1			L	3.5
277				1	1	1	1			L	4.5
278				1	1	1	1			L	3.5
279					1	1	1			L	4.5
280				1	1	1	1			L	2.5
281				1	1	1	1			L	2.5
282				1	1	1	1			L	2.5
283				1	1	1	1			L	3.5
284				1	1	1	1			L	5.5
285				1	1	1	1			L	3.5
286				1	1	1	1			L	6.5
287					1	1	1			L	2.5
288					1	1	1	1		L	2.5
289					1	1	1	1		L	2.5
290					1	1	1			L	2.5
291				1	1	1	1			L	3.5
292					1	1	1			L	2.5
293					1	1	1	1		L	3.5
294				1	1	1	1			L	4.5
295				1	1	1	1			L	2.5
296				1	1	1	1			L	5.5
297				1	1	1	1			L	2.5
298					1	1	1			L	7.5
299					1	1	1			L	4.5
300				1	1	1	1			L	3.5
301				1	1	1	1			L	5.5
302				1	1	1	1	1		L	3.5
303					1	1	1	1		L	3.5
304				1	1	1	1			L	2.5
305					1	1	1			L	3.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
306					1	1	1			L	2.5
307					1	1	1	1		L	4.5
308					1	1	1			L	2.5
309				1	1	1	1	1		L	5.5
310					1	1	1			L	2.5
311					1	1	1			L	4.5
312				1	1	1	1			L	2.5
313					1	1	1			L	4.5
314					1	1	1			L	7.5
315					1	1	1			L	3.5
316				1	1	1				L	5.5
317				1	1	1				L	2.5
318				1	1	1				L	5.5
319				1	1	1				L	2.5
320				1	1	1	1			L	3.5
321				1	1	1				L	2.5
322				1	1	1				L	3.5
323				1	1	1	1			L	4.5
324				1	1	1				L	3.5
325				1	1	1				R	2.5
326				1	1	1	1			L	6.5
327				1	1	1				L	7.5
328				1	1	1				L	2.5
329				1	1	1				L	3.5
330				1	1	1				L	4.5
331				1	1	1				L	4.5
332				1	1	1	1			L	2.5
333				1	1	1				L	6.5
334				1	1	1				L	7.5
335				1	1	1				L	6.5
336				1	1	1	1	1		R	2.5
337				1	1	1				L	1.5
338					1	1	1			R	3.5
339				1	1	1	1			R	5.5
340				1	1	1	1			R	2.5
341				1	1	1	1			R	2.5
342					1	1	1			R	5.5
343				1	1	1	1			R	4.5
344				1	1	1				L	4.5
345				1	1	1	1			R	3.5
346				1	1	1	1			R	3.5
347					1	1	1			R	6.5
348				1	1	1				L	3.5
349					1	1	1			R	6.5
350				1	1	1	1			R	2.5
351				1	1	1	1	1		R	3.5
352				1	1	1	1			R	6.5
353				1	1	1	1			R	2.5
354				1	1	1	1			R	4.5
355				1	1	1	1			R	9.5
356					1	1	1			R	4.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
357					1	1	1			R	3.5
358					1	1	1			R	4.5
359					1	1	1	1		R	6.5
360				1	1	1	1			R	3.5
361					1	1	1			R	8.5
362				1	1	1	1	1		R	6.5
363				1	1	1	1			R	5.5
364				1	1	1				R	2.5
365				1	1	1				L	3.5
366					1	1				L	3.5
367				1	1	1				R	4.5
368					1	1				L	3.5
369				1	1	1				L	2.5
370					1	1				L	3.5
371					1	1	1			R	3.5
372					1	1	1			L	3.5
373					1	1				R	4.5
374					1	1				R	2.5
375				1	1	1				R	2.5
376					1	1				L	6.5
377				1	1	1				R	6.5
378					1	1				L	10.5
379					1	1				R	6.5
380				1	1	1				L	2.5
381				1	1	1				R	3.5
382					1	1				R	3.5
383					1	1				R	3.5
384				1	1	1				L	4.5
385					1	1				L	2.5
386					1	1				R	3.5
387					1	1				L	9.5
388					1	1				L	5.5
389				1	1	1				R	3.5
390				1	1	1				L	3.5
391					1	1				R	5.5
392					1	1				L	4.5
393				1	1	1				R	3.5
394				1	1	1				R	5.5
395					1	1	1			L	2.5
396					1	1				R	6.5
397					1	1				R	4.5
398					1	1				R	3.5
399					1	1				L	5.5
400					1	1				R	2.5
401					1	1				R	3.5
402					1	1				R	2.5
403					1	1				L	3.5
404					1	1				L	5.5
405				1	1	1				L	4.5
406					1	1				L	3.5
407				1	1	1				L	4.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
408				1	1	1				L	4.5
409					1	1				R	4.5
410				1	1	1				R	6.5
411					1	1				L	4.5
412					1	1				L	3.5
413				1	1	1				L	3.5
414				1	1	1				R	6.5
415					1	1	1			L	10.5
416				1	1	1				L	4.5
417					1	1	1			R	8.5
418					1	1				L	2.5
419				1	1	1				R	4.5
420					1	1	1			R	3.5
421					1	1	1			R	5.5
422				1	1	1	1			L	11.5
423					1	1				L	3.5
424					1	1				R	2.5
425					1	1				L	4.5
426					1	1	1			R	3.5
427				1	1	1	1			R	4.5
428				1	1	1	1			R	4.5
429					1	1	1			R	2.5
430					1	1	1			R	8.5
431				1	1	1	1			R	3.5
432				1	1	1	1			R	3.5
433					1	1	1			R	2.5
434				1	1	1				R	5.5
435				1	1	1				L	4.5
436				1	1	1				L	2.5
437				1	1	1				R	2.5
438				1	1	1				R	2.5
439				1	1	1				R	6.5
440				1	1	1	1			R	4.5
441				1	1	1				R	2.5
442				1	1	1				R	9.5
443				1	1	1				R	6.5
444				1	1	1				R	2.5
445				1	1	1				R	5.5
446				1	1	1				R	6.5
447					1	1				R	3.5
448				1	1	1	1			R	2.5
449				1	1	1	1			R	7.5
450				1	1	1				L	4.5
451				1	1	1				L	2.5
452				1	1	1				R	2.5
453				1	1	1				R	2.5
454				1	1	1	1			R	5.5
455				1	1	1				R	4.5
456				1	1	1				R	5.5
457					1	1				R	4.5
458					1	1	1			R	6.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
459				1	1	1				R	4.5
460				1	1	1				R	3.5
461				1	1	1	1			R	3.5
462				1	1	1				R	1.5
463					1	1	1			R	2.5
464				1	1	1				R	2.5
465				1	1	1				R	2.5
466				1	1	1	1			R	8.5
467				1	1	1	1			R	2.5
468				1	1	1				R	2.5
469				1	1	1				R	2.5
470					1	1	1			R	4.5
471				1	1	1				R	8.5
472				1	1	1				R	3.5
473					1	1	1			R	3.5
474				1	1	1				R	6.5
475				1	1	1				R	5.5
476				1	1	1				R	4.5
477				1	1	1				R	2.5
478				1	1	1				R	7.5
479				1	1	1				R	5.5
481					1	1	1			R	6.5
482				1	1	1				R	2.5
483				1	1	1				R	9.5
484				1	1	1	1			R	3.5
485				1	1	1	1			R	2.5
486				1	1		1			R	4.5
487						1				R	4.5
488				1	1	1	1			L	5.5
489							1			R	3.5
490							1			L	2.5
491							1			R	2.5
492								1	1	L	2.5
493							1	1		R	4.5
494							1			L	2.5
495							1			R	5.5
496								1		R	3.5
497							1			L	2.5
498							1			R	3.5
499							1			R	3.5
500						1				L	4.5
501							1			R	4.5
502								1		R	1.5
503								1		R	3.5
504								1		L	3.5
505							1			L	4.5
506								1		R	2.5
507				1	1	1	1			L	6.5
508					1					R	5.5
509							1			R	7.5
510								1		L	2.5

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
511						1				R	3.5
512							1			L	2.5
513								1		L	2.5
514		1								L	0.5
515	1									L	3.5

White-tailed deer	Blain			Mississippian								
Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age	
U1 B7/8							1	1	1	R	2.5	
U1 B7/8									1	R	7.5	
U1 B7/8	1	1	1				1			L	0.5	
U2 B7/8			1	1			1			L	0.5	
U2 B7/8	1	1	1							R	0.5	
U3 B7/8							1	1	1	L	1.5	
P6 B8/8							1	1	1	L	5.5	
P6 B8/8							1	1	1	R	2.5	
U3 H1 B8/8				1	1	1	1	1	1	L	1.5	
U3 H1 B8/8			1	1			1	1	1	L	1.5	
U3 H1 B8/8				1	1	1	1	1	1	R	5.5	
U3 H1 B8/8							1	1	1	L	3.5	
U3 H1 B8/8				1	1	1				R	3.5	
P Bach B8/8	1	1	1				1	1	1	R	1.5	
U3 B8/8	1	1	1				1	1	1	R	1.5	
U3 B8/8				1		1	1	1	1	L	2.5	
U3 B8/8					1	1	1	1	1	R	3.5	
U3 B8/8					1	1	1	1	1	R	2.5	
U3 B8/8	1			1	1					L	1.5	
U3 B8/8				1	1	1	1			L	4.5	
U3 B8/8			1			1	1			R	1.5	
P Schubert B8/8								1	1	L	3.5	
P Schubert B8/8				1	1	1	1	1	1	L	3.5	
P Schubert B8/8									1	L	1.5	
P Schubert B8/8						1	1	1	1	R	4.5	
P 4 B8/8			1		1	1	1	1	1	L	1.5	
P 4 B8/8					1	1	1	1	1	R	1.5	
P Mozart B8/8				1	1	1	1	1	1	R	5.5	
P Mozart B8/8				1	1	1				L	5.5	
U2 B8/8				1	1					L	1.5	
U2 B8/8							1			L	0.5	
U2 B8/8	1	1	1							R	0.5	
U2 B8/8			1				1	1	1	R	1.5	
U2 B8/8				1	1	1	1			L	2.5	
U2 B8/8				1	1	1	1	1	1	L	2.5	
U2 B8/8		1	1				1	1		L	0.5	
U2 B8/8								1		L	3.5	
U2 B8/8			1				1			R	1.5	
U2 A4/A5									1	R	2.5	
U2 A4/A5				1	1	1				R	4.5	
U2 A4/A5						1	1			L	5.5	
U2 A4/A5									1	L	1.5	
U2 A4/A5									1	R	1.5	
U2 A4/A5									1	R	3.5	
U2 A4/A5	1	1								L	1.5	
U2 A4/A5			1							R	0.5	
U2 A4/A5			1							R	0.5	
U3 H1 Tr2									1	R	1.5	
U3 H1 Tr2									1	R	5.5	
U3 H1 Tr2									1	L	1.5	

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
U3 H1 Tr2									1	R	1.5
U3 H1 Tr2									1	R	2.5
U3 H1 Tr2			1							R	1.5
Unknown									1	L	1.5
Unknown			1							R	0.5

White-tailed deer Angel Mississippian (Black 1967)

Catalog number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
1					1	1	1			L	4.5
2				1	1	1	1			R	3.5
3						1	1	1	1	R	4.5
4				1		1	1	1	1	L	2.5
5							1	1	1	L	7.5
6	1	1	1				1	1	1	L	1.5
7		1	1				1			R	0.5
8				1	1	1				R	4.5
9				1	1	1	1	1	1	R	4.5
10							1	1	1	L	3.5
11					1	1	1	1	1	R	5.5
12						1	1	1	1	R	6.5
13							1	1	1	L	1.5
14							1	1	1	R	2.5
15	1	1	1							R	0.5
16				1	1	1	1	1	1	L	2.5
17				1	1	1	1				3.5
18								1	1	L	9.5
19											
20				1		1	1	1	1	R	5.5
21	1	1	1							R	0.5
22								1	1	L	3.5
23						1	1	1		R	8.5
24				1	1	1	1	1	1	L	2.5
25				1	1	1	1			L	2.5
26								1		R	2.5
27		1								L	1.5
28								1		L	1.5
29								1		L	2.5
30							1		1	L	1.5
31									1	R	6.5
32									1	L	3.5
33									1	L	4.5
34								1		R	6.5
35				1						R	1.5
36									1	R	2.5
37		1								R	0.5
38				1						R	1.5
39							1	1	1	L	7.5

White-tailed deer	Bell			Historic							
Catalog Number	D2	D3	D4	P2	P3	P4	M1	M2	M3	S	Age
1				1	1	1	1			R	6.5
2					1					R	0.5
3							1			L	1.5
4	1	1	1				1	1		L	0.5
5	1	1	1				1			R	0.5
6					1	1	1	1	1	R	2.5
7				1	1	1	1			R	3.5
8				1	1	1	1			L	5.5
9				1	1	1	1			L	3.5
10				1	1	1	1	1	1	L	3.5
11								1	1	R	4.5
12				1	1			1	1	L	2.5
13							1	1	1	L	2.5
14								1	1	L	3.5
15					1	1	1			L	3.5
16				1	1	1	1			L	3.5
17			1							L	0.5
18									1	L	2.5
19									1	L	3.5

Appendix 3

White-tailed deer	Rockhouse Hollow			Archaic		
Specimen #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
1527-AST1	2.50	3.97	2.37	4.31	2.74	3.46
1527-AST2	2.23	3.97	2.26	4.16	2.71	3.37
1527-AST3	2.09	3.56	2.17	3.91	2.30	3.06
1527-AST4	2.14	3.78	2.12	4.01	2.40	3.27
1527-AST5	2.36	4.03	2.33	4.32	2.58	3.50
1527-AST6	2.12	3.42	2.14	3.69	2.24	2.94
1527-AST7	2.70	4.41	2.57	4.56	2.73	3.77
1527-AST8	2.16	3.55	2.14	3.96	2.35	3.15
1527-AST9	1.95	3.40	1.97	3.60	2.27	2.94
1527-AST10	2.15	3.57	2.05	3.81	2.37	3.08
1527-AST11						
1527-AST12	2.33	3.90	2.28	4.00	2.54	3.37
1527-AST13	2.31	3.81	2.31	4.13	2.46	3.28
1527-AST14	2.32	3.90	2.25	4.12	2.56	3.40
1527-AST15	2.50	3.78	2.29	4.11	2.72	3.26
1527-AST16	2.37	4.04	2.39	4.35	2.59	3.46
1527-AST17	2.27	3.66	2.17	3.81	2.46	3.16
1527-AST18	2.23	3.70	2.14	4.02	2.35	3.18
1527-AST19	2.02	3.42	2.00	3.60	2.26	2.97
1527-AST20	2.37	3.64	2.24	4.05	2.61	3.23
1527-AST21	2.48	4.04	2.34	4.40	2.68	3.58
1527-AST22	2.45	4.00	2.37	4.19	2.64	3.36
1527-AST23	2.35	3.70	2.19	3.88	2.60	3.22
1527-AST24	2.23	3.65	2.17	3.96	2.52	3.15
1527-AST25						
1527-AST26	2.39	3.95	2.26	4.10	2.65	3.45
1527-AST27	2.52	4.10	2.38	4.41	2.66	3.54
1527-AST28	2.52	4.11	2.46	4.37	2.83	3.63
1527-AST29	2.24	3.50	2.13	3.80	2.35	3.07
1527-AST30	2.26	3.88	2.31	4.05	2.51	3.28
1527-AST31	2.36	3.81	2.32	4.04	2.62	3.27
1527-AST32	2.20	3.63	2.13	3.85	2.45	3.11
1527-AST33	2.11	3.65	2.09	3.95	2.47	3.13
1527-AST34	2.37	3.75	2.25	4.00	2.74	3.19
1527-AST35	2.51	3.94	2.35	4.09	2.72	3.40
1527-AST36	2.31	3.97	2.30	4.25	2.66	3.45
1527-AST37	2.12	3.79	2.12	3.93	2.33	3.75
1527-AST38	2.49	3.91	2.32	4.12	2.63	3.41
1527-AST39	2.27	3.62	2.23	3.94	2.50	3.19
1527-AST40	2.28	3.68	2.15	3.85	2.40	3.13
1527-AST41						
1527-AST42	2.39	3.82	2.29	4.11	2.58	3.29
1527-AST43	2.15	3.55	2.15	3.84	2.51	3.04
1527-AST44	2.31	3.88	2.38	4.16	2.61	3.28

White Tailed Deer	Rockhouse Hollow				Mississippian	
Specimen #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
1527-AST78	2.20	3.75	2.19	3.92	2.44	3.20
1527-AST79	2.34	3.85	2.28	4.17	2.63	3.33
1527-AST80	2.20	3.61	2.19	3.90	2.45	3.01
1527-AST81	2.34	3.91	2.26	4.15	2.63	3.45
1527-AST82	2.30	3.61	2.13	3.99	2.53	3.16
1527-AST83	2.21	3.80	2.11	3.95	2.48	3.23
1527-AST84	2.06	3.64	2.12	3.92	2.36	3.09
1527-AST85	2.10	3.46	2.18	3.73	2.37	2.93
1527-AST86	2.22	3.74	2.16	4.08	2.48	3.20
1527-AST87	2.29	3.74	2.26	3.98		3.23
1527-AST88	1.98	3.63	2.13	3.89	2.27	3.14
1527-AST89		3.74		3.99	2.40	3.17

White Tailed Deer	Ouatenon		Historic			
	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
OUI-AST1	2.27	3.81	2.25	4.17	2.46	3.22
OUI-AST2	2.34	3.91	2.19	4.17	2.49	3.41
OUI-AST3	2.23	3.69	2.20	3.82	2.46	3.23
OUI-AST4	2.28	3.73	2.17	4.24	2.54	3.25
OUI-AST5	2.51	4.08	2.43	4.32	2.67	3.51
OUI-AST6	2.12	3.57	2.08	3.83	2.39	3.14
OUI-AST7	2.41	3.90	2.37	4.19	2.80	3.38
OUI-AST8	2.24	3.85	2.30	4.19	2.68	3.30
OUI-AST9	2.32	3.53	2.14	3.76	2.34	3.15
OUI-AST10	2.26	3.71	2.21	4.02	2.54	3.17
OUI-AST11	2.20	3.71	2.21	3.92	2.38	3.18
OUI-AST12	2.35	3.86	2.29	4.15	2.54	3.38
OUI-AST13	2.41	4.13	2.43	4.35	2.71	3.63
OUI-AST14	2.52	3.97	2.39	4.28	2.67	3.38
OUI-AST15	2.22	3.63	2.07	3.78	2.45	3.11
OUI-AST16	2.25	3.72	2.18	4.02	2.55	3.26
OUI-AST17	2.53	4.08	2.45	4.48	2.68	3.58
OUI-AST18	2.51	3.92	2.36	4.17	2.63	3.42
OUI-AST19	2.37	3.92	2.34	4.16	2.51	3.37
OUI-AST20	2.25	3.90	2.33	4.12	2.72	3.39
OUI-AST21	2.37	3.77	2.25	4.05	2.63	3.30
OUI-AST22	2.42	3.83	2.26	4.06	2.55	3.43
OUI-AST23	2.33	3.80	2.29	4.10	2.56	3.30
OUI-AST24	2.23	3.74	2.20	3.95	2.42	3.25
OUI-AST25						
OUI-AST26	2.59	4.11	2.54	4.55	2.82	3.65
OUI-AST27	2.42	3.91	2.28	4.13	2.78	3.36
OUI-AST28	2.37	3.99	2.37	4.29	2.72	3.42
OUI-AST29	2.47	4.13	2.37	4.42	2.77	3.62
OUI-AST30	2.27	3.93	2.18	4.15	2.46	3.43
OUI-AST31	2.36	4.02	2.32	4.23	2.58	3.41
OUI-AST32	2.12	3.36	1.98	3.65	2.25	2.93
OUI-AST33	2.29	3.96	2.24	4.17	2.46	3.45
OUI-AST34	2.29	3.73	2.19	3.92	2.50	3.14
OUI-AST35	2.61	4.12	2.43	4.33	2.87	3.61
OUI-AST36	2.53	4.02	2.34	4.26	2.62	3.49
OUI-AST37	2.22	3.86	2.17	3.99	2.44	3.38
OUI-AST38	2.40	3.80	2.26	4.15	2.77	3.29
OUI-AST39	2.19	3.66	2.10	3.97	2.34	3.20
OUI-AST40	2.42	3.85	2.25	4.35	2.62	3.33
OUI-AST41	2.21	3.86	2.28	4.02	2.49	3.36
OUI-AST42	2.33	3.66	2.27	3.95	2.54	3.15

White-tailed deer	Murphy			Mississippian		
Catalog #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
215.80.1.1	22.53	38.29	22.48	41.24	26.43	33.27
261.138	21.29	37.52	21.53	38.78	24.01	31.87
261.116	22.57	37.88	22.46	40.75	25.61	32.66
261.113	21.40	36.49	21.34	38.79	24.34	31.42
141.2951.1	25.29	41.70	25.20	43.86	27.00	36.48
141.2936.1	24.21	38.96	24.57	42.70	26.20	34.77
141.2928.1	24.63	42.12	24.22	43.95	27.39	36.32
141.2923.1	22.79	39.48	23.51	41.93	26.87	34.41
141.2921.1	25.18	40.20	23.74	43.21	28.40	35.01
141.2920.1	24.29	38.93	23.50	42.74	26.73	33.46
141.2911.2	26.13	40.64	25.37	44.13	26.96	34.84
141.2909.1	22.71	38.80	22.42	41.30	26.37	34.07
141.2907.1	25.61	40.96	25.04	44.17	27.42	35.43
141.2906.1	23.39	36.04	22.93	40.70	25.61	33.29
141.2901.1	25.18	40.10	24.09	43.67	26.82	35.13
141.2899.1	23.74	37.71	23.29	40.33	25.50	32.56
141.2894.1	24.54	41.87	24.16	44.34	27.78	35.70
141.2893.1	25.36	41.16	24.65	44.29	27.69	35.20
141.2885.2	22.19	38.23	22.33	40.16	25.68	33.62
141.864.1	22.80	36.71	21.96	38.75	25.05	32.11
141.853.1	23.34	40.95	24.24	43.68	27.81	35.83
141.851.1	22.92	39.25	23.12	42.05	25.72	34.67
141.850.1	21.28	36.53	21.60	39.51	24.48	32.10

White-tailed deer	Banks			Mississippian		
Catalog #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
1	22.47	37.40	22.58	40.72	25.56	32.12
2	23.39	38.48	22.82	40.78	25.66	32.87
3	25.62	38.75	24.16	42.01	17.17	34.08
4	24.65	41.47	23.42	43.07	26.56	35.72
5	22.95	38.23	23.23	41.47	25.88	33.09
6	22.21	37.21	21.45	39.47	25.58	31.60
7	23.30	37.28	22.31	41.41	27.04	33.07
8	23.98	39.33	24.67		28.70	34.75
9	23.82	39.44	23.08	44.34	25.58	35.06
10	24.25	40.89	24.23	43.30	28.58	35.30
11	24.15	38.19	23.33	41.55	26.66	33.03
12	24.36	39.78	24.46	43.57	27.72	34.53
13	23.89	39.92	22.46	41.65	24.76	32.94
14	23.77	41.02	24.48	43.90	27.12	
15	22.22	37.47	22.14	40.36	25.00	32.20
16	21.86	37.47	22.62	39.46	25.75	31.96
17	24.20	39.61	23.80	43.82	27.38	33.99
18	22.16	36.35	22.21	39.60	23.74	31.38
19	23.28	36.81	23.14	40.27	23.49	31.55
20	24.52	39.11	24.11	41.91	25.71	33.12
21	22.87	37.71	23.19	40.70	25.52	32.30
22	23.44	37.67	22.73	41.87	25.70	32.69
23	23.83	38.94	23.21	41.29	25.76	33.79
24	24.55	40.50	24.72	44.58	27.69	35.66
25	21.30	35.59	21.62	37.66	25.14	30.37
26	23.48	39.90		42.74	26.33	34.89
27	23.16	38.53	22.54	41.50	27.60	34.13
28	22.18	37.55	22.53	40.82	26.05	32.67
29	26.30	39.95	25.04	43.21	27.40	34.56
30	26.00	42.20	24.62	44.88	27.88	35.87
31	22.79	36.50	22.76	39.90	25.57	30.11
32	23.58	39.30	23.23	43.35	27.48	35.62
33	23.53	36.48	22.73	39.23	26.34	32.21
34	25.33	41.00	24.40	45.00	27.01	36.08
35	21.07	35.40	21.97	39.32	23.72	31.40
36	22.89	36.91	22.12	39.70	26.44	31.74
37	22.45	36.76	22.04	39.50	26.42	32.31
38	23.12	36.16	22.04	38.51	24.42	31.30
39	22.52	39.18	23.84	43.30	25.38	34.74
40	24.13	40.48	23.62	43.93	28.50	35.37
41	24.76	40.14	24.99	43.98	28.10	35.76
42	23.48	40.02	23.90	43.17	26.00	33.91
43	23.79	38.91	23.20	41.12	27.74	32.98
44	22.14	39.46	23.44	41.42	25.84	32.68
45	22.17	37.80	22.86	40.87	24.77	32.80
46	21.82	35.59	20.87	37.18	24.32	30.16
47	21.22	39.40	22.00	40.56	25.39	32.24
48	25.88	41.86	24.42	44.22	29.02	35.92
49	24.48	39.30	24.67	42.53	28.06	34.12
50	22.44	35.60	21.94	37.75	24.44	30.32

51						
52	23.07	39.73	23.41	42.57	26.92	34.81
53	22.23	38.51	22.87	41.28	24.04	33.36
54	21.93	35.66	21.58	39.09	24.96	31.13
55	21.56	36.11	21.55	39.17	24.56	30.59
56						
57	25.71	40.50	25.16	44.04	26.66	35.46
58	22.08	37.02	22.89	40.40	25.24	31.11
59	25.23	42.42	25.45	45.62	28.75	38.81
60	22.71	40.08	23.79	41.98	26.55	33.51
61	23.56	38.63	23.54	41.61	25.74	32.71
62	22.25	35.73	22.29	38.52	26.26	31.14
63	20.44	34.11	20.55	36.80	23.90	30.67
64	23.09	40.50	23.44	42.60	27.08	35.56
65	23.36	40.82	23.86	43.50	27.62	35.67

White-tailed deer	Blain			Mississippian		
Catalog #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
1	24.30	39.13	23.25	42.33	25.10	33.30
2	21.92	37.34	21.43	39.26	26.11	31.80
3	22.32	37.22	21.35	39.37	24.54	31.90
4	21.24	35.62	21.28	38.02	25.27	30.43
5	24.45	39.70	24.30	40.63	27.11	34.26
6	25.75	42.00	24.02	44.52	29.82	37.79
7	25.28	39.92	23.81	43.12	26.70	33.98
8	25.32	42.26	25.53	44.34	28.33	35.75
9	24.05	39.81	23.98	41.56	26.36	34.22
10	23.82	39.90	23.84	42.84	25.70	33.14
11	22.78	37.32	22.53	39.54	25.66	32.48
12	22.75	37.29	22.84	41.72	25.68	32.28
13	22.78	36.02	22.14	40.08	23.95	31.44
14	23.26	39.47	22.93	42.48	27.21	35.12
15	24.00	36.04	21.73	38.10	25.03	31.25
16	24.46	41.96	25.24	44.73	26.46	36.34
17	22.38	37.82	22.45	39.75	24.46	33.62
18	26.03	42.74	24.97	45.45	28.84	37.64
19	24.72	38.92	23.26	41.37	26.15	33.90
20	22.74	38.05	23.21	40.85	26.80	33.44
21	25.91	41.41	24.05	44.87	26.84	36.30
22	25.30	43.24	24.52	46.09	17.48	37.06
23	21.83	37.07	21.58	39.86	26.12	32.68
24	26.19	41.30	24.74	44.82	28.94	36.40
25	25.65	41.22	23.91	43.73	26.54	35.64
26	22.82	37.38	22.64	40.03	25.00	33.08
27	22.82	38.06	22.69	41.99	27.59	34.12
28	23.31	39.00	24.08	41.66	27.15	34.51
29	24.92	40.99	23.83	42.82	28.34	36.00
30	25.17	40.38	23.98	44.32	28.59	35.70
31	22.59	35.66	21.86	38.26	23.95	31.33
32	22.12	36.66	21.42	39.27	24.82	31.21
33	24.36	38.66	22.72	41.32	25.49	33.79
34	22.64	38.07	22.52	40.96	25.17	33.48
35	23.30	40.56	24.55	45.03	26.80	35.71
36	24.00	39.08	23.66	42.36	27.90	34.65
37	25.33	38.10	22.89	40.53	26.95	33.55
38	22.47	36.22	22.55	39.30	26.04	31.45
39	22.39	36.97	22.43	40.18	23.70	32.39
40	21.83	37.58	21.45	40.40	24.44	32.95
41	21.76	36.91	21.53	39.65	24.42	31.98
42	23.78	35.81	22.59	39.48	24.76	31.65
43	23.07	37.10	22.30	40.29	26.62	32.30
44	24.54	39.64	23.99	42.62	26.97	34.05
45	23.75	38.02	23.72	42.29	27.10	33.43
46	25.32	41.52	24.56	44.40	26.44	36.34
47	23.24	37.67	21.92	40.20	26.16	33.19
48	23.73		22.53	41.89	25.86	33.48
49		38.84	21.55	41.59	27.12	33.48

Catalog #	ASMD	ASMLEM	ASLD	ASLLEN	ASDW	ASLEN
50		39.40	23.48	42.58	26.46	34.67
51	22.14		22.23	39.38	25.02	
52	21.26	36.42	20.87	38.51	24.36	31.75
53	22.05	36.33	21.19	39.08	24.35	31.09
54	25.71	39.15	24.57	41.88	27.65	34.65
55	22.52	38.24	22.92	41.39	26.94	33.68
56	21.54	36.49	21.53	39.80	22.88	31.96
57	20.15	35.52	20.68	37.84	24.14	31.32

Appendix 4

Raccoon wear stage, canine width Indian Knoll Archaic

Specimen #	Side	Mandible	Tooth			Canine Width
		Wear Stage	M2	M1	P4	
1	L	4		7	6	
2	L	1		2	3	
3	R	2		2	3	
4	L	4		7	5	
5	R	2		4	4	
6	R	1		2	2	
7	R	2		3	4	4.58
8	L	2		4	4	
9	R	2		3	3	
10	L	4		7	7	
11	R	2		3	3	3.98
12	R	4		8	9	
13	R	1	2	2		
14	R	1	1	2		
15	L	4	8	8		
16	L	2	5	5		
17	L	3		5	5	4.18
18	R	2		5		
19	R	4		7	8	
20	R	1		1	1	
21	R	5	10	10	10	
23	L	2	3	3	3	
24	R	2	4	5	4	
25	L	2	4	4	4	
26	L	2	3	4	5	
27	R	5	9	10	10	
28	R	3	6	6	5	
29	L	4	7	8	8	
30	R	5	10	10	11	
31	R	4	8	8		
32	L	3	6	6	6	
33	R	4	8	10	10	3.62
34	L	5		11	11	
35	R					4.4
36	R					4.24
37	R					3.98
38	R					4.77
39	L					4.15
40	R					4.26
41	R					3.74
42	R					3.27
43	R					3.49
44	L					3.3
45	L					4.02
46	R					3.31
47	L					3.67

Raccoon wear stage, canine width Blain Mississippian

Specimen #	Side	Mandible	Tooth			Canine Width
		Wear Stage	M2	M1	P4	
1	L	2		4		
2	R	4		8	9	4.54
3	L	3	6	7	8	
4	R	4		7	6	3.67
5	R	1		2	2	
6	R	2		3	4	4.61
7	L	5			11	3.94
8	L	2	3	4	3	3.8
9	L	5	11	11	11	
10	R	2		3	3	
11	L	4		7	7	
12	L		2			
13	R			3		
14	L			1		
15	L		1			
16	L					3.81
17	L					3.76
18	R					3.56
19	L					3.56
20	L					4.83

Raccoon wear stage, canine width Murphy Mississippian

Specimen #	Side	Mandible	Tooth			Canine Width
		Wear Stage	M2	M1	P4	
141.2966.2	R	3		7	6	
141.2966.3	R	1	2	1		
141.2961.1	R	2	4	4	4	4.65
142.1.2	L	3		5		
142.33	L	1		2		
142.317.2	L					3.88
142.3.3	R	4		8		
142.405.2	L	3	6	5	4	4.78
142.228.2	L	4	9	9		
142.8.3	R	2		3		
142.14.3	R	2	4	3	4	
142.14.3	L	2		4		
142.288.5	R					4.18
142.206.2	L					3.78
142.216.2	R	1		2		
142.509.3	L	2			4	
142.327.2	R	1		1		
142.438.2	R	3	5			
142.43.2	R					4.48
142.43.2	L					3.55
142.458.1	L	1	1	1	1	4.29
142.454.8	L	5			10	
142.397.2	L	4	11	8	9	3.09
141.2884	L	4	7	7	8	4.13
141.2887.2	L	4		9	11	3.97
141.2888.2	L		8			
141.2924.1	L	4	9	10		4.76

Raccoon wear stage, canine width Angel Mississippian

Specimen #	Side	Mandible	Tooth			Canine Width
		Wear Stage	M2	M1	P4	
1	R	3	5	5	4	4.74
2	L	2	2	3	4	3.58
3	R	4		8	8	4.13
4	L	1		2	3	3.48
5	R	5	10	10	10	4.34
6	R	2	5	4	4	
7	R	2		3	3	
8	L	3	5	5	5	4.31
9	L	4	6	7		
10	R	4	7	7	5	3.14
11	L	4		8	7	
12	L	2		4	5	3.72
13	R	2	3	3	3	
14	L	3	6	7	5	
15	L	2	4	4	4	4.5
16	R	4	7	7	7	4.42
17	L	1	1	2	3	
18	R	3	5	5	4	4.3
19	R	4		7	5	
20	R	2	4	4	4	
21	L	4	7	7	7	
22	R	3	5	5	5	4.26
23	R	1	1	2	1	3.48
24	R	2		4	4	3.54
25	R	2	4	3	3	3.93
26	R	3	7	6	5	
27	L	1	1	2		3.44
28	R	3	5	5	5	3.43
29	L	2	5	4	4	4.85
30	R	4		9	10	
31	R	3	6	5	6	
32	R	1	3	3		3.8
33	L	2	4	4	3	4.56
34	L	2	4	4	4	3.88
35	R	4		8	9	
36	L	4	8	8	9	4.27
37	L	2	3	3	3	3.54
38	L	5	9	10	11	
39	R	2	3	3	3	3.72
40	L	3		6	4	
41	R	1	4	3	3	4.39
42	L	2	4	4	4	
43	R	4		8	9	4.1
44	L	2	1	3	4	

Specimen #	Side	Wear Stage	M2	M1	P4	Canine Width
45	L	5		11	11	
46	L	2	3	3	4	
47	L	3	6	5	5	4.42
48	L	1	1	1	1	
49	R					4.73
50	R	2	2	2	2	3.35

Raccoon wear stage, canine width Cramer Fort Ancient

Specimen #	Side	Mandible	Tooth		P4	Canine Width
		Wear Stage	M2	M1		
1	R	1	2	1	1	3.62
2	R	2	4	3	3	4.02
3	R	2	2	3	3	4.96
4	R	2	3	3	4	
5	R	2	5	4	4	3.9
6	R	3	5	5	4	4.69
7	R	3	5	6	5	3.82
8	R	3	6	6	7	4.48
9	R	4	7	7	7	4.64
10	R	4	8	7	7	
11	R	4	9	9	9	3.85
12	R	4	9	9	10	
13	R	5	11	11	11	3.76
14	L	2	3	3	3	3.65
15	L	1	2	3	2	4.22
16	L	2	4	3	3	
17	L	2	2	3	4	
18	L	3	5	5	5	4.21
19	L	3	5	5	5	3.62
20	L	3	5	7	5	4.7
21	L	4	8	8	10	3.67
22	L	2	2	3		
23	L	3		5	4	3.57
24	L	2		4	4	3.54
25	R	2	5	3		
26	R	4		7	8	3.78
27	R	4		9	5	4.77
28	R	2		3	5	
29	L	2	5	3	4	4.26
30	L	4		8	8	4.99
31	L	1	1	2	2	
32	L	4	8	6	5	5.04
33	L	2	4	4	4	4.67
34	R	3	6	6	5	3.35
35	R	2		4	4	
36						3.79
37						3.75
38						3.75
39						3.35
40						3.52
41						4.39
42						3.9
43						4.74

Raccoon wear stage, canine width Tick Creek Archaic-Woodland

Specimen #	Side	Mandible Wear Stage	Tooth M2	M1	P4	Canine Width
1	L	3		7	6	
2	L					4.77
3	L	1		2	2	
4	L	1		2	2	
5	L	2	4	2	2	
6	L	5	11	11		
7	L	2		4	3	4.37
8	L					3.99
9	L	5		10		
10	L	4		7	6	
11	L	3		5	4	3.91
12	L					4.01
13	L	5	11	11	11	
14	L					3.81
15	L	3	6	6	5	3.68
16	L				4	4.27
17	L	5		11	11	
18	L					3.74
19	L					3.28
20	L	4	9	9	9	3.81
21	L	4		8		4.21
22	L				9	4.82
23	L					3.85
24	L	5		11	10	3.83
25	L	1		2	2	3.91
26	L	2		4	4	4.01
27	L	2		3		
28	L	2	3			
29	L	4		7	8	
30	L					3.46
31	L					4.31
32	L	3	5			
33	L					4.98
34	L	1	2	2	2	
35	L	2	4	4		
36	L	5		10	10	
37	L					3.62
38	L	5		10	10	3.66
39	L	4		8	5	
40	L	5		11	11	
41	L					4.55
42	L					4.81
43	L	4		8		4.33
44	L					4.65

Specimen #	Side	Wear Stage	M2	M1	P4	Canine Width
45	L	5		11	11	
46	L					4.32
47	L	1		2		
48	L	4		8		
49	L	5	11	10	8	4.75
50	L	5		10		
51	L					4.45
52	L					4.36
53	L					3.63
54	L	4		9		
55	L	1		2	2	
56	L					4.81
57	L	3	5	5	3	4.28
58	L	5	12		11	3.49
59	L					3.56
60	L					4.44
61	L					3.93
62	L	1		1	1	3.83
63	L	1		2		4.27
64	L	4		8	7	4.26
65	L					4.63
66	L	3		5	4	
67	L					4.52
68	L	5		11	10	3.95
69	L					3.99
70	L					3.77
71	L	4		9	10	4.03
72	L					3.81
73	L	1		2		
74	L					4.85
75	L	4		8		
76	L	3		6	4	4.27
77	L					4.14
78	L	2	4	3	4	4.87
79	L	2	4	4	3	
80	L					3.61
81	L					4.2
82	L					4.5
83	L	4	6	7		
84	L	2		4	3	
85	L					4.55
86	L	2		3	3	4.54
87	L	3	6		6	
88	L	5		11		3.83
89	L					3.51

Appendix 5. Stable carbon and nitrogen isotope data

Results of stable carbon isotope analysis by Schurr

<u>Sample</u>	<u>Provenience</u>	<u>Species</u>	<u>Extr Date</u>	<u>% Yld</u>	<u>d13C-C</u>
MS01	W10D/13180	<i>Odocoileus virginianus</i>	08/31/98	8.23	-20.29
MS02	P15A/362	<i>Odocoileus virginianus</i>	08/31/98	8.20	-20.02
MS03	S11D/3018	<i>Odocoileus virginianus</i>	08/31/98	5.79	-21.22
MS04	T13C/529	<i>Odocoileus virginianus</i>	08/17/98	2.17	-19.56
MS06b	W10D/13232	<i>Odocoileus virginianus</i>	11/16/98	4.06	-19.73
	PC947-2				
MS07	MdF/2737	<i>Odocoileus virginianus</i>	09/21/98	2.88	-22.05
MS08b	S11D/1607	<i>Odocoileus virginianus</i>	11/09/98	2.35	-21.5
MS09	S11D/3116	<i>Odocoileus virginianus</i>	08/17/98	3.50	-20.16
MS10	T13C/99	<i>Odocoileus virginianus</i>	08/24/98	5.05	-20.11
MS10 -2	T13C/99	<i>Odocoileus virginianus</i>	08/24/98		-21.05
MS11b	W10D/13225	<i>Odocoileus virginianus</i>	11/09/98	9.89	-20.23
	PC950-2				
MS11b-2	W10D/13225	<i>Odocoileus virginianus</i>	11/09/98		-20.41
	PC950-2				
MS12	W10D/13503	<i>Procyon lotor</i>	08/17/98	12.92	-17.04
MS13	S11D/3049	<i>Procyon lotor</i>	09/14/98	2.18	-20.21
MS14	S11D/1262	<i>Procyon lotor</i>	09/28/98	6.80	-20.21
MS15	S11D/3243	<i>Procyon lotor</i>	09/14/98	3.35	-19.16
MS16	N13D/521	<i>Procyon lotor</i>	08/24/98	2.71	-18.18
MS17	T13C/118	<i>Procyon lotor</i>	09/07/98	5.18	-19.82
MS18	W10D/12983	<i>Procyon lotor</i>	09/28/98	6.02	-17.24
MS20	W10D/15554	<i>Procyon lotor</i>	08/17/98	5.79	-17.59
MS21	T13C/692	<i>Procyon lotor</i>	09/21/98	9.21	-19.02
MS23	W10D/15643	<i>Didelphis virginiana</i>	09/07/98	4.73	-19.04
MS24	W10D/15548	<i>Didelphis virginiana</i>	08/31/98	6.29	-18.94
MS24	W10D/15548	<i>Didelphis virginiana</i>	08/31/98		-18.19
MS27	MdF/4000	<i>Sciurus sp.</i>	09/28/98	4.17	-18.45
MS28	P13C/123	<i>Sciurus sp.</i>	08/31/98	3.31	-19.55
MS29	O13D/1153	<i>Sciurus sp.</i>	09/21/98	10.74	-18.4
MS31	MdF/3129	<i>Canis familiaris</i>	08/17/98	11.13	-10.75
MS31 - rep	MdF/3129	<i>Canis familiaris</i>	08/17/98		-10.85
MS32	P15A/476	<i>Felis concolor</i>	08/24/98	3.24	-17.68
MS33	W10D/5049	<i>Meleagris gallopavo</i>	09/21/98	11.21	-19.72
MS34	W10D/3356	<i>Meleagris gallopavo</i>	09/07/98	17.27	-18.45
MS35	W10D/5682	<i>Meleagris gallopavo</i>	08/31/98	4.23	-20.98
MS36	W10D/5044	<i>Meleagris gallopavo</i>	09/28/98	11.37	-21.08
MS37	W10D/5483	<i>Meleagris gallopavo</i>	09/28/98	2.94	-20.84
MS38	W10D/5447	<i>Meleagris gallopavo</i>	08/31/98	16.25	-19.99
MS39	W10D/3258	<i>Castor canadensis</i>	09/07/98	5.05	-17.63
MS40	W10D/3474	<i>Castor canadensis</i>	09/28/98	5.36	-17.68
MS41	W10D/3259	<i>Castor canadensis</i>	09/21/98	5.84	-20.32
MS41 - rep	W10D/3259	<i>Castor canadensis</i>	09/21/98		-18.72
MS42	W10D/5447	<i>Castor canadensis</i>	09/21/98	5.11	-18.7
MS43	W10D/3334	<i>Castor canadensis</i>	09/28/98	8.10	-22.04
MS43 - rep	W10D/3334	<i>Castor canadensis</i>	09/28/98		-18.94

<u>Sample</u>	<u>Provenience</u>	<u>Species</u>	<u>Extr Date</u>	<u>% Yld</u>	<u>d13C-C</u>
MS46	W10D/3513	<i>Aplodinotus grunniens</i>	09/14/98	2.56	-23.02
MS47	W10D/5682-2	<i>Aplodinotus grunniens</i>	09/21/98	0.28	-8.38
MS47 - rep	W10D/5682-2	<i>Aplodinotus grunniens</i>	09/21/98		-8.13
MS48	W10D/3434	<i>Aplodinotus grunniens</i>	08/24/98	3.12	-22.83
MS52	W10D/3373	<i>Canis familiaris</i>	11/09/98	5.02	-11.18
	PC861				
MS53	W10D/3206	<i>Terrapene</i> sp.	11/16/98	2.47	-17.98
	PC861				
MS55	W10D/3206	<i>Mephitis mephitis</i>	11/16/98	8.72	-17.84
	PC861-1				
MS56	W10D/2839	<i>Canis familiaris</i> (small)	11/09/98	9.46	-10.56
	PC861-1				
MS58	W10D/3474	<i>Terrapene</i> sp.	11/16/98	6.55	-18.19
	PC 861				
MS60	W10D/2967	<i>Sylvilagus floridanus</i>	11/09/98	12.27	-21.41
	PC 861-1				
MS61	W10D/3140	<i>Sylvilagus floridanus</i>	11/16/98	6.69	-21.35
	PC 861-1				
MS62	W10D/5377	<i>Sylvilagus floridanus</i>	11/16/98	11.65	-24.07
	PC 869-1				
MS64	W10D/2967	<i>Branta canadensis</i>	11/09/98	12.11	-17.47
	PC 861-1				
MS64 - rep	W10D/2967	<i>Branta canadensis</i>	11/09/98		-17.23
	PC 861-1				
MS65	W10D/3186	<i>Branta canadensis</i>	11/09/98	44.76	-19.15
	PC 861-1				
MS66	W10D/5684	<i>Graptemys geographica</i>	11/16/98	6.89	-22.5
	PC 869-2				
MS67	W10D/3206	<i>Corvus brachyrhynches</i>	11/16/98	14.04	-17.85
	PC 861-1				
MS68	W10D/3137	<i>Anas</i> sp.	11/09/98	13.29	-23.18
	PC 861-1				
MS69	W10D/2948	<i>Anas</i> sp.	11/16/98	13.11	-23.81
	PC 861-1				
MS70	W10D/3513	<i>Anas</i> sp.	11/16/98	14.81	-21.54
	PC 861				
MS72	W10D/5682	<i>Anas</i> sp.	11/09/98	10.60	-19.59
	PC 869-2				
MS72 - rep	W10D/5682	<i>Anas</i> sp.	11/09/98		-20.04
	PC 869-2				

Sample	Catalog number	Species	MS date	d15N	d13C	C/N
MS04	T13C/529	<i>Odocoileus virginianus</i>	09/10/98	4.21	-20.61	3.43
MS09	S11D/3116	<i>Odocoileus virginianus</i>	09/10/98	5.31	-21.31	3.48
MS09-2		<i>Odocoileus virginianus</i>	09/10/98	5.12	-20.16	3.44
MS10	T13C/99	<i>Odocoileus virginianus</i>	09/10/98	3.99	-21.14	3.44
MS11b	W10D/13225 PC950-2	<i>Odocoileus virginianus</i>	01/25/99	4.14	-20.24	3.36
MS12	W10D/13503	<i>Procyon lotor</i>	09/10/98	6.6	-17.62	3.35
MS12-2		<i>Procyon lotor</i>	09/10/98	6.12	-18.8	3.1
MS16	N13D/521	<i>Procyon lotor</i>	09/10/98	6.95	-19.11	3.49
MS19	W10D/12954	<i>Procyon lotor</i>	09/10/98	8.18	-19.31	3.38
MS20	W10D/15554	<i>Procyon lotor</i>	09/10/98	7.03	-18.13	3.47
MS25	W10D/16072-2	<i>Didelphis virginiana</i>	09/10/98	8.53	-18.62	3.09
MS31	MdF/3129	<i>Canis familiaris</i>	09/10/98	7.85	-11.19	3.38
MS32	P15A/476	<i>Felis concolor</i>	09/10/98	7.98	-18.52	3.45
MS41	W10D/3259	<i>Castor canadensis</i>	01/25/99	4.18	-20.84	
MS45	W10D/5484	<i>Aplodinotus grunniens</i>	01/25/99	8.26	-27.57	
MS47A	W10D/5682-2	<i>Aplodinotus grunniens</i>	01/25/99	4.18	-20.84	
MS47B	W10D/5682-2	<i>Aplodinotus grunniens</i>	01/25/99	4.07	-21.21	
MS48	W10D/3434	<i>Aplodinotus grunniens</i>	09/10/98	8.51	-24.32	3.34
MS62	W10D/5377 PC 869-1	<i>Sylvilagus floridanus</i>	01/25/99	3.97	-25.1	
MS64	W10D/2967 PC 861-1	<i>Branta canadensis</i>	01/25/99	6.97	-17.07	
MS72	W10D/5682 PC 869-2	<i>Anas sp.</i>	01/25/99	7.21	-18.42	

Rexford C. Garniewicz
Curriculum Vitae

Indiana State Museum and Historic Sites
650 West Washington Street
Indianapolis IN 46204-2725
(317) 233-2523
rgarniewicz@dnr.in.gov

Professional Experience

July 2005 – Present **Director of Collections**
Indiana State Museum

This is an executive level position responsible for the daily and long-term leadership and supervision of activities related to the care, documentation, processing, use and maintenance of objects and specimens in the museum's collections and is responsible for the operational oversight of ongoing programs, strategic planning, execution, logistics, transportation, administration, external affairs and management in that area. Incumbent holds the additional title of curator of prehistoric archaeology and is further responsible for the daily and long-term curation, fieldwork and conservation of the archaeology collections of the museum

September 2004 – July 2005 **Manager of Archaeology**
Indiana State Museum

Managerial level position responsible for the daily and long-term leadership and supervision of activities related to archaeology and is responsible for the operational oversight of ongoing programs and fieldwork, strategic planning, human resources, procurement, training, budget preparation and execution, logistics, transportation, administration, external affairs and management in that area. Worked on the development and implementation of the Indiana State Museum business Plan. Incumbent maintains duties of curator of prehistoric archaeology.

April 2002 – Present **Curator of Prehistoric Archaeology**
Indiana State Museum

Is responsible for developing and managing the Division's prehistoric archaeology collections. Oversees collection management of these materials and conducts identification, preparation, conservation and scientific interpretation of the collection and associated data. Leads fieldwork to conduct research and collect artifacts while also lending expertise to the professional archaeological community and other Indiana institutions. Regularly provides identification services and information for the general public and provides expert support for public programs and exhibitions as needed.

January 2002 – December 2002 **Visiting Lecturer, Anthropology Department**
Indiana University

Developed and instructed two upper level courses: Prehistory of the Southwest in the fall of 2002 and Invention and Technology in the spring of 2002. Visiting lecturer status was also granted for teaching Field School in Archaeology during the summer of 2000. Previous teaching experience from 1993-2001 includes courses at both the introductory and advanced levels. Introductory courses include multiple years of teaching Introduction to human origins and prehistory. Upper level courses include Native American subsistence, Faunal osteology, Problems in zooarchaeology, Laboratory methods in archaeology and Field school in archaeology.

Community Service

Board of Directors, Prospect Hill Historic Neighborhood Association
High School Mentor, Indianapolis Key School, Careers in Science

Current Professional and Civic Activities

Institutional Member, Association of American Museums
Individual Member, Society for American Archaeology
Individual Member, Midwest Archaeological Conference
Individual Member, Council for the Conservation of Indiana Archaeology
Individual Member, International Council on Archaeozoology

Publications

- Garniewicz, R. In press. Chapter 11, Caborn-Welborn Faunal Exploitation and the Sample from Bone Bank. In C. A. Munson *The Bone Bank Archaeological Site: Rescue Excavations at a Late Mississippian Caborn-Welborn Phase Village in Southwestern Indiana*, Indiana University Press Bloomington.
- Garniewicz, R. 2005. *Zooarchaeological Measures of Resource Intensification and Depletion: Examples from Eastern North America* (Ph.D. Dissertation, in preparation)
- Munson, P. J. and R. Garniewicz 2002. Age-Related Differences in Density, Size, and Strength of Ungulate Mandibles: Their Effects on Survivorship in Canid-Ravaged Faunal Assemblages. *Journal of Archaeological Science* 30(4) 405-416.
- Garniewicz, R. 2000. Age and Sex Determination from the Mandibular Dentition of Raccoons: Techniques and applications. *Archaeozoologia* 11:223-238.
- Garniewicz R. 1998. Patterns Of Late Prehistoric Faunal Exploitation in Central and Southern Indiana. *Indiana Archaeology* 2(1):17-41.

Reports

- Garniewicz, R. 2004. An Archaeological Survey of Proposed Well Sites for the Whitewater State Historic Site. Indiana State Museum, Report of Investigations 2004-01,
- Garniewicz, R. 2004. "Bone tools from 12-H-3" In R.G. McCullough, A. White, M. Strezewski and D. McCullough, *Frontier Interaction During the Late Prehistoric Period: A Case Study from Central Indiana*. IPFW-AS Reports of Investigations 401: 275-283. July 2004.
- Garniewicz, R. 2003. "Appendix I: Strawtown Faunal Analysis" In R. McCullough ed. *Archaeological Investigations at two Late Prehistoric Earthen Enclosures in Indiana*. IPFW Reports of Investigations 301, May 2003.
- Garniewicz, R. 2002. "Appendix 1: Preliminary Analysis of Faunal Materials, Worked Bone, and Human Remains from the Strawtown Enclosure" In White, A., McCullough D., and McCullough R. *An Archaeological Evaluation of Late Prehistoric Village and Subsistence Patterns in North-Central and Northeastern Indiana*. IPFW Archaeological Survey Report of Investigations 216:206-211.
- Garniewicz, R. 2000. Analysis of Faunal Remains from the Murphy and Hovey Lake Sites, Posey County, Indiana. In *Archaeological Survey and Testing at Protohistoric Mississippian Sites in Southwestern Indiana*. By C. A. Munson. Report Prepared for Indiana Department of Natural Resources, U.S. Department of Interior.
- Garniewicz, R. 1999. Appendix D: Faunal Materials. In *Filling in the Blanks: Archaeological Investigations at the Historic Rapp Granary/ D.D. Owens Laboratory in New Harmony, Posey County Indiana*. By P. K. O'Brien, W. L. Natt, M. E. Pirkel, and E. P. O'Brien. Glenn A. Black Laboratory of Archaeology, Report of Investigations 97-05.
- Garniewicz, R. 1998. Faunal analysis. In *Phase II Archaeological Investigations at Sites 33De272 and 273, Defiance County, Ohio*. P.K. O'Brien, ed. Glenn A. Black Laboratory, Report of Investigations 98-19.
- Garniewicz, R. 1997. Faunal Remains from 12 Mg1, 12 Jo 289, and 12 Jo 5. In McCullough and Wright 1997, *An Archaeological Investigation of Late Prehistoric Subsistence-Settlement Diversity in Central Indiana*. Indiana University, Glenn A. Black Laboratory of Archaeology, Research Reports, No. 18.
- Garniewicz, R. 1996. The analysis of fauna from three Late Prehistoric sites in central Indiana. In *An Archaeological Investigation of Late Prehistoric Subsistence-settlement Diversity in Central Indiana*. Report submitted to the Division of Historic Preservation and Archaeology, Indiana Department of Natural Resources.
- Garniewicz, R. 1996. Faunal remains from 12 H 807, In O'Brien, Pirkel, and Bush (1996) *Phase II Subsurface Archaeological Investigations at Site 12 H 807, Hamilton County, Indiana*. Glenn A. Black Laboratory of Archaeology ROI 96-41.

Garniewicz, R. 1995. Faunal Remains from 12Or1. In *The summer 1993-1994 Excavations of the Cox's Woods site (12 Or 1), A Late Prehistoric, Oliver Phase village in the Pioneer Mothers Memorial Forest, Hoosier National Forest, Orange County Indiana*. G.B.L. Reports of Investigations

Field Projects

- 2004 Principle Investigator, Excavation at the Megenity Cave site, Crawford County, Indiana
Principle Investigator, Archaeological Survey at the Whitewater State Historic Site
Field Technician, Pipe Creek Junior Quarry (Paleontological), Grant County, Indiana
Field Technician, Excavation at the New Harmony State Historic Site, Posey County.
- 2003 Principle Investigator, Excavation at the Yankeetown Site, Warrick County, Indiana
Principle Investigator, Excavation at the Megenity Cave site, Crawford County, Indiana
Field Technician, Pipe Creek Junior Quarry (Paleontological), Grant County, Indiana
- 2002 Field Technician, Excavation at Megenity Cave (Paleontological); Field Technician,
Excavation at Anderson Mastodont Locality (Paleontological); Field Technician,
Excavation at the Lick Creek African-American Settlement (Archaeological); Field
Technician Excavation at the Strawtown Late Prehistoric Village (Archaeological).
- 2001 Field Technician, Excavation at the Bone Bank Site, a Caborn-Welborn Village.
- 2000 Field Director: Excavation at the Cedar Bluff rockshelter and associated shell midden,
Martin Co. Indiana.
- 1999 Field Technician, Excavation at the Hovey Lake Site, a Caborn-Welborn Village.
- 1997-8 Associate Instructor for IU Field School in Archaeology, Excavation at Heaton
Farm, a Late Prehistoric Village.
- 1996 Field Supervisor, Excavation at 12 Gr 122, A Late Prehistoric Village. .
- 1995 Excavation at 12Mg1, a Late Prehistoric Oliver Phase Village.
Excavation of the late prehistoric component at 12Jo5.
Survey of earthquake-induced paleoliquefaction of Holocene age in southeastern
Illinois (Illinois State Museum)
- 1994 Excavation at 12Or1 an Oliver Phase village.
Survey of earthquake-induced paleoliquefaction of Holocene age in southeastern
Illinois (Illinois State Museum)
- 1993 Survey of earthquake-induced paleoliquefaction in Southern Indiana (USGS);
Excavation at 12Or1.
- 1992 Survey of earthquake-induced paleoliquefaction in Southern Indiana (USGS)
- 1991 Excavation in the Late Archaic/Early Hellenistic zone of Morgantina Sicily.
- 1990 Survey of late prehistoric and Roman Archaeological sites in Sardinia (Italy).
- 1989 Participation in the University of Sheffield Archaeological and Environmental
Research Program in the Outer Hebrides (Scotland)
- 1989 Excavation of an Early Medieval monastic site at Castelporzzianno, Rome (Italy).
- 1988 Survey of late prehistoric and Roman Archaeological sites in Sardinia.

Presentations

- 2004 Farlow, J., Richards R., Garniewicz, R., Wepler, W., Holman, J., Martin, R., and
Sunderman, J. New Vertebrate fossils from the Pipe Creek Sinkhole (Latest

- Hemphillian, Grant County, Indiana. 38th Annual Meeting, Geological Society of America (April 1–2, 2004).
- 2002 Cook, D. C., C. Munson, R. Garniewicz, T. Martin, and M. Powell. Modification of Human Bone from Mississippian Caborn-Welborn Phase Sites in West-Central Kentucky and Southwestern Indiana. @ Nineteenth Annual Kentucky Heritage Council Archaeological Conference, Frankfort KY.
- 2001 Variation in Prehistoric White-tailed Deer Population Parameters as a Response to Increased Hunting Pressure: Ecological Techniques and Archaeological Applications. Paper presented at the sixty-sixth annual meeting of the Society for American Archeology, New Orleans LA.
- 2001 Indiana University's excavations at the Cedar Bluff Rockshelter, Martin Co. Indiana. Indiana Archaeology Week, Bedford Indiana.
- 2000 Garniewicz, R. and L. Pate. Possible Late Archaic Ceramics from Martin County Indiana. Paper presented at the 116th Annual Meeting of the Indiana Academy of Science. November 3, Richmond IN.
- 2000 Garniewicz, R. and P. Munson. Age-correlated Differences in Bone Size, Density, and Strength: Their Effect on Survivorship in Canid-ravaged Faunal Assemblages. Paper presented at the Annual Meeting of the Society for American Archaeology, Philadelphia PA.
- 1999 Bush, L., R. Garniewicz and L. Pate. Subsistence Strategies at the Heaton Farm Site. Poster presented at the 63rd Annual Meeting of the Society for American Archaeology. Chicago IL.
- 1999 The Archeology of Hunting in Southern Indiana, Prehistoric Patterns and Prey. Indiana Archaeology Week, Alexandrian Public Library, Mt Vernon Indiana.
- 1998 Age and Sex Determination from the Mandibular Dentition of Raccoons: Techniques and Applications. Paper presented at the 8th International Council of Archaeozoology. University of Victoria, Victoria, British Columbia, Canada.
- 1998 Patterns of Oliver Phase Faunal Exploitation. Paper presented at the 43rd Annual Midwest Archaeological Conference, Muncie, IN.
- 1998 Raccoon Mortality Profiles: Indicators of Prehistoric Hunting Intensity in the Midwestern U.S. Paper presented at the 63rd Annual Meeting of the Society for American Archaeology. Seattle, WA.
- 1997 Faunal Remains from the Heaton Farm Site. Paper presented at the Annual Meeting of the Indiana Academy of Science.
- 1996 Late Prehistoric Subsistence and Seasonality Based on Faunal Remains from Central and Southern Indiana. Paper presented at the Annual Meeting of the Indiana Academy of Science, Greencastle, IN.
- 1996 Animal Utilization by the Mississippian People at Angel Mounds. Archaeology Week Public Lecture Series at Angel Mounds Museum.
- 1995 Faunal Remains from 12 Mg 1: Subsistence and Seasonality of an Oliver Phase Village. Presented at the Annual Meeting of the Indiana Academy of Science, Indianapolis, IN.
- 1995 Obermeier, S. F., R. Garniewicz and P. Munson. Seismically Induced Paleoliquefaction Features in Southern Half of Illinois. Seismological Research Letters, in Seismological

- Society of America 91st annual meeting. (R. B. Hermann, chairperson). v. 67, no. 2, April 1996. p. 49.
- 1994 Some Osteological Correlates of Stone Tool Manufacture. Paper presented at the Annual Meeting of the Indiana Historical Society. Published in *Current Research in Indiana Archaeology and Prehistory: Research Reports*, No. 17, 1995.
- 1994 Hajic, E.R., S. Obermeier, P. Munson, M. Wiant, K. Tankersley and R. Garniewicz. Distribution and Dating of Prehistoric Earthquake Liquefaction in Southeastern Illinois, Central U.S. Paper presented at the Geological Society of America.
- 1993 A Diachronic Perspective on Prehistoric Deer Utilization in the Midwest. Paper presented at the Annual Meeting of the Indiana Historical Society. Published in *Current Research in Indiana Archaeology and Prehistory: Research Reports*, No. 15.
- 1992 A Preliminary Report on Middle Woodland Animal Utilization at the Mann Site. Paper presented at the Annual Meeting of the Indiana Historical Society. Published in *Current Research in Indiana Archaeology and Prehistory: Research Reports*, No. 14, 1993.
- 1992 Munson, P. J., C. Munson and R. Garniewicz. Earthquake-induced Paleoliquefaction of Holocene Age in Southwestern Indiana: Interim Report. Presented at the Annual Meeting of the Indiana Academy of Science, Muncie.
- 1992 Munson, C. A., P. Munson and R. Garniewicz. Geoarchaeological Dating of Holocene-age, Earthquake-induced Paleoliquefaction Features in Southwestern Indiana. Presented at the Annual Meeting of the Geological Society of America, Cincinnati.

Awards

National Park Service, 2003 Honor Award for public service to the Lick Creek African American Heritage Group, for sustained cooperation in the research and interpretation of Indiana's heritage.

Glenn A. Black Laboratory of Archaeology Prehistory Research Fellow, 1992-2002

David Bidney Graduate Paper Prize, 1993

Indiana University Skomp Fellow, 1991-1992

BA with high honors, Wesleyan University, 1991

Education: Currently PhD Candidate at Indiana University

MA.	Indiana University	2002	Anthropology (Archaeology)
BA	Wesleyan University	1991	Earth & Environmental Science; Archaeology

Other Educational Experiences

2005 State of Indiana, Diversity training

2004 State of Indiana, Project management training

1998 Sheffield University, Sheffield S10 2TN, UK, Wesleyan/Sheffield Program in Archaeology