

MID-HOLOCENE CLIMATE CHANGE
IN THREE CAVE SITES FROM CENTRAL MISSOURI
FROM MAMMALIAN BODY MASS DISTRIBUTIONS

A Thesis
presented to
the Faculty of the Graduate School
at the University of Missouri-Columbia

In partial fulfillment
of the requirements for the degree
Master of Arts

By
JASON A. CHRISTY
Dr. R. Lee Lyman, Thesis Supervisor

MAY 2015

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

MID-HOLOCENE CLIMATE CHANGE IN THREE SITES FROM CENTRAL MISSOURI FROM MAMMALIAN
BODY MASS DISTRIBUTIONS

Presented by Jason Christy

A candidate for the degree of Master of Arts and hereby certify that, in their opinion, it is worthy of
acceptance

Professor R. Lee Lyman

Professor Todd VanPool

Professor Mark Ryan

Acknowledgements

I would like to thank Dr. R. Lee Lyman whose own personal interest led me to undertake this study, and whose patience with countless revisions, and insightful suggestions made the work much easier. I would also like to thank my other committee members, Dr. Todd VanPool and Dr. Mark Ryan. Their questions and insights during draft revisions helped me develop a better written thesis.

Table of Contents

Acknowledgments.....	ii
List of figures.....	v
List of Tables.....	vi
Chapter 1: Introduction.....	1
Chapter 2: Methods and Materials.....	4
Body Mass in Paleoecology.....	4
Paleoecology and Paleoenvironments.....	6
Cenograms.....	7
Body Mass Clumps.....	11
The Modern Environment and Paleoenvironmental History.....	16
Late Wisconsin.....	16
Holocene.....	17
Hypsithermal.....	18
Summary.....	18
Materials.....	19
The Sites and Previous Work.....	19
The Faunal Assemblages.....	29
Predictions.....	32
Chapter 3: Results.....	34
Archaeofaunal Cenograms.....	34
Archaeofaunal Body Mass Clumps.....	40
Chapter 4: Comparisons with Modern Faunas.....	44
Comparative Modern Cenograms.....	44
Comparisons of Modern and Paleo Cenograms.....	49
Comparing Paleo and Modern Body Mass Clumps.....	53

Chapter 5: Conclusion.....	62
Appendix 1	67
Appendix 2.....	72
Appendix 3.....	75
Appendix 4.....	76
References.....	81

List of Figures

Figure 1. Sample Cenogram.....	7
Figure 2. Cenogram Shape and Corresponding Characteristics.....	9
Figure 3. Vegetation Map of Midwest Prairie Peninsula.....	15
Figure 4. Missouri Areas of Study.....	24
Figure 5. Cenogram for Arnold Research Cave.....	35
Figure 6. Cenograms for Graham Cave Compared.....	37
Figure 7. Rogers Shelter Comparative Cenograms.....	39
Figure 8. Clumps for Arnold Research Cave.....	41
Figure 9. Graham Cave Comparisons.....	42
Figure 10. Comparisons at Rogers Shelter	43
Figure 11. Modern Comparative Cenograms.....	47
Figure 12. Modern Comparative Cenograms and Arnold Research Cave.....	50
Figure 13. Graham Cave Cenogram and Konza Prairie.....	51
Figure 14. Modern Comparative Cenograms and Rodgers Shelter.....	52
Figure 15. Modern Comparative Body Mass Clumps.....	54
Figure 16. Body Mass Clump Comparisons at Arnold Research Cave.....	54
Figure 17. Body Mass Clump Comparisons at Graham Cave.....	55
Figure 18. Body Mass Clump Comparisons at Rodgers Shelter (Early Holocene).....	56
Figure 19. Body Mass Clump Comparisons at Rodgers Shelter (Early Hypsithermal).....	57
Figure 20. Body Mass Clump Comparisons at Rodgers Shelter (Mid-Hypsithermal).....	58
Figure 21. Body Mass Clump Comparisons at Rodgers Shelter (Late Hypsithermal).....	59
Figure 22. Body Mass Clump Comparisons at Rodgers Shelter (Historic)	60
Figure 23. Cenograms and Clumps Comparing Different Time Periods at Rodgers Shelter.....	64

List of Tables

Table 1. Studies Using Cenograms, and Cenogram Success.....	10
Table 2. Correlation of Dates and Levels.....	30

Abstract

The Mid-Holocene was a dynamic period of changing environments. The climate was becoming more dry (Xeric), and prairie grassland was encroaching into areas previously inhabited by deciduous forest. Mammal taxa were changing as well to accommodate the changing flora. The mammal faunas from three cave sites in Central Missouri were chosen to test two methods of paleoecological reconstruction. The Cenogram Method uses the distributions of body masses of represented taxa to infer environmental conditions, whereas the Body Mass Clump Method concerns relationships between the distributions of clumps and gaps between clumps of body masses of multiple taxa and the environment. Previous studies at the cave sites have shown a forest edge environment during the early Holocene, changing to a predominantly prairie habitat during the Mid-Holocene (Hypsithermal) event, and returning to forest edge towards the historic period. Both the cenograms and the body mass clumps concur with these previous assessments for Rodgers Shelter, and Arnold Research Cave. The early Holocene was a mixed forest and grassland environment, with more grassland during the Hypsithermal, and returning to a mixed forest and grassland at the end of the Hypsithermal. Graham Cave however, was prairie type habitat throughout the Holocene with little habitat change.

CHAPTER 1: INTRODUCTION

Chapman (1975:1) states that it is important to consider the environment in which a society exists. The natural environment provides the basic materials and resources for furnishing food, clothing, and shelter. Rocks, minerals, soils, animals, plants, weather, climate, and topography are all important elements in cultural development. Any group of people living in a particular area must adapt to these characteristics of their environments to survive. Therefore it is important to know the characteristics of past environments, to facilitate comprehension of the archaeology of the people who lived in them.

Further, any study of cultural change through time necessitates knowledge of the changing environment in which people lived. One of the roles that Culture plays is the cumulative collection of adaptive strategies used to survive in a given environment. To understand why some strategies existed, changed, or became extinct, requires an understanding of the environment in which they were developed and used. Both Shippee (1966) and later Chapman (1975) made use of changes in stone tools to show cultural adaptations to changing environments, and to disprove suggestions that those changes in stone tools were the result of migrations of people from other areas. One method to identify changes in an environment that affect the people living in it is to examine the environment itself. Klippel (1971b) referred to just this method when he lamented that archaeology has not used faunal materials to the fullest extent, as he attempted to do. Since then, archaeology has seen the benefit of intensive study of archaeofaunal material (faunal remains recovered from archaeological sites, as opposed to paleontological material or faunal remains without associated artifacts), and with knowledge borrowed from paleontology among other fields, has made many advances in the understanding of prehistoric environments and their impact on the people who lived within them.

It is commonly known that animal taxa reflect aspects of the environments in which they live. It follows then that the taxonomic composition of a prehistoric fauna should allow inferences about certain aspects of the environment. One attribute of a fauna that can be used to gain insight to past environments is body size. Damuth (1992) notes that the relationship between the distributions of mammals and of vegetation is well known, and analysis of body size has been instrumental in identifying climate change in the Pleistocene and Holocene. A particular method used to examine the relationship between body size and environments is the cenogram method. A cenogram is a graph of the rank ordered, descending body masses of the mammal taxa in a particular assemblage. Here, the validity of cenograms is tested by examining how well Holocene climate change is reflected in three mammalian faunas recovered from cave sites located in central and western Missouri. I also test a similar but lesser known technique referred to as body mass clumps using those same three faunas.

The purpose of this thesis is to test the validity of the two techniques (cenograms and body mass clumps) of analyzing mammalian body mass distributions as means to infer paleoecological conditions. I test those techniques with Holocene mammal data from Missouri because I have access to both well represented archaeological materials from that period, and because I have access to other paleoecological information that allows me to predict what a cenogram and body mass clumps should look like.

In Chapter 2, I discuss the methods starting with a short discussion on the importance of body mass to biology, and the basic methods of paleoecological and paleoenvironmental reconstruction. Then I discuss my materials, the cave sites and their local history, as well as my analytical techniques, the cenogram and body mass clump methods. In chapter 3, I discuss my results, namely that the two methods do reflect similar environmental histories as previous studies have suggested. Following that I

discuss comparisons with modern faunas and paleo faunas in chapter 4. I conclude with a discussion of the usefulness of the two methods for further paleoecological and paleoenvironmental investigations.

CHAPTER 2: METHODS AND MATERIALS

In this chapter, I introduce the notion of body mass and its significance in biology. I then turn a brief consideration of the basic methods of paleoecological and paleoenvironmental reconstruction. A description of the cenogram and body mass clumps analytical techniques follows. Because the literature on cenograms is large and indicates there is some controversy over the validity of this technique, I summarize that literature in tabular form to save words. Because the literature on body mass clumps is limited, fewer words can be devoted to it. I then turn to a consideration of the materials used to evaluate the two analytical techniques. I begin with a brief description of the known environmental history of the area from which the archaeofaunas used to test the techniques derive. This is followed by brief descriptions of the sites that produced the archaeofaunas, and then a consideration of how I have chosen to parse the faunas into temporally distinct units (previous studies were both natural and arbitrary stratigraphic units). I conclude the chapter with an outline of predictions about what the cenograms and body mass clump graphs should reflect in light of paleoenvironmental conditions at particular times in the past.

Body Mass Analysis in Paleoecology

The body size of an animal is the result of a complex interaction of both intrinsic (genetic constraints) and extrinsic (environmental limits) factors. Genes can only build on existing forms and mutations, while the environment and interactions with other organisms provide additional constraints and influences on body size (Cumming and Havlicek 2002). Because of the close interaction between an animal and its environment, body size is one of the most tightly correlated and readily used factors for quantitative analysis of patterns in the comparative life history and physiology of animals (Calder 1984).

Body size may be the single most useful predictor of a species' adaptations (Damuth and McFadden 1990).

Body size has limits as an ecological signal, however. There are size limits on function, such as the ability of some insects to walk using the surface tension of water, or the need of whales to support the weight of their large bodies using the buoyancy of water. Size can be limited by different metabolic types, food preferences, and body temperature regulation. There are limits to the maximum and minimum sizes that can be reached (Calder 1984; Schmitt-Nielson 1984). These limits on body size can fall under three headings, *Size Independent*, *Scale Independent*, or *Non-Scalable*.

Size Independent constraints are those such as physical and chemical constants that cannot be changed, such as the need to supply energy and oxygen to muscle. Plants and animals must find the best possible solutions within these limitations of the physical world. These constraints can set limits on how large or small an animal can become. For example birds and mammals have a lower size limit of about 2g due to necessities of blood and oxygen circulation. Insect size is also limited by their ability to oxygenate their muscles. *Size Independent* constraints are those that must be met regardless of body size.

Scale Independent constraints are the properties of biological materials that are similar in large and small mammals, such as the physical strength of bones and tendons. Muscle filament diameter, sarcomere strength, and filament overlap, and therefore the force that muscle can exert, are the same in mice as in elephants.

Non-Scalable constraints are forces that cannot be changed, such as gravity, the properties of water, or the laws of thermodynamics. They do not vary with animal size, and body shapes and sizes must work around them (Schmitt-Nielson 1984).

Optimization is an evolutionary attempt to balance the constraints. There may be some overlap in that a design is optimal in one respect but not in another, and there are multiple variables to be balanced, but it is assumed that as far as possible, animals are optimized. *Symmorphosis* is the formation of structural elements, and is meant to satisfy, but not exceed, the requirements of the system. Excessive material to build unneeded structures is expensive and useless (Schmitt-Nielson 1984).

Numerous books and papers deal with the multitude of bodily and environmental variables that are involved in body size (see Calder 1984 and Schmitt-Nielson 1984). To understand how these variables vary across species and environments, the concept of *Allometry* has proved useful. *Allo*, meaning different, and *metric*, meaning measures, *Allometry* is the biology of scaling, or as Gould (1966) defines it, the study of size and its consequences. Calder (1984) is devoted to identifying the numerous variables and interactions that result in body size.

Paleoecology and Paleoenvironments

There are now a variety of methods that can be used in the reconstruction of past animal communities. Many center on inferences concerning diet and life ways, while others seek to reconstruct the environment. Wing et al. (1992) discuss three categories of paleoenvironmental reconstruction or paleoecology. They are taphonomy, ecological characterization of extinct species, and ecological characterization of extinct ecosystems.

One method of characterization of paleoenvironments concerns *Taxon Free* techniques. *Taxon Free* characterizations of a community examine the aggregation of species in a community as a character of the community. The character of a community may change over time, and can be measured and

compared with other communities. It does not require that the same species exist in each community under investigation (Damuth 1992). Some useful taxon free variables are ecomorphology and ecological type assignment to classes such as grazer, or browser, functional morphology of teeth, locomotion, or behavior. Fleming (1973) famously used trophic classifications among other things to categorize mammal communities, and more recently, the distributions of body sizes in a community have been useful in inferring the environment (Legendre 1986). Both the cenogram technique and the body mass clump technique are taxon free, though they typically are based on mammals.

Cenograms

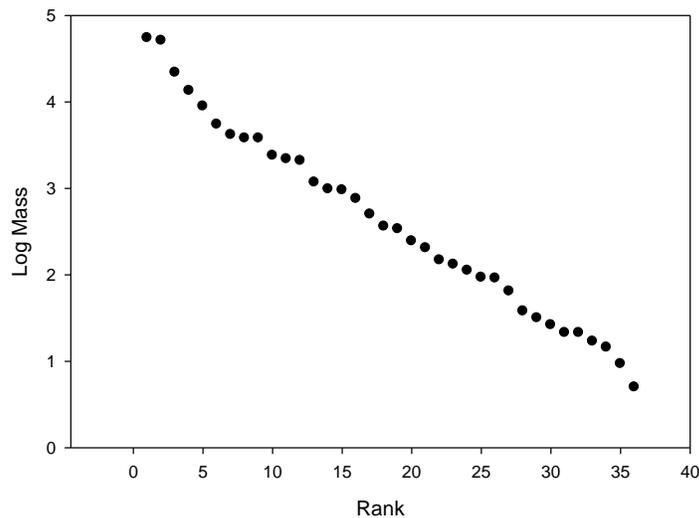


Figure 1 Sample Cenogram Showing Log Mass on the Y-Axis and descending Taxon rank on the X-Axis.

A cenogram is a graph showing the body mass distribution of taxa, usually mammals, in a faunal assemblage (Figure 1). It is constructed using the average body mass of an individual of each species, logged on the Y-axis, and the rank order from greatest to least mass on the X-axis. “Cenogram” comes

from the Greek, *koinos* meaning community, and *gramme* meaning a line (Gingerich 1989). Cenograms were first proposed by the Spanish ecologist, Jose Valverde in the mid 1960's, to analyze the relationship between the size of predators and their prey (Rodriguez 1999). Valverde concluded that amphibians, reptiles, and mammals are trophically grouped into microcommunities that are structured and independent of other microcommunities (De Bonis 1992). Each community can be considered a self-trophic chain, more or less independent of the other communities. Interactions between communities can be studied separately and each compared to the other communities in the same category in different areas. The body weight distribution is under the control of both the environment and relationships between prey and predators. The shape of the curve, defined by species-specific body masses, thus depends on predator pressure and the environment. In forest or closed environments, there is continuity to the curve, possibly due to higher trophic ecological niches. In open environments there is a break in the curve, generally in medium sized prey (DeBonis 1992).

The cenogram method developed by Valverde was modified by Legendre (1986). Legendre removed predators and created a graph of log body masses descending from largest to smallest. Bats were removed also because as flying creatures their interaction with the environment is different from terrestrial animals. Predators also likely react differently to the environment. Legendre took a large sample of mammals from several areas in Africa and in Europe. He plotted the body masses of each mammal species, excluding bats and carnivores, on his cenogram. Mammals were divided into three size categories: small (less than 500g), medium (from 500g to 8kg), and large (those over 8kg). He compared the cenograms from the different areas, and identified three patterns (Figure 2):

- A gap in the medium species should indicate an open environment, whereas a more continuous distribution of the species should suggest a more closed environment.

- The slope of the large mammals reflects the degree of aridity in their environment, the more pronounced the slope, the more arid the environment.
- The slope observed for the small species could be an index of minimal temperatures. In more temperate conditions, there are fewer small species than found in tropical conditions.

Legendre argued that cenograms allow one to infer some general aspects of the physical environment of fossil communities. Since Legendre's seminal work, the cenogram has been used in a variety of studies, as a standalone indicator of past environments, as a check or comparison to new or different analytical techniques, and as one of several tools used in larger multiple technique analyses of an environment.

Cenograms have also frequently been subjected to critical scrutiny.

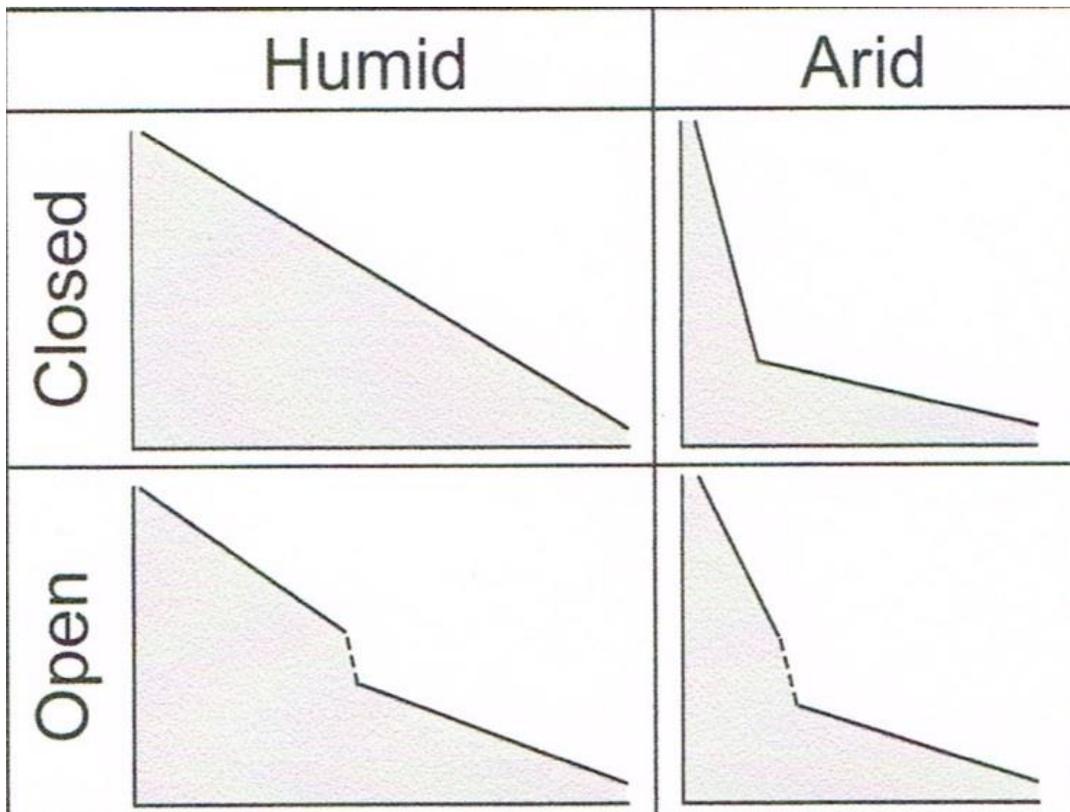


Figure 2 Cenogram shape and corresponding environmental characteristics from Costeur and Legendre (2008).

Cenograms have been used by many authors to infer paleoecology in various geographic places and for various time periods. From Legendre’s seminal (1986) paper, until present, cenogram use can be loosely categorized into three groups: those that use them to grant insights to paleoecological conditions, those that involve testing the validity of cenograms, and those that use cenograms as a check to test another method. These groups are not necessarily chronological, and reflect the ongoing debate over the validity of cenograms as a useful technique for revealing paleoecological details. Table 1 contains a synopsis of the American literature pertaining to the use of cenograms. The validity of cenograms for inferring paleoecology will be tested in this thesis using Holocene mammal collections from Missouri.

Table 1 List of studies using cenograms, and cenogram success.

Study	Cenogram technique	Purpose of study	Valid?	Concerns
Legendre 1986	Paleoecological Reconstruction	Develop a Technique	Yes	
Gingerich 1989	Test of Validity	Test Cenograms	Yes	
De Bonis 1992	Cenogram as a check	Test Other Methods	Yes	
Gunnell 1994	Multicomponent study	Examine Paleocology of Site	Yes	
Gunnell and Bartels 1994	Cenogram as a check	Test Earlier Work	Yes	
Montiure and Desclaux 1997	Paleoecological Reconstruction	Examine Paleocology of Site	Yes	
Sen et al. 1998	Multicomponent study	Examine Paleocology of Site	Yes	
Wilf et al. 1998	Multicomponent study	Examine Paleocology of Site	Yes	
Montiure et al. 1998	Paleoecological Comparison with Previous Method	Test of Evolutionary Response	Yes	
Montiure 1999	Paleoecological Reconstruction	Examine Paleocology of Site	Yes	
Rodriguez 1999	Test of Validity	Test Cenograms	No	Lacks Quantitative Strength
Alroy 2000	Test of Validity	Test Cenograms	No	Lacks Quantitative Strength
Croft 2001	Test of Validity	Test Cenograms	Yes, But	Identifies Weaknesses
Montiure and	Paleoecological	Examine	Yes	

Marcolini 2002	Reconstruction	Paleoecology of Site		
Flynn et al. 2003	Multicomponent study	Examine Paleoecology of Site	Yes	
Geraads et al. 2003	Multicomponent study	Examine Paleoecology of Site	Yes, But	Subjective Interpretation
Valensi and Psathi 2004	Paleoecological Reconstruction	Examine Paleoecology of Site	Yes	
Tougaard and Montiure 2005	Paleoecological Reconstruction	Examine Paleoecology of Site	Yes, But	Identifies Weaknesses
Polombo et al. 2005	Paleoenvironment Check	Test Earlier Work	Yes	
Hernandez- Fernandez 2006	Test of Validity	Test Cenograms	Yes, But	Identifies Weaknesses
Costeur 2007 a	Cenograms to look at Change over time	Examine Paleoecology of Site	Yes	
Costeur 2007 b	Cenogram as a check	Test Earlier Work	Yes	
Escaraguel et al. 2007	Paleoecology in Local Communities	Examine Paleoecology of Site	Yes	
Costeur and Legendre 2008	Paleoecological Reconstruction	Examine Paleoecology of Site	Yes	
Travouillon and Legendre 2009	Test of Validity	Test Cenograms	Yes, But	What is Measured?
Travouillon et al. 2009	Test of Validity	Test Cenograms	Yes, But	What is Measured?
Merceron et al. 2012	Paleoecological Reconstruction	Test Earlier Work	Yes	
Lyman 2013	Cenogram as a check	Test Other Methods	Yes	

Body Mass Clumps

Another method that makes use of the distribution of mammal body masses concerns body mass clumps. Mammal body mass distributions show a discontinuous clumpy pattern that reflects the discontinuous nature of the environments from which they come (Holling 1992). Holling (1992) showed that a few processes, such as the interaction between plant, animals, and abiotic variables, operating at different frequencies in time and space, structure the ecosystems and ultimately can be seen in the distributions of body masses. Holling's (1992) *Extended Keystone Hypothesis* states that these processes, the interactions of plant, animal and abiotic forces, interacting at different scales of time and space such

as centimeters to kilometers, and months to centuries, structure the ecosystem. Further, these cycles or periods that are made up of the processes of the keystone variables are discontinuous and nested. All other ecosystem variables must then track or be determined by one or more of these variables (Holling 1992).

If ecosystems are discontinuous, then attributes of animals that live in those ecosystems should be scaled to the discontinuous nature of those landscapes in which they live, for example in gaps in body mass distributions that separate clumps or categories of body mass. The *Textural Discontinuity Hypothesis* states that the discontinuous nature of the landscape is reflected in the discontinuous distribution of body masses (Holling 1992).

In later papers by Lambert and Holling (1998), and Lambert (2006), the notion of body mass clumps was put into analytical practice comparing prehistoric and modern faunas. The underlying assumption of the textural discontinuity hypothesis is that environments are top driven, that is, in Lambert's words, the behavior of the plants and animals in an area are driven by a relatively few overriding factors. A bottom driven environment is one where an ecosystem is the sum total of the numerous interactions among the components of a system. In a top driven environment there is a possibility of *Functional Convergence*. This results when two environments have relatively similar forces acting on them, and therefore result in similarly structured ecosystems (Lambert 2006). If two ecosystems are functionally convergent, then their discontinuous structures should be similar. Thus, the premise of Lambert's work is to identify similar environments to compare, and one should be able to identify or distinguish, for example, a forest environment from a savannah by the pattern of the clumps (and attendant gaps) of body masses. The idea that faunas from structurally different habitats have significantly different body mass clump distributions is Holling's *Bioassay Corollary* (Lambert and Holling 1998; Holling 1992).

Lyman (2013) was the first, to my knowledge, to apply this methodology to zooarchaeological remains. He compared a late Pleistocene fauna/early Holocene fauna from Washington State with the modern faunas in the area. The body mass clump method, as well as the cenogram method were used to test predictions (based on known environmental history) of the species richness and body size that should be present at the site. In comparisons with six modern faunas, the results of the two methods confirm predictions concerning the prehistoric habitats. Because Lyman (2013) examined only one fauna, additional tests of the body mass clump method are advisable given the still controversial nature of cenograms and the seldom used body mass clumps technique.

The body mass clump technique used to define clumps and gaps is a more rigorous technique than the visual identification of a gap in cenograms. Clumps describe body mass distributions in a different manner than a cenogram, a manner that is theoretically guided (e.g. Holling's work), unlike the cenogram method which seems to be empirically derived rather than theoretically informed. Taken together, these facts make body mass clumps quite a bit more scientifically rigorous than cenograms. While body mass clumps have not been used to the same extent as cenograms (Holling 1992; Lambert and Holling 1998; Lambert 2006; Lyman 2013), there is no real dispute over their validity (Seiman and Brown 1999). Perhaps the lack of dispute is a result of the rare use of body mass clumps, but whatever the case, the validity of body mass clumps needs to be evaluated. As well, comparisons of the results of one body mass technique with the results of the other may facilitate interpretation of both.

To identify gaps in the distributions of body masses, the logged body masses of the mammals from each stratigraphically distinct prehistoric fauna, and from comparative modern faunas used in the cenogram analysis, were ordered from smallest to largest, including carnivores. Carnivores are included in this case, because the relationships of all terrestrial mammals to the environment is being examined. To define body mass clumps, the method I used follows the procedure outlined in Lyman (2013). First

the magnitude of the total range of difference was calculated for each fauna by subtracting the body mass of the smallest taxon from the largest. That value was then divided by the number of taxa minus 1 from each fauna to determine a uniform interval of change in body mass from taxon to taxon per fauna. For example, a fauna with 36 taxa, spanning a logged body mass range of 4.73 to .7 gives a range of 4.03. That range divided by the number of taxa in the fauna minus 1 ($4.03/35 = .115$), gives the uniform interval. The difference in log mass was then calculated for each pair of adjacent taxa in the rank ordered list. "Gaps" were defined as a difference between the log masses of a pair of adjacent taxa that is greater than 1.5 times the uniform interval, so the gaps in the example would be significant if they were greater than $1.5 \times .115 = .173$. This calculation gives the *Gap Criterion Value*.

A bar graph was created in Excel with the rank order on the x axis, and the difference in log mass between each pair of adjacent taxa on the y axis. The resulting graph displays peaks and dips. The gap criterion was used to identify significant gaps by selecting the highest peak that rises above the value of the gap criterion. For example, for a gap criterion of .173, peaks whose values are higher than .173 would be examined, the highest peak is identified as the significant gap. The process is repeated for the next series of peaks that exceed the gap criterion. In some cases, the gap criterion value was not exceeded, but a gap was inferred. This was done because the resulting body mass clump graphs would be composed of overly large clumps of species with similar body masses covering a large range of masses that would be difficult to interpret. Missing taxa, likely in this case, skew clumps and give inaccurate data. While clump distribution graphs were made for both the inferred and strict interpretation of the body mass clumps, the graphs with inferred clumps were used in comparisons.

Once significant gaps had been identified, clumps and gaps were plotted with the number of species in each clump (taxonomic richness) on the y axis and the magnitude (range of log of mass) of the clump on the x axis. Clumps were defined by identifying significant gaps (see above) in the smallest to

largest ordered body masses. All species within each group of body masses separated by gaps were included in a clump. The significant gaps separate the clumps that define an ecosystem. The resulting graphs were compared with modern faunas and to observe change over time at each site.

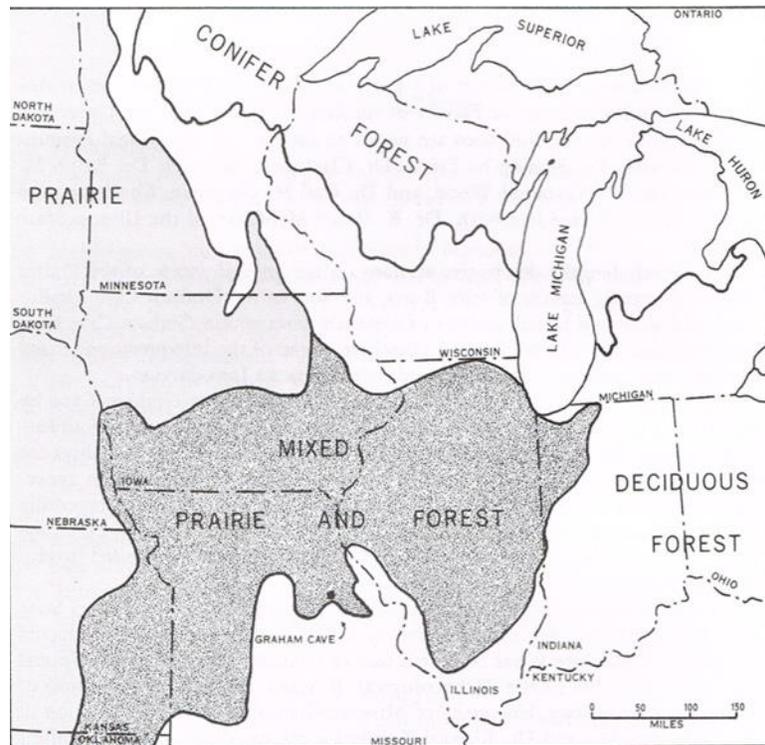


Figure 3 Vegetation Map of Midwest Prairie Peninsula as delineated by Transeau (1935). After Klippel (1971b: 2).

The Modern Environment and Paleoenvironmental History

Missouri and the greater Midwest are comprised of a complicated system of moisture, temperature and air current relationships that can have diverse effects even from one area to another in relatively close proximity (O'Brien and Wood 1998). The area under consideration here is the southern reaches of the Prairie Peninsula (Transeau 1935), defined by King (1973) as a wedge like expanse of grassland that extended eastward from the central Great Plains in to the forested regions of eastern North America (figure 4). This prairie occupied parts of Iowa, Missouri, and most of Illinois. The prairie peninsula extended as far east as Indiana with outliers in Ohio and Michigan. It is comprised of the mixed prairie and forests of the southern portion of the grassland mixing with the endemic deciduous forests of the Eastern United States (McMillan and Klippel 1981). Changes in climate during the end of the Pleistocene and through the Holocene had major influences on the distribution of the Prairie Peninsula and other habitats in the Midwest.

Late Wisconsin

The late Wisconsin (full glacial) period, starting around 23,000 years ago and ending about 11,000 years ago, was the last major glacial period in North America (King 1981). Ice sheets covered North America as far east as central Illinois and central Iowa (McMillan and Klippel 1981). Ocean temperatures were also generally lower (Kutzbach and Guetter 1986). Boreal forests, dominated by spruce, blanketed the mid-latitudes of eastern North America to as much as 1000km south of the ice. In the Midwest, taiga conditions may have existed near the glaciers with a narrow belt of tundra adjacent to the ice sheet. Tundra occurred in the higher elevations of the Appalachians to the east. Throughout the plains of Missouri and Illinois, spruce dominated other trees such as pine (King 1973; McMillan and Klippel 1981). During the Pleistocene, Ozark small mammals show evidence of disruption, as boreal species moved south to cohabitate with more southern taxa. Afterward, many small boreal species were

stranded in southerly ranges, species that have relatives that are located much farther north today (King 1973, 1981; McMillan and Klippel 1981).

After about 14,500 years ago (McMillan and Klippel 1981), the late glacial is marked by rapid deglaciation (Kutzbach and Guetter 1986). The glaciers had retreated from the prairie peninsula and there was a gradual increase in thermophilous deciduous trees in what had been boreal forest (McMillan and Klippel 1981). As the glaciers retreated, pine, spruce, and deciduous trees followed in their wake.

Holocene

The post glacial or Holocene officially starts 11,700 years ago. The Holocene was the result of changes in atmospheric circulation resulting in temperatures similar to that of today (McMillan and Klippel 1981).

In the upper troposphere, there are a number of currents, including the arctic air mass, the eastern flowing maritime tropical air mass, the pacific air mass, and a number of smaller ones. As glacial ice retreated, these masses which had been present in narrow bands, spread and mixed with each other changing seasonal air mass patterns. This resulted in a distinctive climate for the prairie peninsula. The Midwest was relatively dry in winter but rainfall and snowfall increased along the eastern portion of the prairie peninsula. And in summer, the East has rather uniform rainfall, while the Midwest is subject to more variability. The Midwest follows a 5 year drought cycle with 25 year drought periods (O'Brien and Wood 1998). The end result of this was that boreal spruce and pine forests were driven north along with animal taxa that prefer these habitats, while in the east and southern parts of the prairie peninsula deciduous thermophilous (requiring warm temperatures) trees and attendant animal taxa became dominant. In the Midwest dry conditions from the West brought grasses and prairie taxa into the peninsula and left it with a mosaic of deciduous trees and tall grass prairies, inhabited by some stranded boreal small mammals along with prairie and deciduous taxa.

Hypsithermal

Another climatic event that shaped the modern prairie peninsula happened from about 8500 – 5000 years ago (Wolverton 2002, 2005), or 7 – 6550 BC (O’Brien and Wood 1998). This has been called alternatively the *Hypsithermal*, *Altithermal*, or *Xerothermic* (O’Brien and Wood 1998 and citations therein), but following Wolverton (2002, 2005), will be referred to here as the *Hypsithermal*. The Hypsithermal (identified by decreased tree pollen and reduction of soil grain size) was a period of warmer and drier climate than that found today on the Great Plains. The change in climate allowed the expansion of prairie taxa into the prairie peninsula. This caused an increase in the abundance of prairie and timber edge taxa as well as changes in diet and body size in a number of taxa including people (Ahler 1973; Klippel et al. 1978; McMillan and Klippel 1981; O’Brien and Wood 1998; Wolverton 2001, 2002, 2005).

Summary

At the height of the late Wisconsin full glacial, ice sheets stretched well into the Midwest and temperatures were cooler and drier than today. Boreal forests of spruce and pine extended throughout the United States. As the ice sheets retreated, weather patterns favored a warmer and moister environment that allowed deciduous forest and grasslands to move North and East. During the Holocene warming the Hypsithermal, a period of warm dry conditions, favored the spread of grassland east into the prairie peninsula, and finally, a return to conditions similar to the early Holocene is present today.

Materials

Faunas were chosen for this thesis from three cave sites in central Missouri. The sites were chosen because previous archaeological work has been done on all of them. Materials recovered from all three have served as a basis for paleoecological or paleoenvironmental inferences already, so predictions can be made about what cenograms and body mass clumps should look like.

Along with prehistoric faunas, modern faunas were chosen and cenograms and body mass clumps were generated for them. The modern faunas will facilitate interpretation and evaluating the paleoecological meaning of prehistoric cenograms and body mass clumps by helping to predict what the cenograms and body mass clumps should look like during the early Holocene, the middle Holocene or Hypsithermal, and during the late Holocene.

The Sites and Previous Work

Rodgers Shelter has had a long history of archaeological investigation. It was intensively examined as a result of the Pomme de Terre excavations (Wood and McMillan 1976). Rodgers Shelter is located in Benton County, Missouri, on the north side of the Pomme de Terre river, on the border between the Salem (or Ozark) Plateau in the east, which is dominated by deciduous forest, and the Springfield Plain in the west, comprised of grasses (Figure 5). The area has since been flooded to create the Harry S. Truman reservoir. Rodgers Shelter was formed by a projecting dolomite bluff 6 meters in height that paralleled the river for approximately 400 meters. A narrow floodplain and terrace separated the shelter from the river's edge south of the opening to the shelter. The terrace (T-b1) contained all of the site's cultural deposits. The terrace forms a gently sloping, southward facing platform that provided living space for aboriginal people as well as the shelter itself. Debris scattered across the terrace indicates that most of the activities were performed in front of the shelter. On either side of the shelter are two short but

steep hollows that played significant roles in the depositional history of the terrace. The shelter itself is an overhang, about 24.5 meters long in the bluff providing a cave about 8 meters deep.

Rodgers Shelter was initially excavated in 1963 by two graduate students from the University of Missouri under the guidance of Carl Chapman. Later, from 1964 – 1968 excavations were overseen by R. Bruce McMillan, initially under the direction Chapman and later W. Raymond Wood. Originally, a trench was dug under the point of maximum overhang that was backfilled at the end of the 1963 summer. McMillan began excavating the terrace in 1964 with test pits that grew to 4 trenches at 90° angles to each other, leaving a block for profiling in the center. A single test pit to the bedrock was also dug that later revealed the oldest cultural deposits at a depth of 9 meters. Large block excavation was used to save time as a result of the depth of the materials and to best sample the site. A large excavation in the midden in front of the shelter was later extended to the bluff wall in the rear of the shelter (McMillan 1976).

Sediments of Rodgers Shelter were examined by Ahler (1973, 1976) from 25 samples representing 11 thousand years of accumulation and erosion. Using visual inspection and a combination of hydrometer and wet sieving, Ahler (1973) was able to provide a history of the habitat setting of the shelter, progressing from dense forest and seasonally moderate precipitation from 10 thousand to 9 thousand years ago, to increasing precipitation and dense grassland vegetation by 8600 years ago. From that point until 6300 years ago, evidence indicated continually decreasing seasonal precipitation, and increasing dominance of grassland, driving the forest onto hilly slopes along water ways. This suggestion is similar to McMillan's (1971) data documenting similar changes at the same times in cultural materials from Rodgers Shelter.

"Prehistoric Man and His Environments" is the end result of a comprehensive set of studies conducted at Rodgers Shelter over a decade from 1963 – 1974 (Wood and McMillan 1976). Starting

with McMillan's work at the shelter and continuing up to the mid-1970s it offers a comprehensive analysis of the remains recovered from the shelter.

Parmalee et al. (1976) conducted a plant and animal count for Rodgers Shelter in which they correlated the provenience of the samples to the level in which the samples were found. Aside from lists of the taxa found and their locations, they provide little more than cursory inferences about the taxa present in the area and inferred human dietary preferences. The plant remains are likely rodent accumulations as well as human, with hickory and black walnut nuts making up the likely human preferences. Fish and amphibians likely represent a small part of the diet and are species local to the area, the most common were catfish and suckers, but Parmalee et al. (1976) do not distinguish between human preference or local availability. Birds made up only 4% of the total faunal assemblage and the remains are mostly wild turkey and small perching birds. Waterfowl, prairie chicken, and bobwhite were found in early levels though not in numbers enough to suggest much importance. Counts of the mammals (90% of the remains) proved more interesting. Small mammals and bats were found, including some like the pocket mouse (*Perognathus*) and meadow vole (*Microtus pennsylvanicus*) which are no longer present in the area. Larger rodents were likely food, such as flying squirrels, woodrats, and woodchucks. Aquatic mammals were scarce and indicate the presence of streams along with fish. Cottontail rabbits made up a large part of the assemblage and were likely an important food source. The presence of some jackrabbit bones indicate possible prairie nearby. Coyote or dogs were present in all but the earliest levels. So too were medium carnivores and omnivores such as skunks, raccoons, and badgers (which no longer live in the area). Whitetail was the most numerous taxon found, and represented the most important food source though Parmalee et al. do not list abundances. Bison, elk, pronghorn, and an extinct peccary were all found though were not likely a major food source, the peccary was thought to represent a redeposit as it had been extinct for quite some time.

Ahler and McMillan (1976) used the classification of cultural materials from McMillan's earlier work (1971) to study the cultural remains from Rodgers Shelter. They infer artifact function or use based on the classification system used by McMillan (1976), and provide a list of stone and bone tools found at the site. Classes such as projectile point, hafted cutting tools, and miscellaneous worked bone, are used to infer activities such as fishing, hunting, woodworking, or storage. The materials are also counted and correlated with the level in which they were located.

Finally, McMillan (1976b) compiled results of the faunal evidence, tool functional activity data, and soil data into a comprehensive look at change in subsistence activities and the environment at Rodgers Shelter from 10500 – 1000 years ago. He was able to show a gradual but major reduction in forest edge environment to one of increased grassland and reduced trees beginning about 8600 years ago. The soils around the shelter indicate changes in erosion characteristics from more distant erosion to more local erosion linked to reduction in hill slope vegetation above the shelter (Ahler 1973, 1976). In the faunal assemblage, changes in frequency of forest taxa especially raccoon, and reductions in white tailed deer around 8600 years ago to more grassland species concur with the sedimentological data. Culturally, the people of Rodgers Shelter show a reduction in the availability of deer and an increased dependence on rabbits around the same time. Tools reflect the changing subsistence patterns from dependence on deer and forest taxa to more grassland taxa and dependence on rabbits. After 3000 years ago, an increase in the frequency of deer and a disappearance of all grassland vertebrates reflects a return to forested environments.

Klippel et al. (1978) examined the frequency and size of shells through time. While not heavily exploited until the later archaic period, Klippel et al. were able to show that changes in size are likely due to the presence of deep, fast moving water in wetter climates. The shells recovered from Rodgers Shelter show an increase in the use of mussels as a food source from the Middle Archaic to the late

Woodland, as well as a gradual increase in size throughout this period. Klippel et al. (1978) interpret this as evidence backing McMillan's (1976b) data of a drier climate during the early Archaic.

Purdue (1980) used squirrels and rabbits from Rodgers Shelter and Graham Cave to infer climatic events during the Holocene. He used the body size of *Sciurus niger*, *Sciurus carolinensis*, and *Sylvilagus floridanus* to show that in the squirrels, *S. carolinensis* increases in size from east to west and south to north while *S. niger* decreases east to west, and south to north in modern populations. Squirrels were smaller in the early Holocene at both sites, but increased in size during the middle Holocene to sizes similar farther west. Rabbits show a decrease from east to west. Rabbits were largest in the early Holocene, shrinking during the middle Holocene, and returning to modern sizes during the late Holocene. The results indicate that all species were correlated with Holocene climatic events from a mesic early Holocene, to a shift to sizes similar to modern western populations during the drier middle Holocene, and a return to modern sizes in the late Holocene.

Wolverton (2001) studied faunal assemblages from Rodgers Shelter, Graham Cave, and Arnold Research Cave. He was looking to see if changes in Holocene faunas were the result of environmental stress or population pressure due to human exploitation. Using box turtles, rabbits, and white tail deer Wolverton predicted frequency and body size relating to harvest pressure or environmental stress. He was able to show that during the middle Holocene Hypsithermal, cottontails remain abundant relative to turtles at Graham Cave. Deer however, fluctuate little in relation to cottontails, suggesting that forest edge, and open grassland increased to the detriment of turtles, but favored deer and cottontails. Frequencies in human subsistence patterns indicate that deer were not depressed in the area, while turtles were. This finding backs up the findings of Klippel (1971a) that forest taxa reduced during the Hypsithermal and prairie taxa increased likely in response to increased grassland. At Rodgers Shelter, the faunal data show that prairie increased during the Holocene. Rabbits were more prevalent than deer

indicating that either grassland favored rabbits over deer, or hunting reduced deer populations forcing a shift to rabbits. This is similar to McMillan's (1976b) analysis indicating that increased grassland forced deer away causing an increased reliance on rabbits. The grassland increased at both sites during the Hypsithermal, but more so near Rodgers Shelter (Wolverton 2001, 2005).



Figure 4 Missouri areas of study from Wolverton (2002).

Graham Cave is located near Mineola, Missouri, in Montgomery County on the southern border of the prairie peninsula (Transeau 1935). Prior to Euro-American settlement, it was a mosaic of upland prairie openings amongst oak-hickory woodland, continuously interrupted on valley slopes by mesic deciduous forest (Klippel 1971a). It is approached from the south, and is located on the north side of the Missouri River. The cave itself is about eight feet tall and can be walked into to a depth of about 60 feet, and crawling, an additional twenty feet can be reached (Klippel 1971b). The cave was initially excavated by Wilfred Logan (1950, 1952). He laid the initial grid and dug one foot vertical levels 1 – 6. His main concern was salvage and the only screening of sediments was done around human burials. Later, from 1950 – 1955 Carl Chapman took over and dug 6 inch levels 1a – 6b, and additional natural levels. Chapman screened with one quarter inch hardware cloth. Following Chapman's work, the site was returned to livestock and excavations ceased. Following a transfer to a public landmark, Walter Klippel was hired in 1966 to re-establish the grid used by Logan and a new datum. He used 3 inch levels and water screened through one sixteenth inch hardware cloth. Klippel worked over Logan's previous materials but included analysis deeper into the cave.

Cave deposits have been divided into four stratigraphic zones. The uppermost level, level one, is Euroamerican, and the result of stabling animals and plants in the cave. The second and third strata are both heavily disturbed by animal burrowing, and the lowest stratum, level four, is the culture bearing deposits.

Following Klippel's excavations in the mid 1960's he published a dissertation and an article on the excavations at Graham Cave. His unpublished Ph. D. dissertation (Klippel 1971a), looks at the environment from the Archaic through to about 3 thousand years ago. He looks at the geology, the vegetation, the animals, and the cultural manifestations during that time, with special attention to the preference of animal taxa for forest or prairie habitat. Klippel (1971a) concluded that major changes in

the climate of the prairie peninsula occurred between 8000 – 5000 years ago. Prior to 8000 years ago, the climate was cool and moist, inferred from pedological deposits of the strata at Graham Cave and the presence of forest preferring taxa in the lowest levels. Between 8000 – 5000 years ago, the climate was warmer and drier. This is seen in changes in taxa to forest border preferences that continue through the archaic. Finally, after 5000 years ago, the climate becomes moister. The cultural artifacts were less helpful, suggesting only that the cave was used in a similar fashion throughout time.

Klippel (1971b) is a revisit to the site and a re-printing of the data from the dissertation. His conclusions do not change: a cool, moist environment at the end of the glaciers that begins to warm after 10000 years ago, but before 8000 years ago. From 8000 – 5000 years ago a warm, dry period prevailed and allowed prairie grasses to move eastward across the prairie peninsula. After 5000 years ago, there is a return to lower temperatures and moister conditions along the northern border of the prairie peninsula. The cultural materials support these conclusions based on morphology of artifacts, however the deposition of the artifacts is in debate. Klippel (1971b) identifies two hypotheses: Willey (1966) claims that Plains hunters moved into the eastern areas during the Archaic in response to changes in the environment, and Stephenson (1965) claims that Archaic hunters from the Missouri area moved into the Plains when big game was no longer locally available.

Wolverton (2002) used frequencies of prairie taxa to show xeric middle Holocene conditions. He focused on the presence of prairie taxa such as *Spilogale putorius*, *Bison bison*, and *Taxidea taxus* with associated radiocarbon dates. He was able to show that the presence of these prairie taxa at Graham and Arnold Research Caves (located in the patchy forest/prairie border to the north of the Ozark Highlands) suggests drying of the area during the Hypsithermal that allowed the expansion of grassland, and with it prairie taxa into the area around the caves.

Arnold Research Cave has not been the focus of much archaeological work. Sometimes known as Saltpeter Cave, Arnold Research Cave is located two miles north of Portland, Missouri, in Calloway County, on the north side of the Missouri River (Shippee 1966). The cave is 120 feet wide and 70 feet deep. The cave has been alternately occupied by both man and animal resulting in a six foot deep deposit of trash over the entire interior of the cave (Shippee 1966). The last major occupation by American Indians seems to have been during the Late Woodland period when they primarily used the front of the cave. Since then, hogs, cattle, and sheep have been stabled there, tobacco has been cured, maple syrup has been boiled, cave tourists with lanterns, and saltpeter extractors have all used the cave resulting in an almost stratigraphically uselessly mixed deposit (Falk 1970; Wolverton 2005).

Prior to 1955, there seems to have been no archaeological excavations, the only digging being saltpeter extraction. In that year, J.M. Shippee began excavations by laying off the cave and the talus in five foot units. Both were dug in arbitrary six inch levels; the cave also had natural stratigraphic deposits recorded. Considerable digging and backfilling was evident by both Indians and saltpeter miners. Several trenches were dug, and depths of 18 – 60 inches as well as up to eight feet were dug and screened through one quarter inch mesh.

Shippee's (1966) publication of his 1955–1958 excavations notes the incredible amount of disturbance of the site but he still manages to generate an estimation of the cave's history. In the lowest levels of the cave, there is a six inch thick layer of fill that is relatively undisturbed, where they identified fire pits and some lanceolate points and scrapers that they have dated to around Dalton times by comparison with soil and artifacts from Graham Cave and other sites in the area. Above this level is one of relatively few artifacts and little disturbance about a foot thick. The few artifacts found are similar to those of older groups. Above this is a possible Mississippian occupation, followed by a longer more continuous woodland occupation, made up of thick layers of rotted organic matter, cordage, and

pottery sherds, where the occupants were likely making cordage, clothes, and pottery rather than working hides. They were likely there more continuously as indicated by the presence of pits dug and overall depth of refuse. Later there was no presence of Indians in historic times, but European settlers moved into the area and began stabling animals, digging for saltpeter, exploring and processing other materials in the cave resulting in a heavily disturbed layer at the surface (Shippee 1966).

Falk (1970) applied a factor analysis to the faunal data from Arnold Research Cave. His goal was to find the regularity and order within the faunal counts available to reach cultural conclusions. He was able to identify two contrasting subsistence bases. The first was generalized while the second was more specialized. The earliest inhabitants of the cave made use of a wide variety of animals. Gradually, however, groups began to narrow the portion of the environment which they exploited, and to exploit this portion with greater efficiency. His conclusions support Shippee's (1966) inference that nomadic paleoindians inhabited the cave in the earliest layers, followed by an absence and finally, woodland Indians, specializing in pottery and textile manufacture.

Summary

The evidence from the various sources implies that at Rodgers Shelter, Paleoindians with Dalton points were living in the area of the shelter in a forest edge environment from 10500 – 9500 years ago. Following an absence of a thousand years, mid Archaic people lived in the area as the forest began to shift to more grassland about 8600 years ago with the advent of the Hypsithermal warm dry period. The Hypsithermal peaks at around 7500 years ago and grassland taxa dominate the environment. People are increasingly dependent on small game as deer become scarce. By about 2300 years ago, there is a gradual return to mixed forest prairie environments as the late archaic transitions to woodland peoples. Deer begin to increase in number and more mixed habitat taxa take up residence (McMillan 1976b).

At Graham Cave, from 10000 – 8000 BP a forest environment existed that was warming following the cooler period of the glaciers. Animals were primarily forest taxa. About 8000 years ago, a period of warm dry climate began allowing the spread of grasses and the erosion of soils around the cave as trees declined. Forest edge and grasslands spread until about 3000 years ago when a return to colder wetter climates produced a forest to mixed forest/prairie habitat. Cultural evidence suggests that subsistence did not change much during that time, and immigration into the area was not likely as most of the stone tools are of local materials (Klippel 1971b).

Arnold Research Cave, near Graham Cave, shows a mixed stratigraphy due to the heavy digging and backfilling, but Shippee (1966) was able to identify nomadic Paleoindians living in the early layers of the cave, followed by more permanent Woodland residents that conducted significant digging and domestic crafts. Falk (1970) was able to distinguish different subsistence patterns, an unspecialized hunting strategy by the early paleoindians, using a variety of animals, and a later more specialized and efficient hunting strategy used by woodland groups. Without good chronology, this only loosely supports the change in subsistence resulting from environmental change at nearby Graham Cave, namely that Hypsithermal conditions caused increased grassland and dependence on smaller game. This is also in agreement with carbon dated prairie taxa found in the site corresponding to Hypsithermal changes (Wolverton 2002).

The Faunal Assemblages

Rodgers and Graham caves were each divided into four stratigraphic levels (Table 2). Those levels were based on both natural depositional levels and arbitrary stratigraphic levels, as well as some carbon dates associated with excavated material. For Graham Cave, the cenograms created from the four depositional levels correspond roughly to before the Hypsithermal, during it, the end of the Hypsithermal and historic times. Rodgers Shelter, because it had excavations both inside and outside

with different natural levels, required that natural levels be correlated for the shelter and the talus field with data provided by Wood and McMillan (1976). After the levels had been correlated with carbon dates, stratigraphic levels 1 -4 yielded five cenograms dated to the early Holocene (11 – 10.5 thousand years ago), the early Hypsithermal (8.6 – 8.2 kya), the middle Hypsithermal (6.7 – 6.3 kya), the late Hypsithermal (6.3 – 3 kya), and historic times (3 – 1 kya). All Arnold Research Cave materials were left lumped together because the amount of mixing was too great to allow sorting by stratigraphic unit or arbitrary excavation level.

Table 2. Correlation of dates and levels in the sites under study.

Correlation of Levels (In Thousands of Years Before Present)					
	1 Early Holocene	Early Hypsithermal	2 Middle Hypsithermal	3 Late Hypsithermal	4 Historical
Rodgers Shelter	11 - 10.5	10.5 - 7	7 - 6.3	6.3 - 3	3.0 - 1
Graham Cave		IV 9.7 - 9.3	III 7.9	II 7.6	I Euroamerican
Arnold Research Cave		9130 - 8190	7180	(Samples from Statigraphic levels 50 - 66 inches deep)	

Body masses for the taxa present at the three sites were taken from Smith et al. (2003). The body masses represent species averages and do not account for geographic differences. Only taxa that were identified to species were used, as body masses differ between similar species in the same genus. Modern domestic species were excluded as were invasive European species. There is one fragment from *Platygonis compressus*, found in Rodgers Shelter. According to McMillan (1976b), the species was extinct in the area earlier than the period under examination, and likely does not represent a species in the proper depositional unit, and so has also been excluded.

Carnivores have been removed from the cenogram analysis so that they can be compared to the model created by Legendre which does not include carnivores. Cenograms were made for each time period from the archaeological sites as well as a cenogram for each site that includes all time periods

together to compare change over time at each site. Individual cenograms for each level at the three sites were then visually compared to modern cenograms taken from several areas that border Missouri's physiographic regions. Cenograms were also made from modern faunas in relatively close proximity to the locations of the caves.

The mammal fauna from Ft. Leavenworth military base was taken from Brumwell (1951). Ft. Leavenworth is in Leavenworth Co., Kansas, just north of Kansas City, Missouri. The mammals from Leavenworth are identified as part of the Kaw Valley biotic district and represent mostly deciduous forest communities that have been subject to recent clearing, allowing tall and mixed grasses to intrude into the area typical of a savannah (Brumwell 1951). The mammals here should thus be primarily taxa that prefer forest with some forest edge inhabitants. Carpenter's (1940) article on the grassland biome was used to compile cenograms characteristic of the prairie peninsula. Carpenter compiled faunas from a large number of studies. He divided the prairie into tall grass prairies, short grass prairies, and mixed. The tall grass prairie is located on the eastern side of the peninsula, and is characterized by higher rainfall. In the west, the short grass prairies are more xeric and extend into the very dry regions of the west. Between the tall and short grass prairies is an area of moderate rainfall where conditions that favor one or the other type of prairie plants and animals fluctuate and create a mixed grass area. Carpenter (1940) also separates the areas by their northern and southern extents (from the border with Canada to northern Texas), as well as maximum eastern and western extents. For purposes of this study, only tall, short, and mixed grass areas have been included, with no separation by latitude. Mammal faunas from southern Illinois were included to represent faunas similar to the Ozark plateau of southern Missouri. The data were taken from Layne (1958). Those data were comprised from 14 counties from southern Illinois, though for this study only 5 counties from the Shawnee Hills region were used. The mammal faunas represent an area that is 26% forested with heavy cultivation (Layne 1958).

Mammal faunas from Missouri counties in proximity to the archaeological sites were also included. From data compiled by Enders (1932), Saline and Camden Counties, Missouri, were used. Saline Co. is south of the Missouri River about 70 miles east of Kansas City near the Great Bend of the river. Saline Co. is relatively close to Graham Cave and Arnold Research Cave, and has an environment characterized as a prairie with a scattering of trees, the land being under cultivation and the forests used for Pasture (Enders 1932). Camden Co. borders Benton Co. where Rodgers Shelter is located on the Ozark Plateau. Farming is done, but the majority of the region is covered by small woody growths of various deciduous trees (Enders 1932). The final site is from Ozark Co., in south central Missouri along the border with Arkansas. The faunas were taken from 5500 acres in a game refuge north of Gainesville, Missouri, in the Ozark Plateau (Leopold and Hall 1945).

The modern faunas were compared to the prehistoric faunas following the method of Legendre (1986), that is, visually. Cenograms showing similar patterns in both prehistoric and modern faunas indicate environmental conditions in modern faunas that are similar to past environments and allow the inference of an estimate of conditions at different periods in the past. The results of cenogram analyses can be compared to results derived from different methods used in previous studies of the prehistoric sites.

Predictions

Because Graham Cave and Arnold Research Cave are on the southern border of the prairie peninsula (Figure 4), I expect more fluctuations from forest to prairie taxa and back as the prairies move during the Holocene. I expect the early Holocene cenograms to reflect a more closed environment with abundant large taxa, and slopes that are not steep with many taxa of all sizes and no major gaps. In body mass clumps, I would expect taxonomically rich clumps of large mammals. I expect the mammalian fauna at Rodgers Shelter to reflect a more or less continuous presence of prairie or perhaps forest edge

taxa. Cenograms should show a gap in the medium sized animals, and fewer large mammals. The cenogram will display two distinct slopes, the slope defined by large mammals above the gap will be much steeper than the small mammal slope below the gap. Body mass clumps should show distinct gaps between large and medium mammals, and small mammals should be divided among clumps distinct from each other as small mammals should be clumped around fewer, but larger (taxonomically richer) clumps.

CHAPTER 3: RESULTS

Archaeofaunal Cenograms

Arnold Research Cave

Arnold Research Cave has been difficult to analyze because of poor stratigraphy, but previous analyses of recovered materials have been able to determine possible subsistence changes due to changing environmental conditions. Shippee (1966) identified changes in subsistence from hunter-gatherers in early deposits, to more sedentary cultures making pottery and cordage in the later deposits. Falk (1970) was able to identify two contrasting subsistence bases. The first was generalized while the second was more specialized. The earliest inhabitants of the cave made use of a wide variety of animals. Gradually, however, groups began to narrow the portion of the environment which they exploited, and to exploit this portion with greater efficiency. Falk's conclusions support Shippee's (1966) inference that nomadic Paleoindians inhabited the cave in the earliest layers, followed by an absence and finally, Woodland Indians, specializing in pottery and textile manufacture.

Both studies indicate a change from a hunting strategy that supports nomadic hunters to one requiring a broader diet breadth with smaller mammals included. Both studies are consistent with a local habitat going through changes as prairie taxa move into an opening forest area. Wolverton (2002) carbon dated this influx with remains of prairie taxa from the site that correspond to the Hypsithermal.

The cenogram for Arnold Research Cave (Figure 5) has few small mammal taxa. It shows a steep slope for the large animals that intersects (taxon ranks four and five) a shallow slope made up of medium and smaller animals. The two discernable slopes indicate a dry habitat, and the lack of a gap indicates that the habitat is relatively closed. The shape of the cenogram may, however, be a result of mixed stratigraphy, Taxa from both an open prairie and an earlier closed forest habitat mixed together

in the same level. In general however, Arnold Research Cave appears to have been an arid, yet closed habitat.

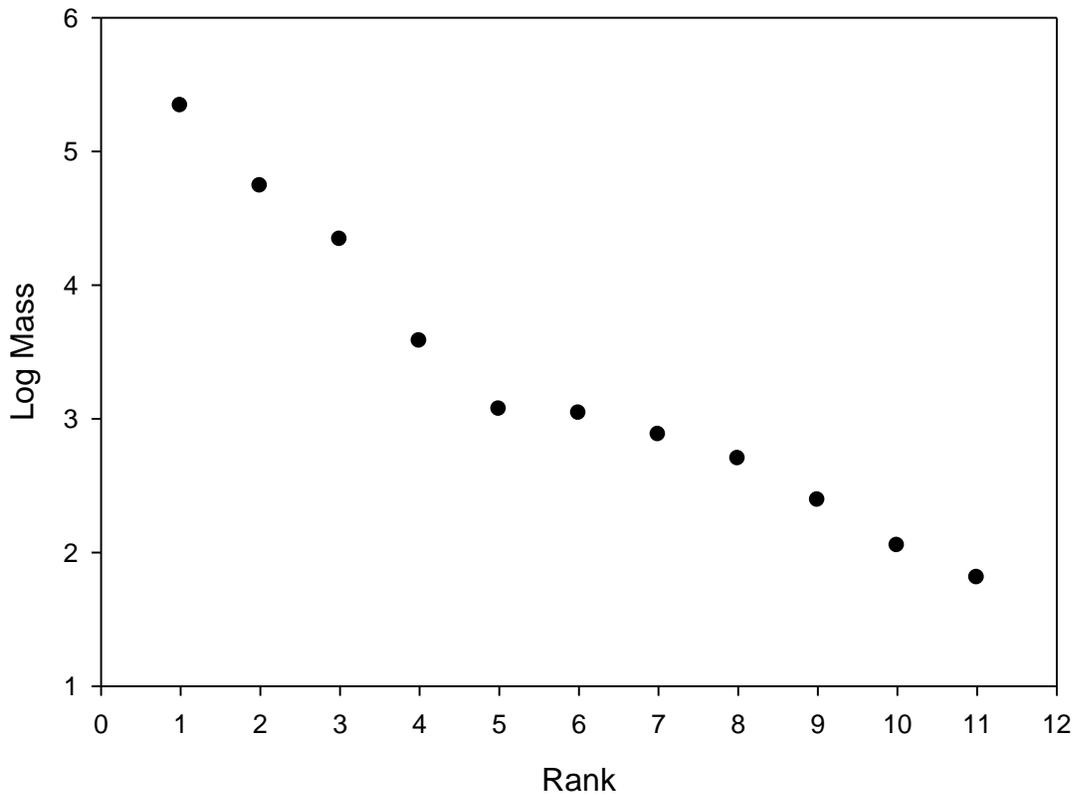


Figure 5 Cenogram Arnold Research Cave. Rank represents the rank order of body mass of individual species (1, 2, etc.).

While previous data make indicate subsistence strategy changes and movement of prairie taxa into the area during the Hypsithermal, the cenogram for Arnold Research Cave lacks resolution concerning changes over time. Thus I can only infer an average habitat over time, composed of dry, yet closed or mixed forest conditions. Importantly, the cenogram does not contradict previous analyses of the fauna from the site, though this might be attributed to its coarse resolution.

Graham Cave

Klippel (1971b) showed that a forest existed at Graham Cave 10,000 years ago. About 8,000 years ago, warmer and dryer conditions allowed an increase in grasses for the next 5,000 years. Finally, 3,000 years ago the climate returned to one similar to shortly after early glacial conditions around 10,000 years ago. The result is a mixed forest/prairie habitat.

The cenograms for Graham Cave (Figure 6) lack good representation of small animals, but some patterns can still be identified. The cenogram for the earliest level, Graham IV, shows a single clear slope from the largest taxa to the smallest. There appears to be no gap in the medium sized animals, and no difference in slope as we progress from large to small bodied species. The environment around Graham Cave in the early Holocene appears to have been relatively humid and closed. The other three cenograms, for the period from the start of the Hypsithermal to the most recent period of time, all appear to comprise the same array of body sizes. They all have a distinctly steeper slope in the large animals, and a less steep one for the small animals, but the small number of taxa in each indicates caution is warranted. In the medium sized animals there appears to be the absence of a gap, though there are too few species to warrant confidence. It appears that the environment was closed and humid, becoming more arid from the start of the Hypsithermal and remaining that way through later times. While the climate changed to greater aridity, the vegetation appears to have remained closed. A larger number of small mammals likely would have provided greater resolution.

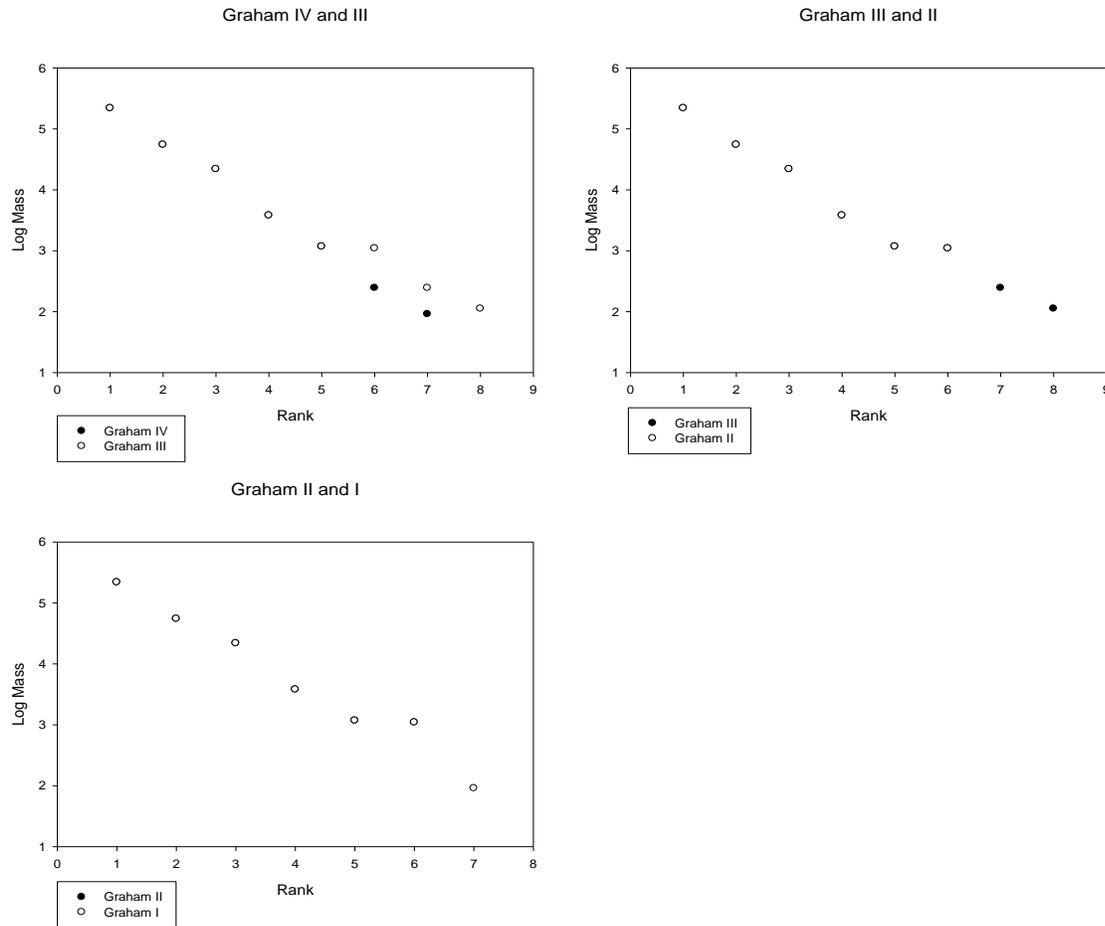


Figure 6 Cenograms for Graham Cave Compared.

Cenograms for Graham IV and III (Figure 6) tentatively confirm the predicted change from closed forest to a mixed habitat. At the end of the Hypsithermal, the climate returned to one similar to early Holocene conditions, yet the cenograms suggest that the taxa present in the area remained. This may be due to the fact that a mixed forest edge habitat cannot be easily distinguished from a closed forest in these cenograms, or the return to wetter conditions did not force the community to change its taxonomic makeup. All cenograms confirm Klippel's observation that with the return to colder wetter climates the environment remained mixed without returning to closed forest.

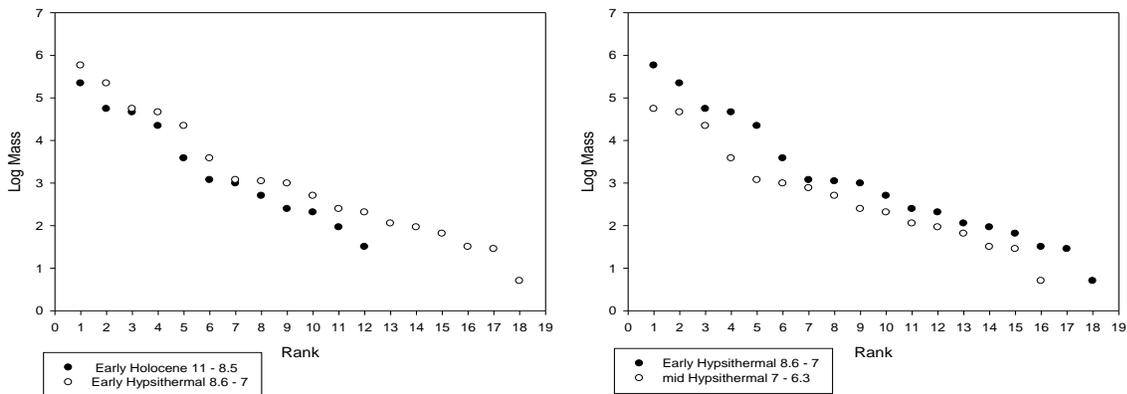
Rodgers Shelter

Previous studies at Rodgers Shelter have shown cultural activities and taxa present in the area originally reflect a forest edge environment at the Pleistocene/Holocene transition. Subsequently the environment becomes increasingly grassy. During the peak of the Hypsithermal at 7500 years ago, grassland taxa dominate and people are dependent on small game as deer are scarce. A gradual return to mixed forest/prairie environments occurs at about 2300 years ago and deer begin to increase in number. Mixed habitat taxa become common.

At Rodgers Shelter (Figure 7), a more detailed history is perceivable in the cenograms because of greater taxonomic richness. The cenograms suggest early Holocene habitats were closed and humid. There is some fluctuation in the slope, but not enough that I would characterize it as arid. It remains a continuous line from the large body sizes to the small. At the early Hypsithermal, a definite turn to aridity can be seen because the slope of the large animals is steeper than that of smaller taxa (division between taxa 6 and 7). There is no obvious gap so the environment remained closed, but it was drier than the early Holocene. By the middle Hypsithermal, the slope for the large animals diminishes somewhat indicating a return to more humid conditions. The slope of the entire range of body sizes is more continuous, perhaps also indicating greater humidity relative to the early Hypsithermal. There is still no obvious gap leading to a more closed vegetation interpretation. At the end of the Hypsithermal the slopes of the large animals is identical to the cenogram from the early Hypsithermal indicating a return to the drier conditions. The lack of a gap indicates the environment has remained closed throughout. Finally, more recently the environment resembles the humid period present in the middle Hypsithermal. The slope of the large body sizes is identical to the middle Hypsithermal. The slope of the smaller sized animals looks more like the slope of the earliest Holocene. The lack of a gap continues in this closed environment as well.

At Rodgers Shelter, a closed humid environment becomes more xeric. As time passes it fluctuates from dry to more humid until the present, never quite reaching the previous humidity of the early Holocene. However, the middle Hypsithermal, when aridity should be peaking in the prairies, seems to show a trend towards a wetter environment, but still not as wet as the early Holocene. Perhaps this is because the agents that accumulated the faunal remains focused their efforts more on what likely were more abundant prey in riverine habitats than more rare prey in arid upland habitats. Detailed taphonomic study of the faunal remains is required to test this possibility.

In this case, previous studies broadly reflect a change in environment. The cenograms for the area reflect a more dynamic view of community change. They confirm the previous work, but show that the area was flexible, changing back and forth as conditions were changing.



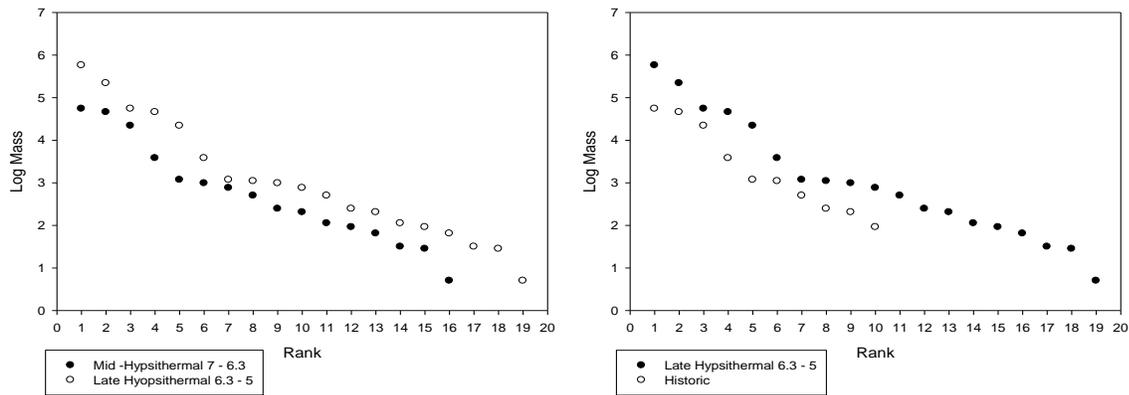


Figure 7 Rodgers Shelter Comparative Cenograms.

The cenograms reflect the previous paleoecological inferences, in which the early Holocene progressed to a more xeric habitat during the Hypsithermal, and returned to conditions similar to early Holocene conditions at the end of the Hypsithermal as shown in (Figure 2).

Archaeofaunal Body Mass Clumps

The graph for Arnold Research Cave shows five clumps of body masses (Figure 8). There is a lack of small mammals which, if present, might create an additional clump. Two large (taxonomically rich) clumps of medium sized mammals occur. The clumps of Arnold Research Cave bear some resemblance to the clumps from the modern sites in southern Illinois (Figure 16). The gaps are in the same places but the clumps in Illinois are smaller, the Arnold clumps overlap one, or in some cases, two of the Illinois clumps with the same gaps.

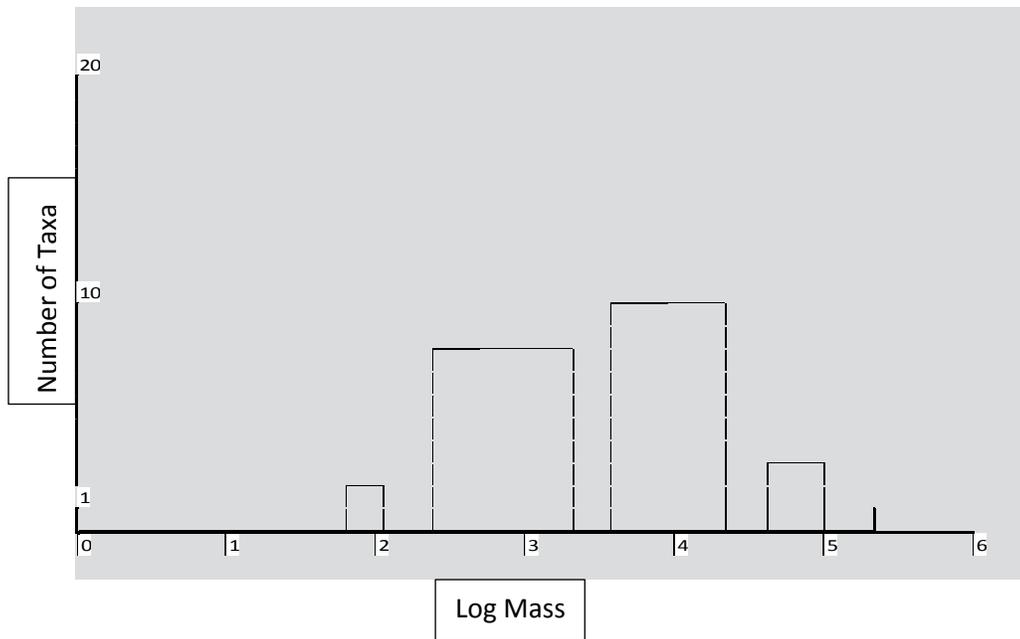


Figure 8 Clumps for Arnold Research Cave.

The clumps for Graham Cave show a continuous trend of changing environment (Figure 9). The earliest graph shows three clumps, a small one near log 2 in mass, a large one that encompasses the entire medium sized masses, and a third made up of large mammals. The clump at log 2 shrinks over time from Graham IV to Graham I. It is absent in Graham II due to lack of small mammals in the sample. Clump 2 which begins at log mass 3 shrinks in the range of sizes in mass over time from Graham IV to Graham II. Clump 2 increases in the number of species in the clump in Graham II. Clump 2 in the graph for Graham I has decreased in the number of species, but has shifted in range to include smaller mammals. Clump 3 (not present in Graham IV), shifts to smaller masses following Graham III, and remained the same from that period on in Graham II and I. Finally, clump 4, a single species of large body mass is present in all four graphs (*Cervus canadensis*) and cannot be placed into a clump.

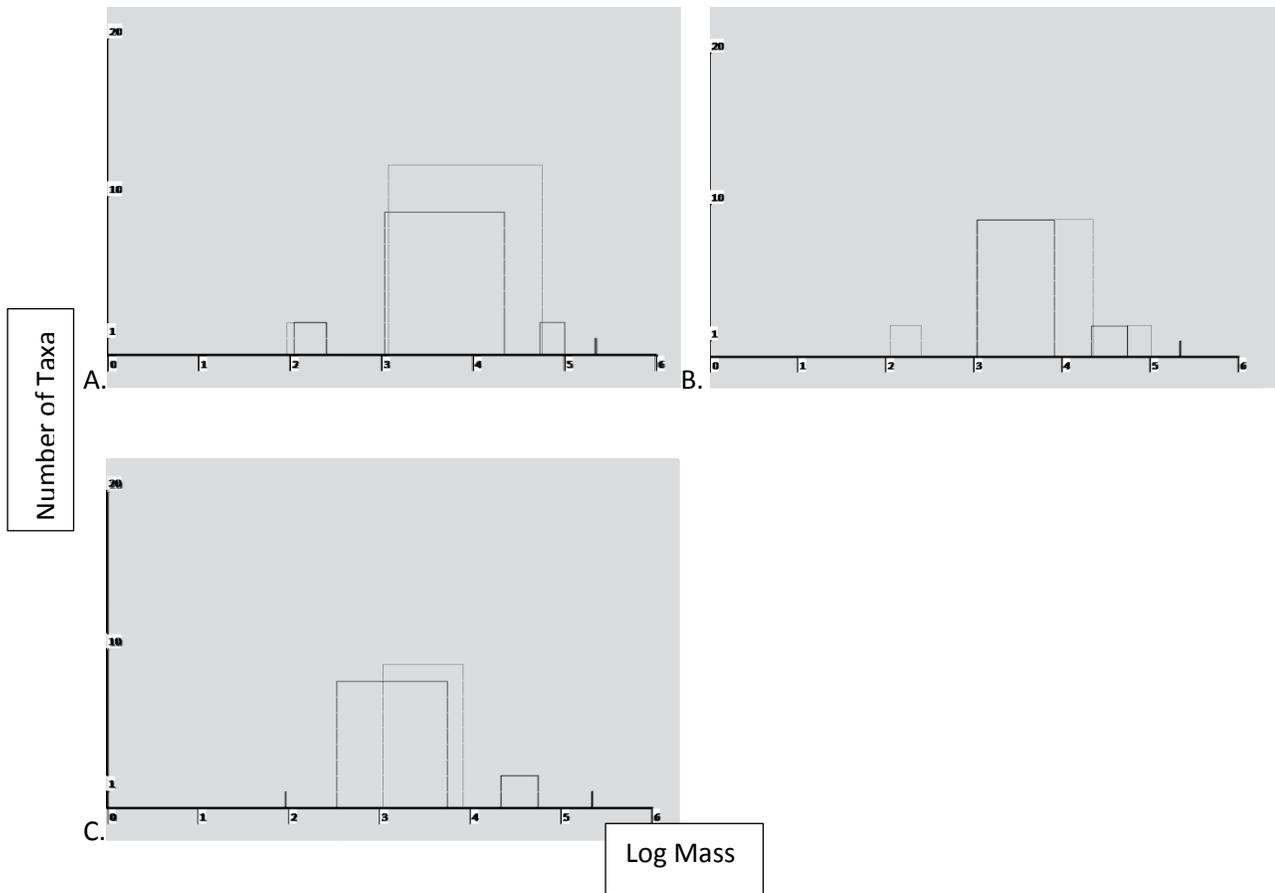


Figure 9 Comparisons at Graham Cave a. IV and III, b. III and II, c. II and I. but which is which, the black bars are one, the gray bars are the other (tell us which is which)

The graphs for Rodgers Shelter (Figure 10) seem to show more drastic change in the makeup of the environment. The graph for Rodgers 1, the early Holocene, has four clumps. The first represents a single small species, probably reflecting a lack of small species in the sample. The second and third clumps are most similar to clumps from the modern short grass prairie (Appendix 4). The second ranges from log mass 2 to 3 and the second from about log mass 3.5 to about 4.5. There is a fourth clump representing a single species as well. At the beginning of the Hypsithermal, Rodgers Shelter changes a great deal. Six clumps are now present resembling the modern graphs of Konza Prairie, or the mixed grass prairie. Change from a forest to a clear prairie is evident. The graphs for the middle Hypsithermal and the late Hypsithermal are almost identical, showing a similar environment for both periods. The

environment changes again in the historic period to one resembling the early Hypsithermal, indicating that the environment changed back to one similar to the early Hypsithermal during modern times.

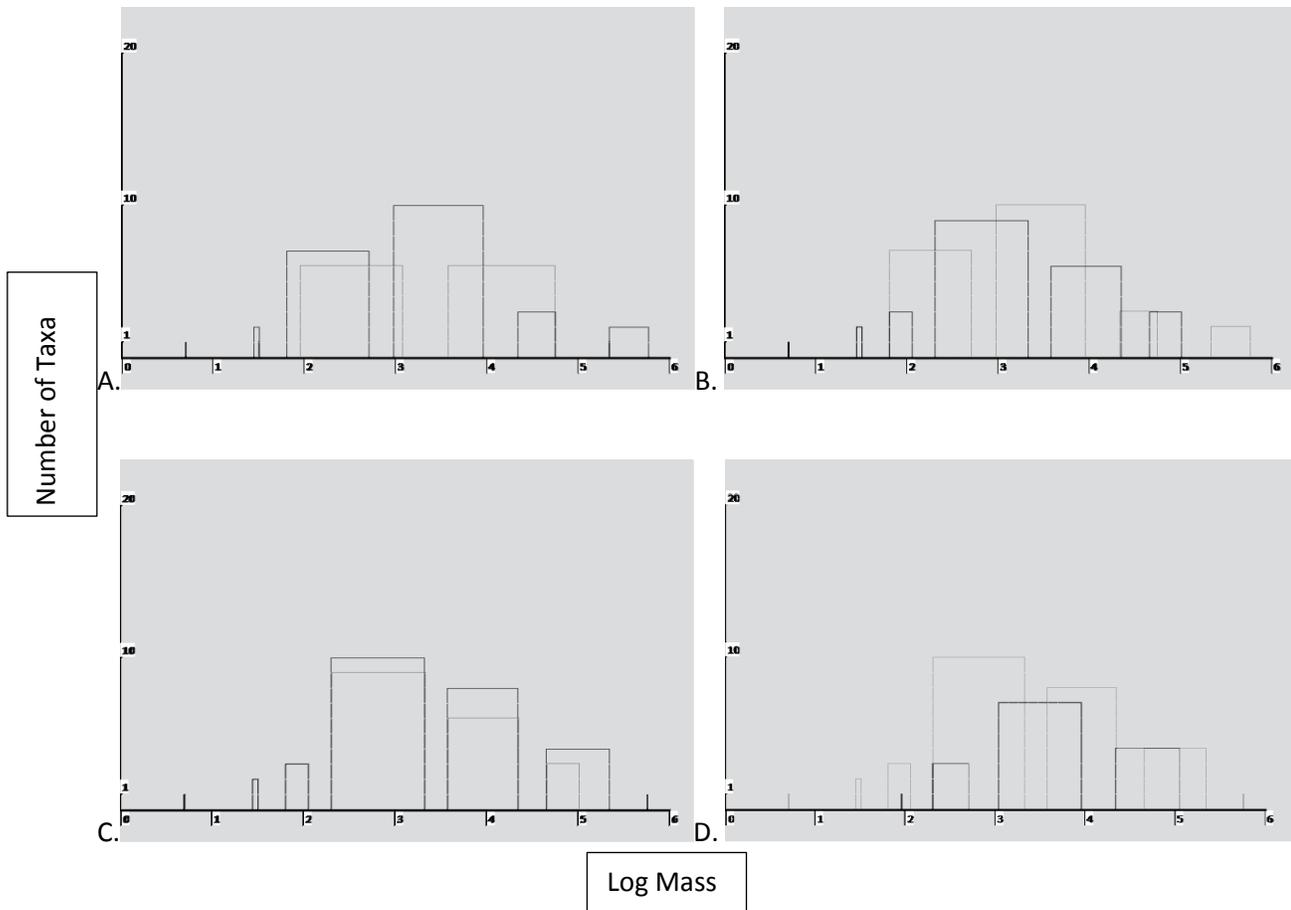


Figure 10 Comparisons at Rodgers Shelter a. Early Holocene and Early Hypsithermal, b. Early Hypsithermal and Mid-Hypsithermal, c. Mid-Hypsithermal and Late Hypsithermal, d. Late Hypsithermal and Historic.

Summary

Thus far, both the cenograms and the body mass clumps seem to accurately reflect with greater or lesser resolution the habitats inferred by previous researchers. This bodes well for the two analytical techniques, but in Chapter 4 I apply a more robust test to the results of both techniques by comparing the archaeofaunal cenograms and body mass clumps graphs to cenograms and clump graphs derived from modern faunas originating in known habitats.

CHAPTER 4: COMPARISONS WITH MODERN FAUNAS

Although the cenograms and body mass clump graphs derived from the archaeofaunas tend to not contradict inferred paleohabitats at the three cave sites, previous analyses of cenograms in particular have depended on comparisons of paleo-cenograms with cenograms derived from modern faunas documented in habitats of known kind. When a close match is found between a modern cenogram and a paleocenogram, the habitat structure of the latter is inferred to be the same as that of the former. Such comparisons also allow finer resolution paleoenvironmental inferences, such as more precisely how closed or open a particular paleohabitat may have been. I perform just such comparative analyses here as a second test of the validity of cenograms and body mass clumps as paleoecological indicators.

Comparative Modern Cenograms

Modern cenograms (Figure 11) were constructed based on faunas in environments near the three archaeological sites. Comparative environments were chosen to show local variation in habitat types and the diversity of habitat in relatively close proximity to the archaeological sites. Local habitat comparisons comprise a forest habitat, a forest edge mixed habitat, a prairie habitat, and a prairie with the intrusion of forest.

Leavenworth County, Kansas (Brumwell 1951) represents an intrusion of deciduous forest into mixed and tall grassland following the Missouri river. The faunas from the area show primarily small (under 500g) mammals, and an apparently continuous graph indicating a closed environment (Figure

11). There is a gap at the top of the medium mammals around 8kg, and the very few large animals generating the steeper slope, indicate an arid habitat.

Ozark County, Missouri (Leopold and Hall 1945), is located in south Central Missouri on Missouri's Southern border. The habitats in the area are within the deciduous forests of southern Missouri, and are composed of mostly forest taxa. The cenogram shows a slope that is broken only by a small gap between large and medium taxa (Figure 11). The overall slope is continuous and shallow indicating a closed and humid (very little difference in slopes between large and medium sizes) environment.

The Tall, Short, and Mixed Grass prairies are within the grassland biome. The habitat includes prairie adapted taxa, with variation depending on preferences towards grass height. The cenograms for the three heights of grass found on the prairies all show two distinct slopes (Figure 11). The first made up of large taxa is steep (has few taxa). There is also a large gap separating large and medium species. The cenograms suggest open and dry conditions.

Southern Illinois (Layne 1958) is composed of several counties. Habitats in the area were primarily farmland and floodplains cut out of the forests of the Ozark Plateau. Fauna are likely composed of mixed forest and forest edge species with some taxa that have preferences related to agriculture. The cenogram for southern Illinois shows a small gap and a slight change in slope ending with rank 6 (Figure 11). The slope of the small mammals is less steep. The cenogram indicates a predominantly closed, humid environment overall.

Saline and Camden Counties, Missouri (Enders 1932), were chosen for their proximity to the archaeological sites. Both counties are in central Missouri, with Saline County having the Missouri River as its northern boundary, and Camden is farther south. Saline county should be the closest representation to the modern faunas in the area and Camden should show more forest adapted taxa as

it is farther from the prairies in the north of Missouri. Both assemblages lacked large taxa, and the possible gaps or changes in slopes are thus hidden.

Konza Prairie, Kansas (Brown and Niccoletto 1991) illustrates the best example of an open and dry prairie. It has two distinct slopes, the first steep slope is made up of large and medium sized taxa and shows a large gap at the medium sized border at log 3.9 (Figure 11). The second slope is much less steep and is made up of the small taxa.

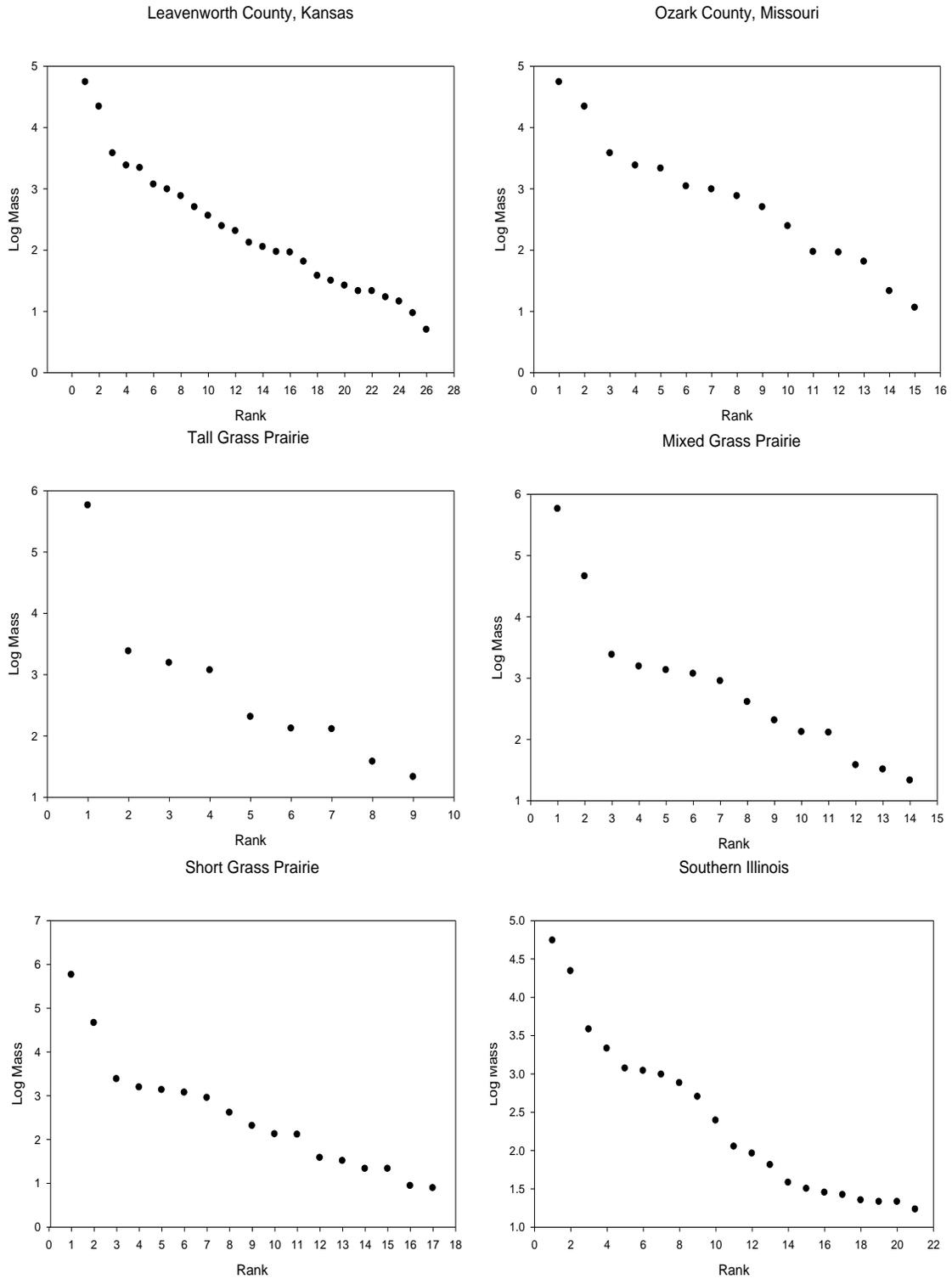


Figure 11 modern comparative cenograms.

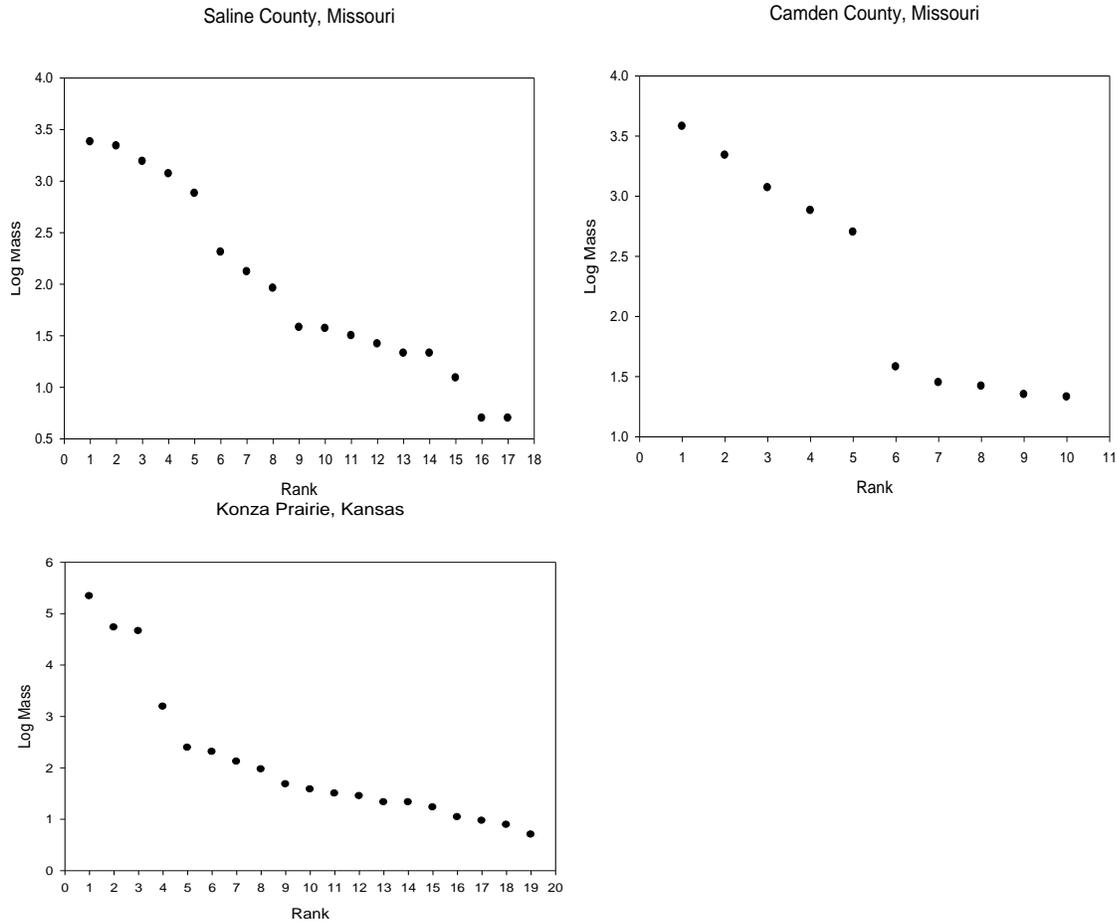


Figure 11 Modern Cenograms, continued.

For the purposes of comparison, Konza Prairie will serve as an open, arid prairie. Ozark County, Missouri will serve as a closed forest, and Leavenworth, and Southern Illinois approximate a more mixed, forest and prairie habitat.

Given the inferred Holocene environmental history of Missouri, particularly in the Hypsithermal climatic episode, the expectations for cenograms are that a forest should be distinguished from grassland by a closed, wet pattern. It should be noted that Travouillon and Legendre (2012) could not distinguish between a forest and a savannah, probably because the arboreal taxa present skewed the

cenogram into resembling a more closed environment. A mixed environment then would be difficult to see in a cenogram. It would likely be more arid, but may contain enough arboreal species to appear closed. An open environment should show up reasonably well in a cenogram. The slope of the large animal curve would be steep and separated from the smaller by a gap in the medium sized animals.

Comparisons of Modern and Paleo Cenograms

Arnold Research Cave, based on visual comparison, most closely resembles the cenograms for Southern Illinois and Ozark County, Missouri. The southern Illinois cenogram comes from an area of forest and agricultural lands likely reflecting a forest or forest edge habitat. Ozark County, Missouri is also forest habitat. The cenograms for both modern faunas show a general continuous trend from large to small species with no gaps to indicate open habitats.

While the cenogram for Arnold Research Cave shows a trend towards a drier habitat by the change in slope between the larger and smaller mammals, the overall trend resembles the closed forest of Ozark County, Missouri the most (Figure 12). The cenogram from Arnold Research Cave is based on a stratigraphically mixed (time averaged) fauna, however, and likely only reflects the habitat overall. It appears that in general, the area around Arnold Research Cave was similar to that of southern Missouri and Illinois, a closed forest, or mixed forest edge habitat.

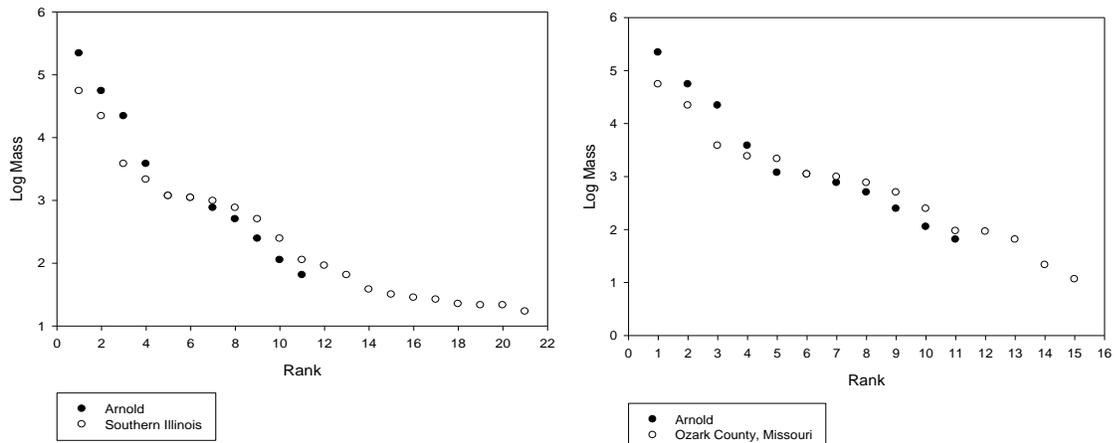


Figure 12 Modern comparative cenograms with Arnold Research Cave.

The comparisons with modern cenograms for Graham Cave (Figure 13) illustrate how different inferences can be if taxa are missing. When examined with a modern comparative cenogram available, Graham Cave cenograms show a much steeper slope than when viewed alone. The cenogram from Graham Cave looks less closed, and more like a dry habitat. It resembles the cenograms from Leavenworth, Kansas and Konza Prairie, Kansas the most. In particular, Konza prairie has a body mass distribution most like Graham Cave, suggesting that Graham Cave was a dry prairie environment throughout the Holocene and Hypsithermal.

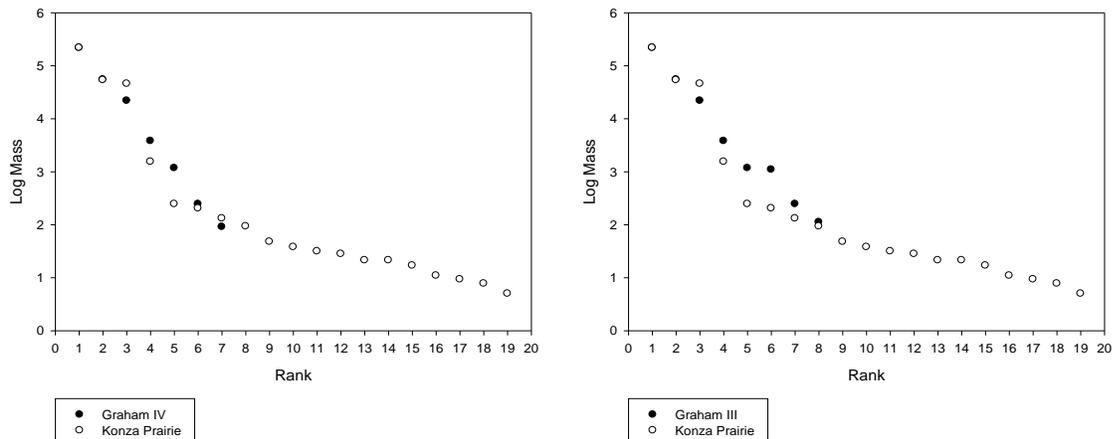


Figure 13 Graham Cave cenogram and Konza Prairie.

The early Holocene around Rodgers Shelter (Figure 14) resembled the modern fauna in Ozark County, Missouri. The slopes indicate a closed, if slightly arid habitat similar to the one in the south of Missouri today.

The cenograms indicate that Rodgers Shelter remains similar to Ozark County through most of the Hypsithermal. By the mid-Hypsithermal, Rodgers Shelter is almost identical to Ozark County, Missouri. Toward the end of the Hypsithermal, Rodgers Shelter begins to resemble a more mixed prairie, such as Leavenworth County, Kansas. The slopes of the large animals begin to become steeper, indicating a drying of the environment around the cave.

Following the Hypsithermal, the cenograms for Rodgers Shelter indicate a return to a more closed forest. The cenogram shows fewer taxa, but the slopes are similar to the forest or mixed forest habitats from Ozark County and Southern Illinois.

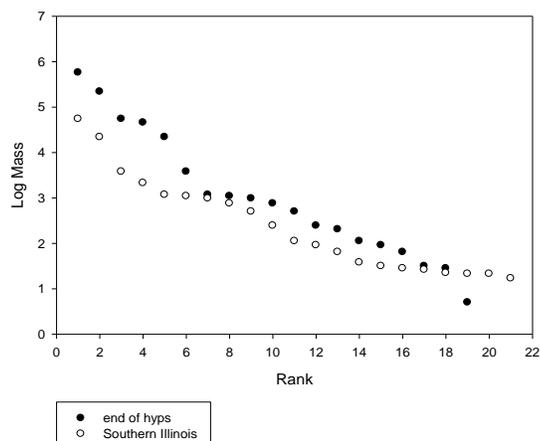
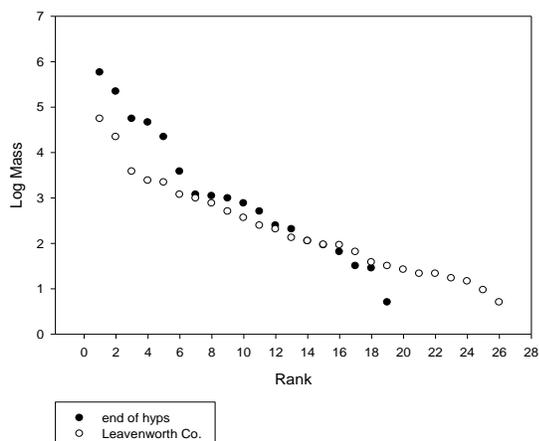
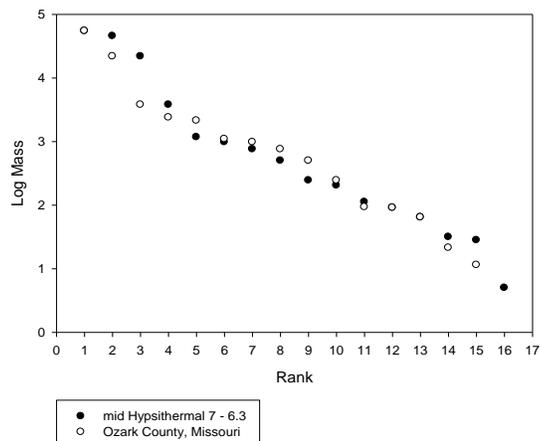
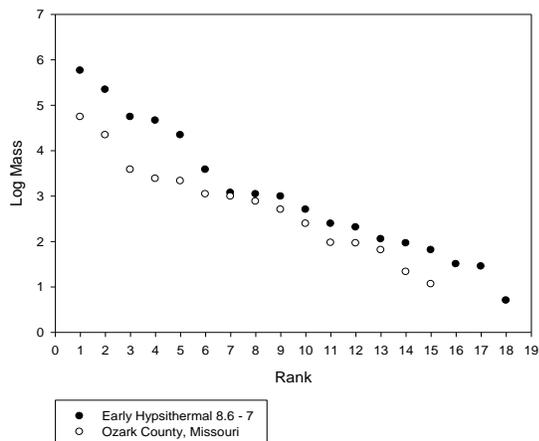
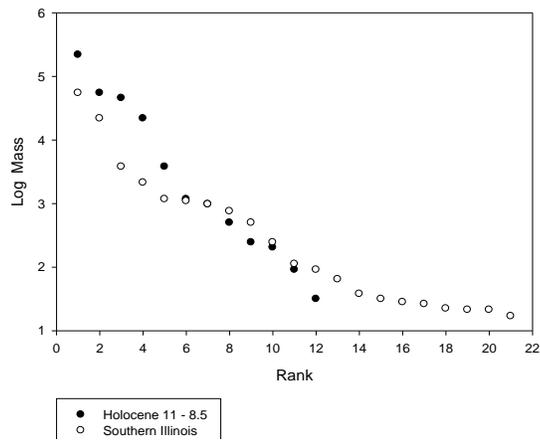
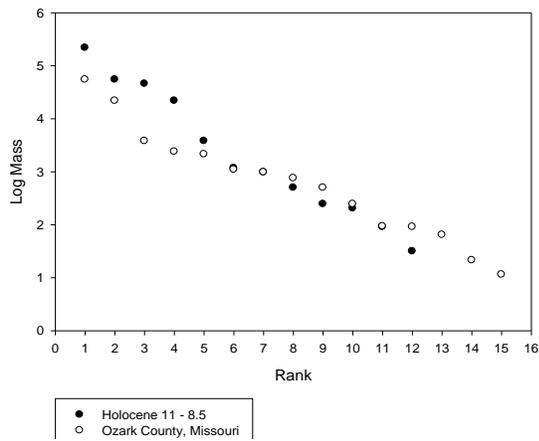


Figure 14 Modern comparative cenograms with Rodgers Shelter.

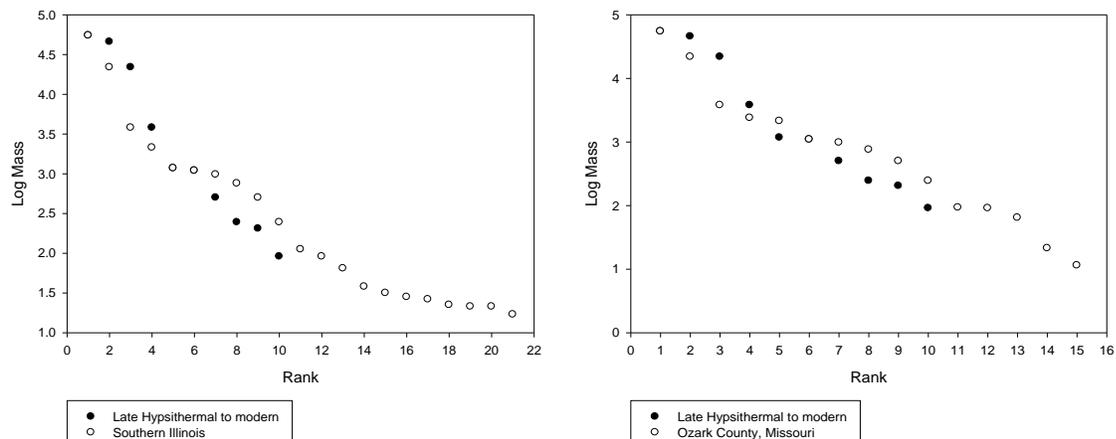


Figure 14 continued.

Comparing Paleo and Modern Body Mass Clumps

In comparing the body mass clumps derived from faunas in modern environments, it was apparent that conclusively being able to distinguish between differing environments as Lambert and Holling (1998) suggest is not straight forward in the mixed environments of the central United States. When compared (Figure 15), certain patterns seem to present themselves. Konza Prairie, the most like a true prairie has five clumps with the largest clump, the first clump at the smallest sized mammals. Clump three, is the next largest, at the medium to large sized mammals. The clumps are large and widely spaced apart. Ozark County, Missouri, a closed forest, also has five clumps. Here the clumps are largest at the medium sized mammals.

The two mixed habitats, Leavenworth, a prairie with forest intruding, and Southern Illinois, a forest, that has been cultivated to prairie, show interesting trends. Leavenworth has seven clumps with two large clumps at the smallest sized mammals. It also has a large clump at the medium to large sized mammals. Southern Illinois also has seven clumps, with the largest clumps near the middle size classes, and a large clump at the smallest size class. It appears that the habitats significant clumps were altered

to account for the intrusion of new taxa, but retain the general qualities of the dominant habitat type either forest or prairie.

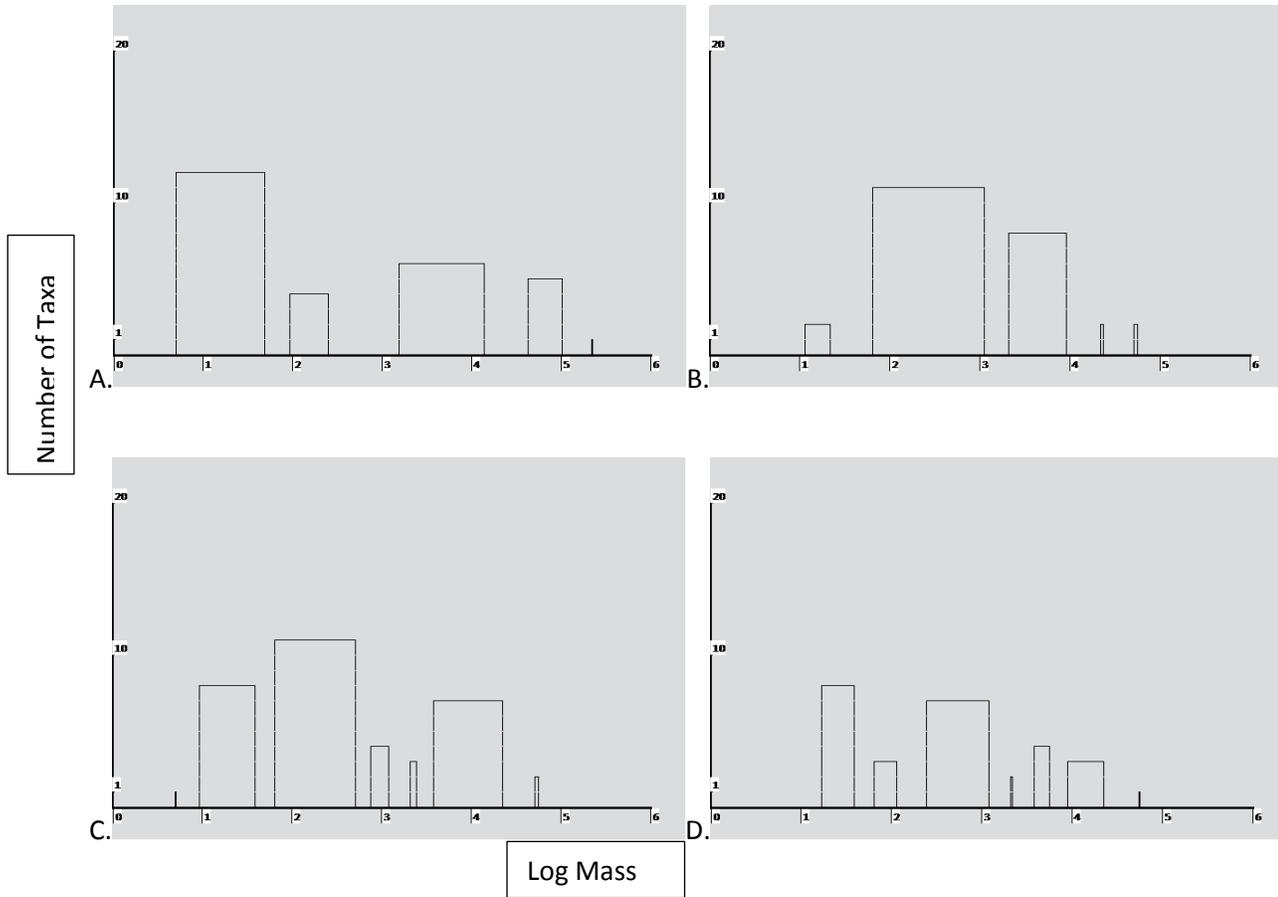


Figure 15 Modern comparative clumps, a. Konza Prairie, Kansas, b. Ozark County, Missouri, c. Leavenworth, Kansas, d. Southern Illinois.

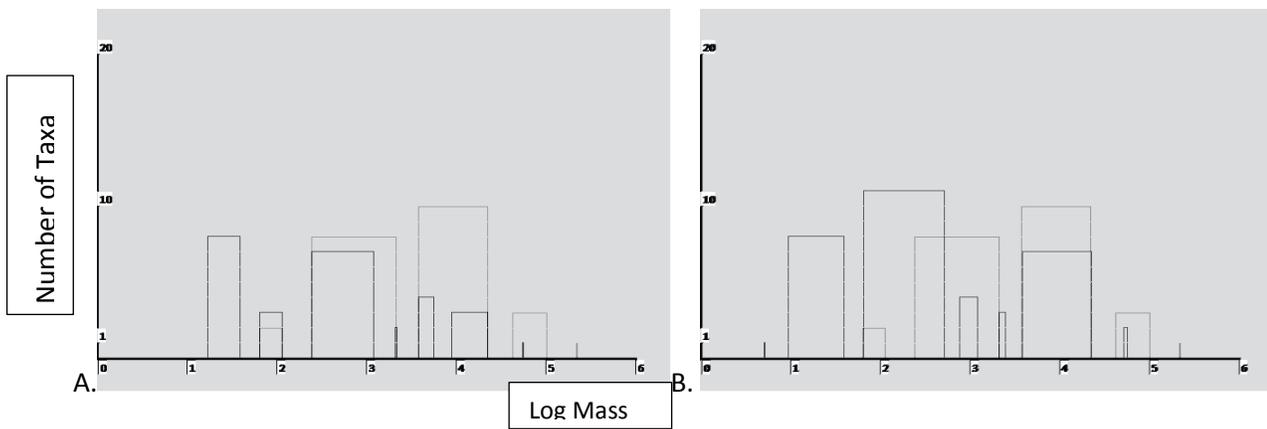


Figure 16 Arnold Research Cave (Faded) a. under Southern Illinois, b. under Leavenworth, Kansas.

Arnold Research Cave shares some clumps with both mixed type habitats (Figure 16). With Leavenworth, Kansas, Arnold shares a clump at about log mass four that has the same size range in mammals, but more taxa. With Southern Illinois, it shares a general clump and gap structure. Both share the same gaps at the same size ranges, yet Illinois has more than one clump and fewer species per clump in the same range. This may show missing taxa in the Arnold clumps, or the more mixed nature of the Southern Illinois clumps.

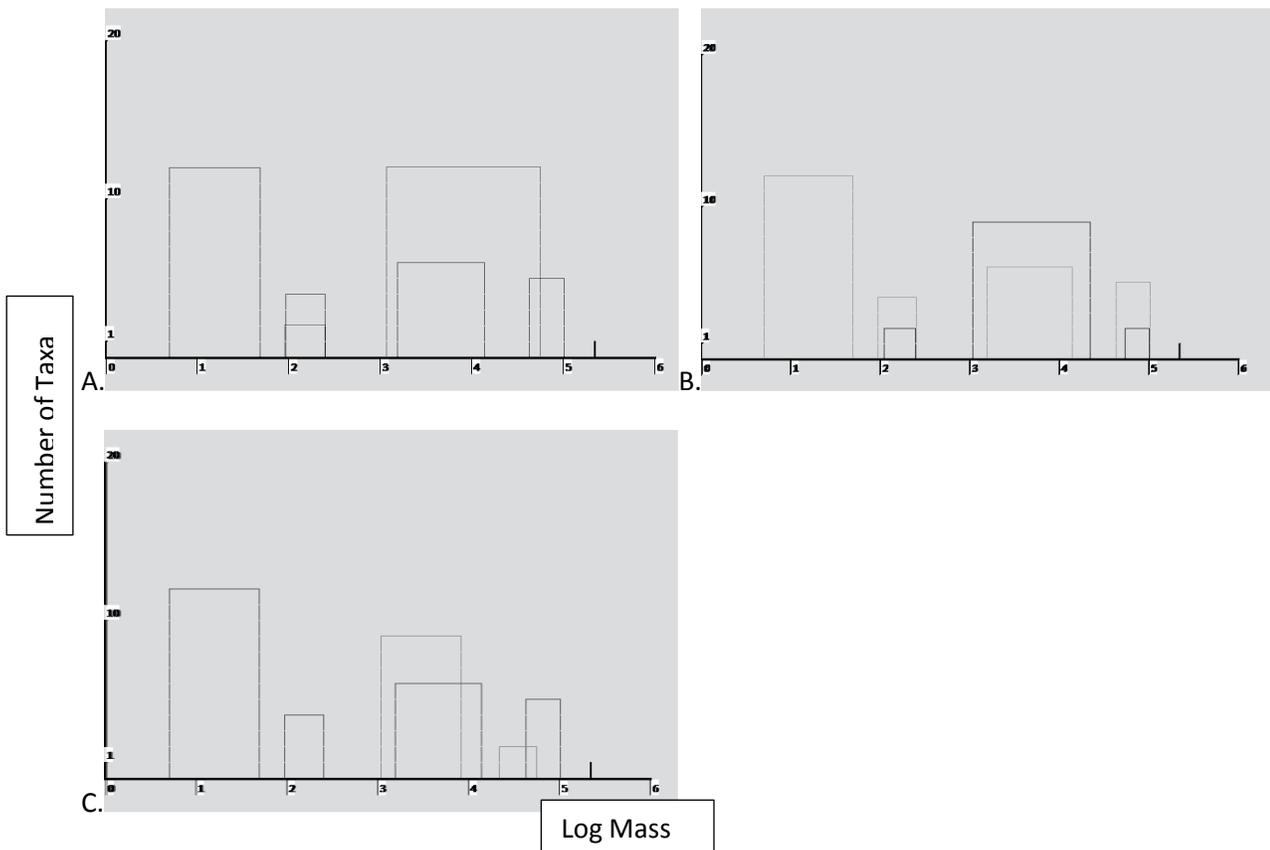


Figure 17 Graham Cave Clumps (Faded) and Konza Prairie, Kansas.

The body mass clumps identified for Graham Cave (Figure 17) do not seem to show a major change in the environment that would be expected in a transition from forest to prairie. The clumps seem to have stayed in the same general body mass areas over time. The major clump at Graham Cave shrinks in size range, and taxa overall shift toward smaller sizes.

The clumps at Graham Cave very clearly share similarities with open prairie like the clumps from Konza Prairie. Both Konza and Graham Cave have a similar clump and gap distribution. Graham Cave shares no similarities with the Ozark County, Missouri clump graph. Graham Cave lacks good small mammal representation, when viewed with the small mammal heavy clumps of Konza Prairie, can account for the dissimilarity.

Graham Cave was an open prairie at the start of the Holocene, and remained so throughout its history. It shows very little change throughout the climate changes associated with the middle Holocene.

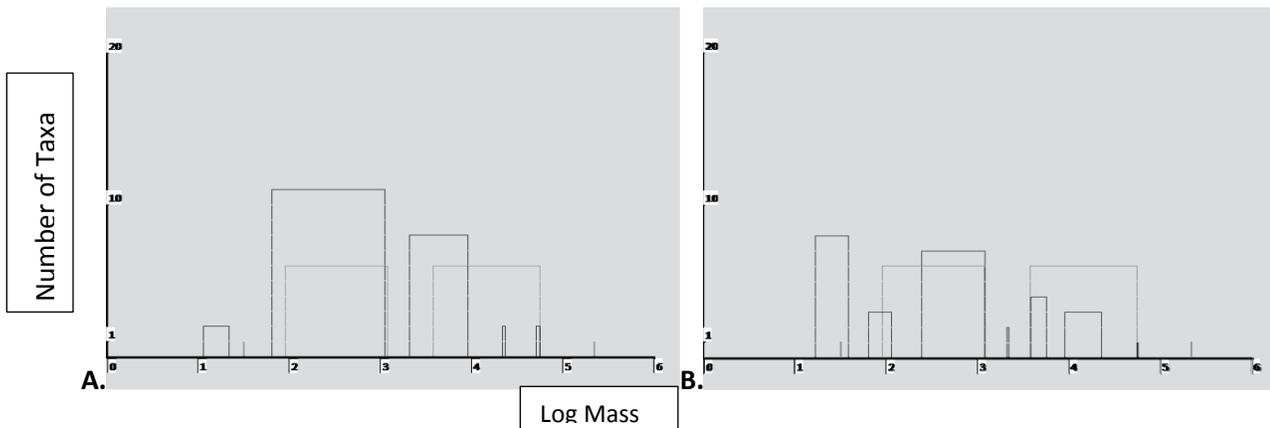


Figure 18 Rodgers Shelter clumps from the early Holocene (Faded) and a. Ozark County, Missouri, b. Southern Illinois.

The early Holocene clump graphs for Rodgers Shelter (Figure 18) bear little resemblance to the modern comparative clumps. Only the modern clump graphs from Ozark County, Missouri and Southern Illinois bear any resemblance. In the modern clumps for Ozark County, some overlap can be seen in the second clump from Rodgers and the second clump from Ozark County. In the modern clumps from Illinois, the last three clumps seem to be enclosed within the third clump from Rodgers.

This may be evidence of a non-analog environment from the early Holocene, or the effects of missing taxa, missing species alter the calculations, and thus can effect the significance of clumps and gaps. Clumps compared to the Prairie type habitats bore no similarity. Southern Illinois, seem sto have a similar clump and gap distribution, with three small clumps within the same range of size as one large clump for Rodgers. Both modern comparative clump graphs represent a forest (Ozark), and a forest edge environment (Illinois). The distributions of taxa and size in the clumps from forests, are heavy with medium sized species, the more mixed habitats have more clumps.

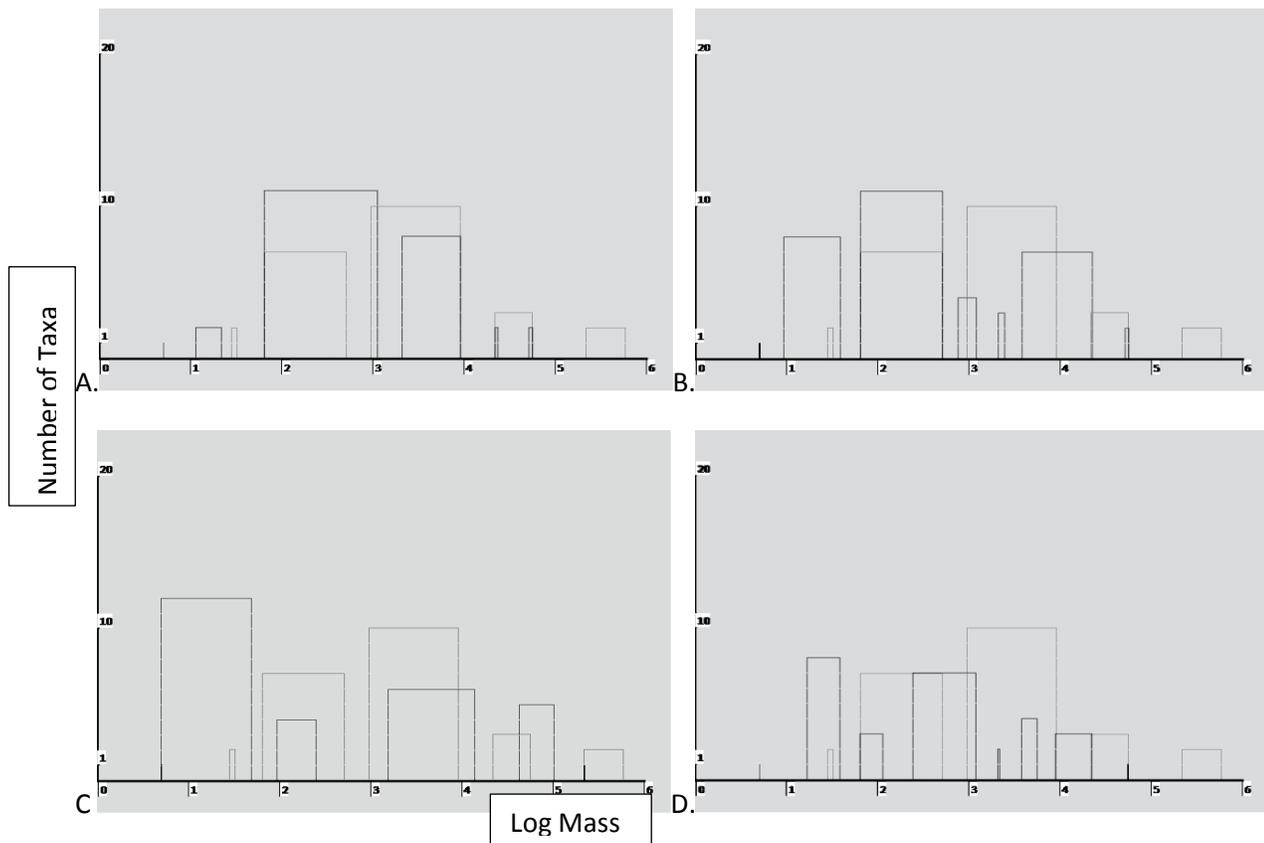


Figure 19 Early Hypsithermal Clumps from Rodgers Shelter (Faded) and a. Ozark County, Missouri, b. Leavenworth County, Kansas, c. Konza Prairie, Kansas, d. Southern Illinois.

Clump comparisons from the early Hypsithermal at Rodgers Shelter (Figure 19) are difficult to decipher. There is almost no similarity in the early Hypsithermal habitat and any modern comparative habitats. The early Hypsithermal at Rodgers Shelter may have been experiencing significant habitat change that hides any high resolution analysis. It may also be as possible with the early Holocene graphs from Rodgers Shelter that the archaeological representation is poor and readily interpreted comparisons cannot be made.

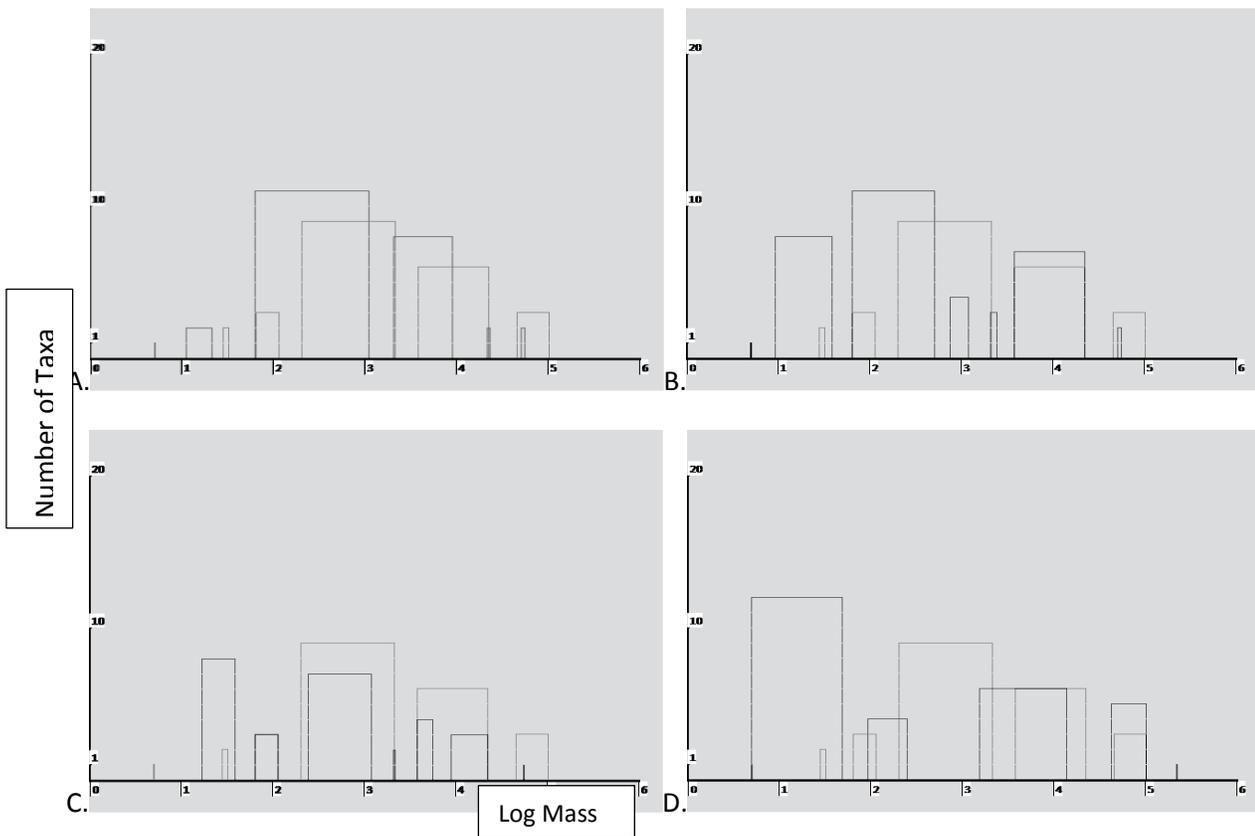


Figure 20 Rodgers 2 Mid-Hypsithermal (Faded) and a. Ozark, b. Leavenworth, c. Illinois d. Konza

The Mid-Hypsithermal (Figure 20) seems to have been relatively similar to Southern Illinois today. Clumps for Rodgers Shelter are larger, but both seem to share general clumps at similar sizes. The other three comparisons have very little in common with the Mid-Hypsithermal at Rodgers Shelter. As with the clumps at Arnold Research Cave, the Illinois clumps seem to have a similar distribution to those

for Rodgers Shelter. Illinois is a mixed forest edge environment, and may have increased clumps as multiple similarly sized species compete for resources; Rodgers Shelter may reflect a similar habitat but lack a full representation of species.

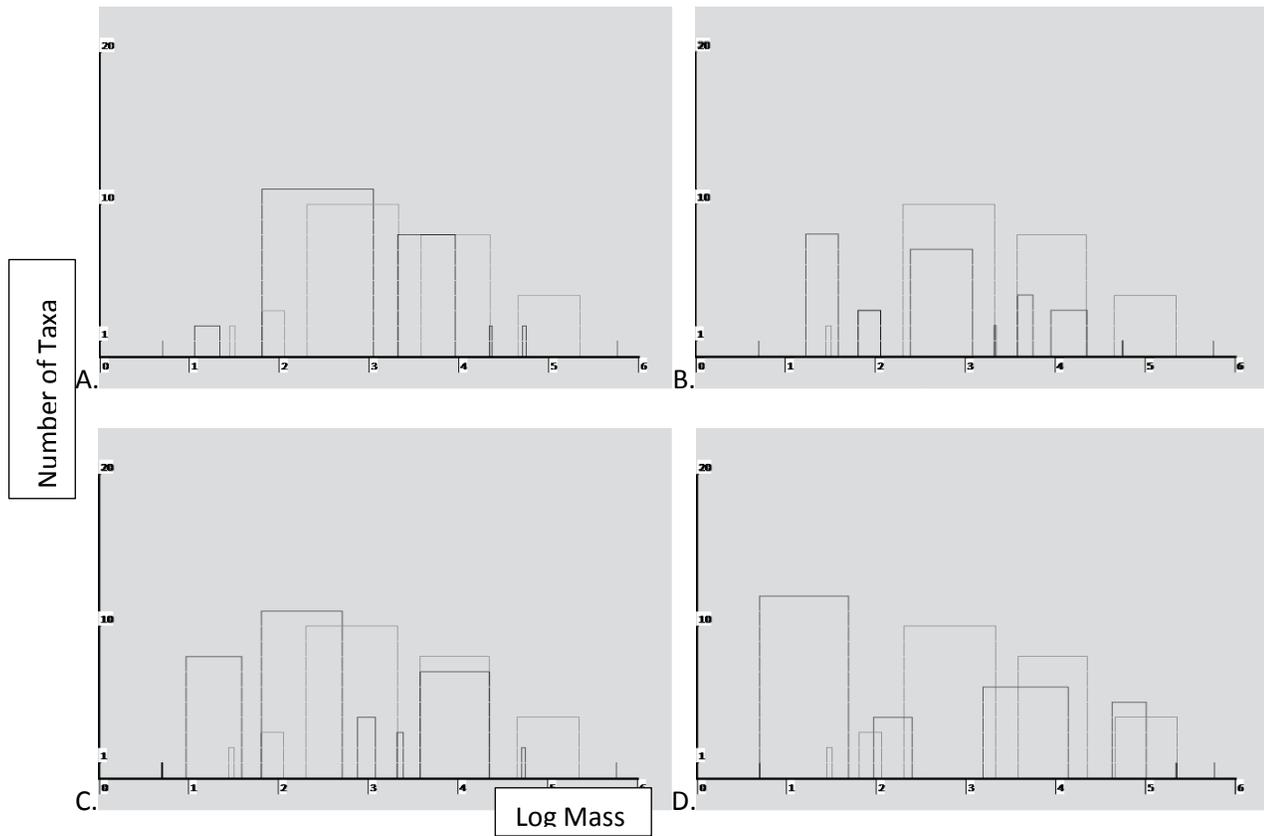


Figure 21 Rodgers Shelter 3 Late Hypsithermal (Faded) and a. Ozark, b. Illinois, c. Leavenworth, d. Konza

The late Hypsithermal at Rodgers Shelter (Figure 21) is very similar to the middle Hypsithermal. The area was comprised of mixed forest taxa and forest edge taxa. Like the middle Hypsithermal, clumps are similar to Southern Illinois in distribution of clumps and gaps, just the number of clumps within the same range in body mass differs.

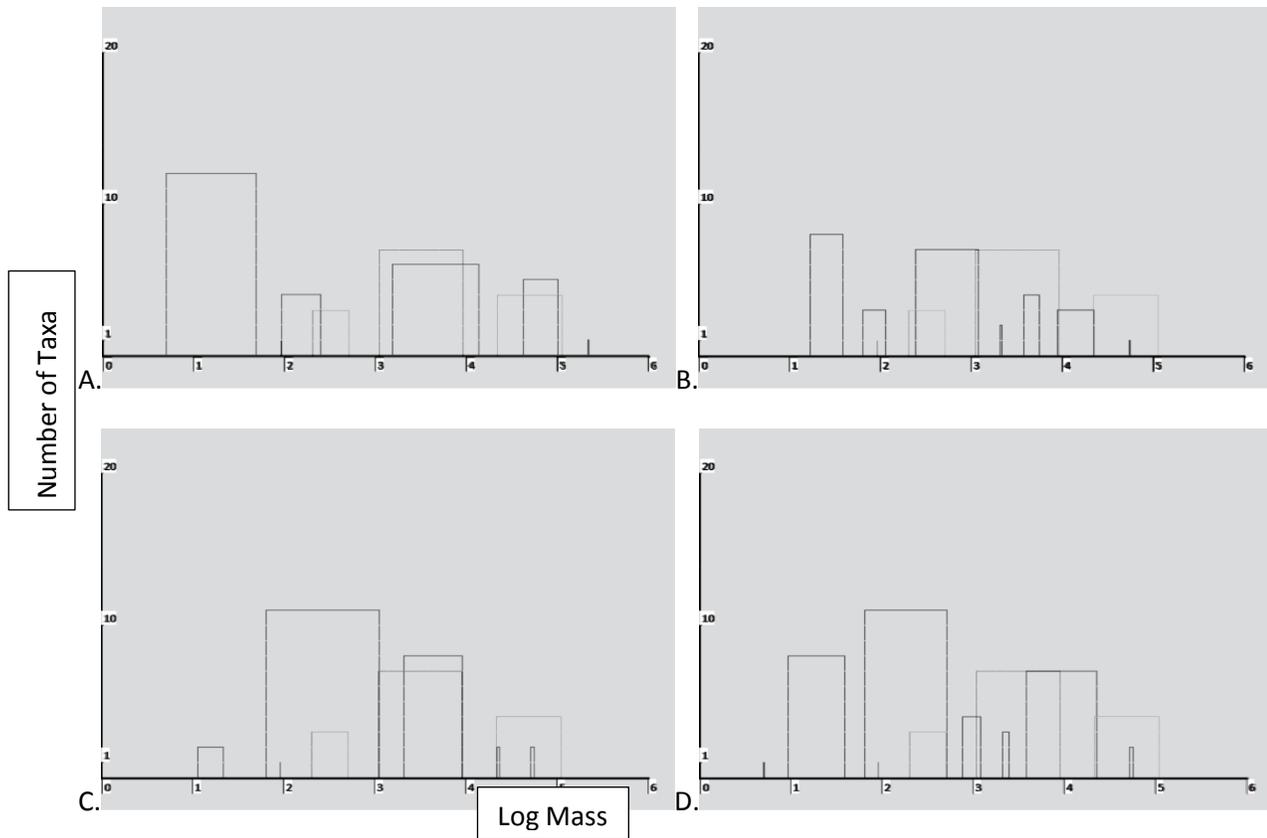


Figure 22 Historic Konza, Illinois, Ozark and Leavenworth.

The historic Rodgers Shelter clump (Figure 22) bears a similarity with Konza Prairie, Kansas. However, many of the clumps are not composed of the same size ranges, indicating they are different taxa, and thus not a similar environment. Rodgers Shelter is missing many of the smaller taxa, but it bears no similarity to the other comparative clump graphs.

Rodgers Shelter was similar to Southern Illinois during the Hypsithermal. Throughout the Hypsithermal climate changes, it appears to have remained a forest environment with open mixed forest areas. As the Hypsithermal progressed the environment remained the same locally until after the late Hypsithermal when more open conditions dominated (fewer clumps and small mammal dominated clumps).

Summary

Comparisons between modern cenograms and paleo cenograms, and between modern body mass clumps and paleo body mass clumps fail to invalidate the two techniques for summarizing mammalian species body mass distributions. When resolution is poor among the paleo distributions of body masses, it seems to be a function of taphonomy (poor preservation or incomplete accumulation of all taxa in an area), stratigraphic mixing, and/or incomplete recovery of taxa that likely were present. This is not unexpected in paleozoological collections (Lyman 1994), and it is in fact a serious problem regardless of the analytical technique used to access paleoecology (Andrews, Peter. 2006. Taphonomic Effects of Faunal Impoverishment and Faunal Mixing. *Palaeogeography, Palaeoclimatology, Palaeoecology* 241:572–589). In the next and final chapter, I elaborate a bit on these observations.

CHAPTER 5: CONCLUSION

The purpose of this study has been to test two methods of paleoecological reconstruction via the analysis of the mammalian archaeofaunas from three cave sites in Missouri with deposits spanning the Holocene. In general, the tests seem to corroborate the utility of cenograms and body mass clumps as viable techniques of paleoecological analysis as has been found in previous studies. Although one might hope for more rigorous tests, say, using quantitative measures of goodness-of-fit, such are not the norm for either analytical technique. To subject them to a test more rigorous than is demanded of them as analytical tools seems a bit unfair. However, given the facts that both techniques of summarizing body mass distributions are interpreted somewhat subjectively (visual comparison of graph form), combined with their relatively low paleoecological resolution (e.g., open *versus* closed habitat), I conclude that they can be used with confidence but that any supplemental paleoecological information available should also be consulted.

At Arnold Research Cave, the mixed stratigraphy made high-resolution inferences impossible, but a few low resolution inferences can be made. Initially, when the cenogram was viewed by itself, it suggested a closed but arid habitat. Previous analysis had suggested a forest edge habitat becoming more grassland as a result of mid-Holocene drying through subsistence changes. When viewed in comparison with modern cenograms, it became obvious that Arnold Research Cave appeared closed because it had few taxa in several sizes. When compared to modern cenograms, it was in fact more similar to the closed forest edge habitats in the south of Missouri and to the east. This general view of a forest edge habitat throughout the Holocene cannot show changes but is largely consistent with the expected change to prairie and reversal to forest habitat. Body mass clump analysis is consistent with

the cenogram analysis. It shows that the mammalian fauna from Arnold Research Cave is most similar to Southern Illinois throughout the Holocene.

Graham Cave viewed alone appeared to show a closed wet habitat that gradually became dry. This is consistent with studies done on changes in forest and prairie taxa in the site done previously. However, when compared to modern cenograms, the cenograms for Graham Cave show that missing small mammal taxa create the impression of a single slope and therefore closed habitat. The cenograms compared with modern cenograms in fact show that throughout the Holocene, Graham Cave was most similar to Konza Prairie, an open grassland. Cenograms show very little deviation through time. This is inconsistent with previous work on animal taxa recovered from the site, but not with subsistence studies that show little change through time. Body mass clump analysis was consistent with cenograms, suggesting that the area was open prairie throughout the Holocene.

Rodgers Cave cenograms are consistent with previous work. They show a forest edge habitat opening by the end of the Hypsithermal, and returning to a more closed forest edge by more modern times. This is illustrated in comparisons of cenograms and clumps for early and later periods of Rodgers History (Figure 23). This is consistent with the general trend of the Hypsithermal, but the dates are somewhat lagging behind (dry at the end of the Hypsithermal, and not during). The body mass clumps show the same trend, but they lag even further, with the driest period of the Holocene approaching modern times. Perhaps analysis on species shows changes faster than analysis of communities, or community interactions.

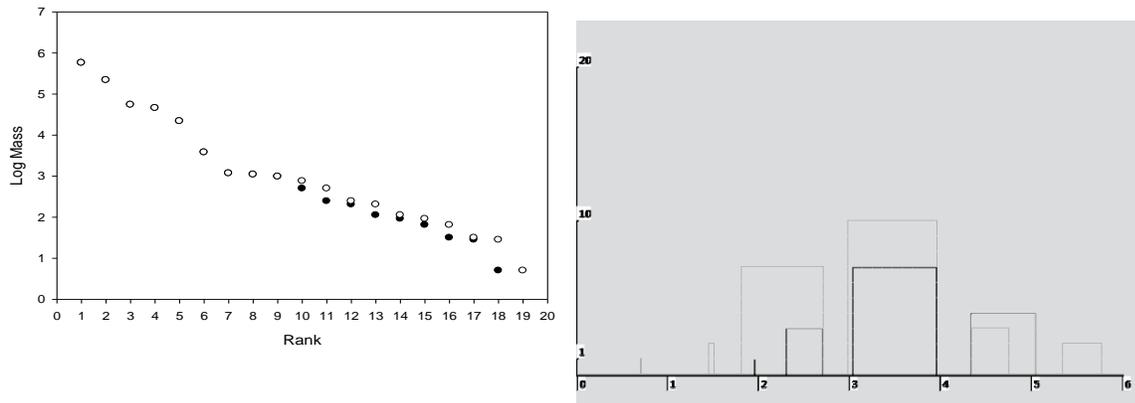


Figure 22 Cenograms and Clumps comparing Rodgers Shelter time periods (early and late Hypsithermal in cenograms) and early Hypsithermal and Historic in body mass clumps.

Several issues arose that play a role in the reliability of both analyses. While inferences can be made with missing taxa, cenograms can be misinterpreted when those missing taxa are in key areas of the cenogram (at the gaps, or in the large- or the small-body mass series). Body mass clumps appear to be even more dependent on complete taxa representation, as missing taxa alter the calculations and thus the significance of clumps. Another issue involves the comparisons themselves, many authors have suggested that very old assemblages or very unique assemblages of animals will be difficult to compare with cenograms. It would also seem that dynamic environments can cloud cenograms as it is hard to differentiate a prairie from a forest in a habitat sharing both types of taxa. Body mass clumps, being more quantitative are also more likely to be very specific to a habitat (no two are the same). Along with mixed habitats, human activity has changed modern habitats and altered the taxa living in them; this can confuse modern comparative cenograms. There are likely no “typical” environments with which to base a comparison. Lastly, a large database has been collected for cenogram comparisons, and the technique is fairly popular, but body mass clump analysis has not been widely used, a much larger comparative database is needed to be able to better identify subtle variations in habitat type.

Both the cenograms and the body mass clumps have, for the most part, been in agreement with the previous paleoecological studies of the three sites. Cenograms have been shown to be fairly robust and accurate in paleoenvironmental reconstruction (Croft 2001). Body mass clumps seem to add to our ability to generate accurate pictures of the environments of extinct ecosystems. It says something about the validity of both methods that they tend to be in agreement with each other even to the exclusion of other methods, as well as when they are in agreement with the various methods used previously such as taxonomic composition, habitat preferences, and subsistence studies. Where the cenogram and body mass clumps are not in exact agreement or in cases where they do not seem to match the known paleoecological history of the sites, may not be a weakness of the two methods. The clarity of the cenograms may be clouded by the mixed forest and prairie nature of the sites in question. Legendre's (1986) comparisons were largely based on African faunas which may or may not be a good comparison with the American Midwest, with a history of fluctuation between grassland and forest. Croft (2001) noted that cenogram patterns do not measure well with the unique South American faunas from his study. Tavouillon and Legendre (2009) also had difficulties with Australian faunas. Other issues that plague both methods of analysis are violations of Croft's (2001) criteria. Time averaging made fine resolution interpretation of Arnold Research Cave impossible, and Graham Cave is plagued by missing taxa. Montuire and Girard (1998) discovered that cenograms may have a lag of several thousand years before the community responds to a change in environment. In the case of the Holocene climate, there were multiple changes in a relatively brief amount of time that may not be accurately measured with the cenogram. The body mass clumps may also suffer from lack of species present. In some cases clumps were assumed to facilitate comparisons, because otherwise no discernable pattern can be made from the single large clump present.

Two methods that have been used to examine paleoenvironmental in various areas have been evaluated here. Cenograms and body mass clumps based on Holocene mammal assemblages compared

with modern faunas to identify changes in mammal taxa during the well-documented Hypsithermal period of climatic drying at three archaeological cave sites in Missouri. Results indicate that both cenograms and body mass clumps reflect changes in the distributions of mammal body masses coincident with known changes in environment. The body mass changes agree with previous studies on the effects of Hypsithermal climate change on the environment of Missouri. The two methods have also shown to be fairly robust tools to make inferences even when ancient faunas have missing taxa as a result of sampling error.

The cenogram method has been used many times in the last few decades for paleontological studies as well as paleoclimatic analyses. Study of cenograms as well as body mass clumps could provide valuable insights into archaeological investigations in the future.

Appendix 1. Species Lists for Prehistoric Taxa and Modern Sites

Species	Log Mass	Graham Cave	Rodgers Shelter	Arnold Research Cave
<i>Bison bison</i>	5.76	X	X	X
<i>Cervus canadensis</i>	5.34	X	X	X
<i>Ursus americanus</i>	5	X	X	
<i>Odocoileus virginianus</i>	4.74	X	X	X
<i>Antilocapra americana</i>	4.66		X	
<i>Canis lupus</i>	4.63			X
<i>Castor canadensis</i>	4.34	X	X	X
<i>Canis familiaris</i>	4.13		X	X
<i>Canis latrans</i>	4.13		X	X
<i>Lynx rufus</i>	3.95	X	X	X
<i>Lutra Canadensis</i>	3.91	X		X
<i>Taxidea taxus</i>	3.85	X	X	X
<i>Procyon lotor</i>	3.74	X	X	X
<i>Vulpes fulva</i>	3.62	X		X
<i>Martes pennant</i>	3.6	X		X
<i>Marmota monax</i>	3.58	X	X	X
<i>Urocyon cinereoargenteus</i>	3.58	X	X	X
<i>Mephitis mephitis</i>	3.32	X	X	X
<i>Sylvilagus floridanus</i>	3.07	X	X	X
<i>Didelphis marsupialis</i>	3.04	X	X	X
<i>Ondatra zibethicus</i>	2.99	X	X	
<i>Mustela vison</i>	2.98		X	X
<i>Sciurus niger</i>	2.88		X	X
<i>Sciurus carolinensis</i>	2.7		X	
<i>Spilogale putorius</i>	2.53	X	X	X
<i>Neotoma floridana</i>	2.39	X	X	X
<i>Geomys bursarius</i>	2.31	X	X	
<i>Tamias striatus</i>	2.05	X	X	X
<i>Scalopis aquaticus</i>	1.96	X	X	X
<i>Microtus pennsylvanicus</i>	1.81		X	
<i>Glaucomys volans</i>	1.81	X		X
<i>Microtus ochrogaster</i>	1.58			X
<i>Synaptomys cooperi</i>	1.5		X	
<i>Blarina brevicauda</i>	1.45		X	
<i>Cryptotis parva</i>	0.7		X	

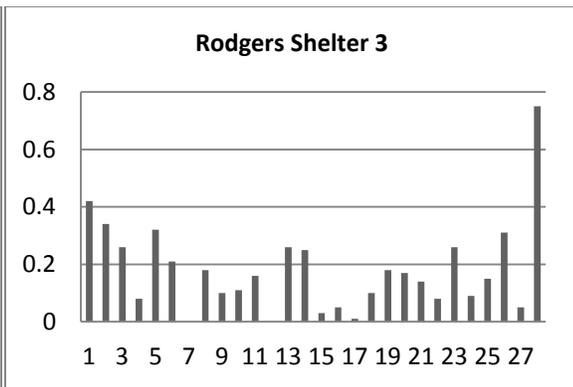
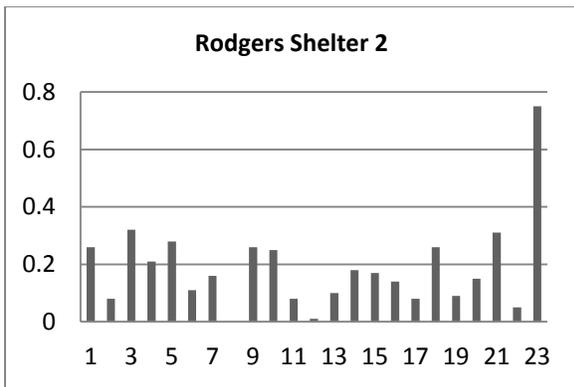
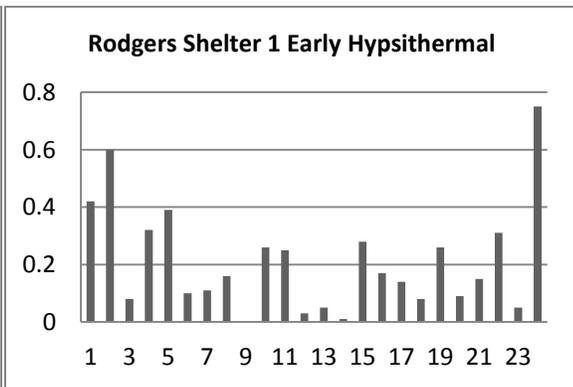
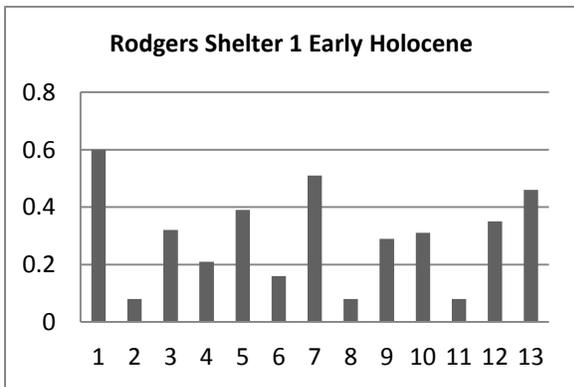
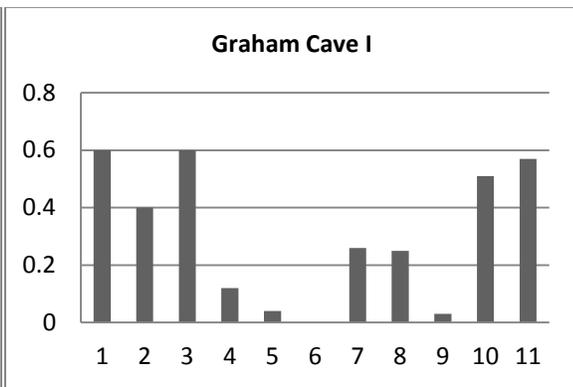
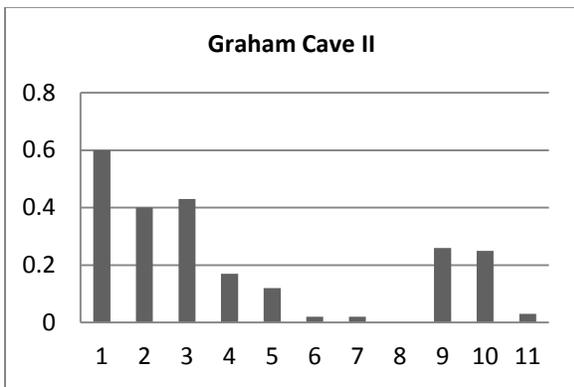
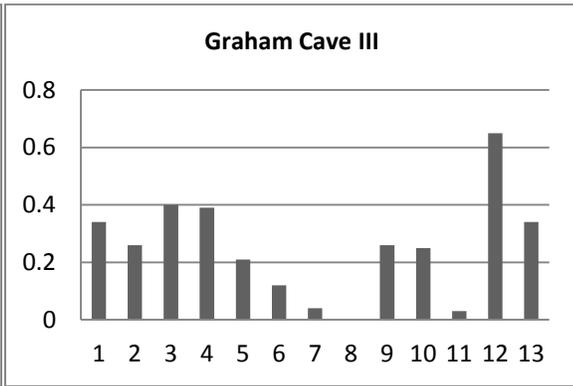
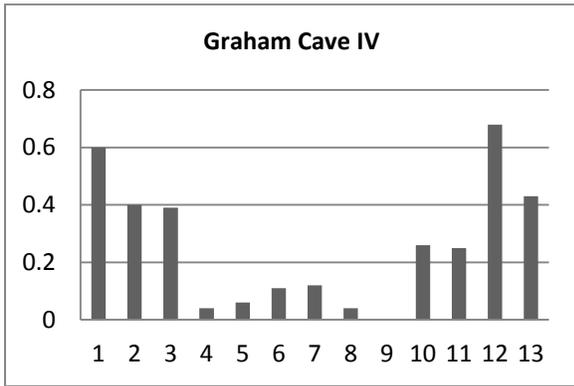
Species	Modern Comparative Faunas Prairies				
	Log Mass	Tall Grass Prairie	Mixed Grass Prairie	Short Grass Prairie	Konza KS
<i>Bison bison</i>	5.76		x	x	
<i>Cervus elaphus</i>	5.34				x
<i>Ursus americanus</i>	5				x
<i>Odocoileus virginianus</i>	4.74				
<i>Odocoileus hemionus</i>	4.73				x
<i>Puma concolor</i>	4.71				x
<i>Antilocapra americana</i>	4.66	x	x	x	x
<i>Canis lupus</i>	4.63				x
<i>Canis rufus</i>	4.36	x	x		
<i>Castor canadensis</i>	4.34				
<i>Canis latrans</i>	4.13	x	x	x	x
<i>Lynx rufus</i>	3.95				x
<i>Taxidea taxus</i>	3.85				x
<i>Mustela longicauda</i>	3.82		x	x	
<i>Procyon lotor</i>	3.74				
<i>Vulpes fulva</i>	3.62				x
<i>Marmota monax</i>	3.58				
<i>Urocyon cinereoargenteus</i>	3.58				
<i>Lepus californicus</i>	3.38	x	x	x	
<i>Didelphis virginiana</i>	3.34				
<i>Vulpes velox</i>	3.34		x	x	
<i>Sylvilagus aquaticus</i>	3.33				
<i>Mephitis mephitis</i>	3.32	x	x	x	x
<i>Lepus townsendii</i>	3.19	x	x	x	x
<i>Cynomys ludovicianus</i>	3.13		x	x	
<i>Sylvilagus floridanus</i>	3.07	x	x	x	
<i>Didephis marsupialis</i>	3.04				
<i>Ondatra zibethicus</i>	2.99				
<i>Mustela vison</i>	2.98	x	x	x	
<i>Sylvilagus audobonii</i>	2.95		x	x	
<i>Mustela nigripes</i>	2.93			x	
<i>Sciurus niger</i>	2.88				
<i>Sylvilagus nuttalli</i>	2.88				
<i>Sciurus carolinensis</i>	2.7				
<i>Citellus richardsonii</i>	2.61		x	x	
<i>Spermophilus franlinii</i>	2.56				
<i>Spilogale putorius</i>	2.53	x	x	x	
<i>Neotoma floridana</i>	2.39				x
<i>Geomys bursarius</i>	2.31	x	x	x	x
<i>Mustela frenata</i>	2.17				

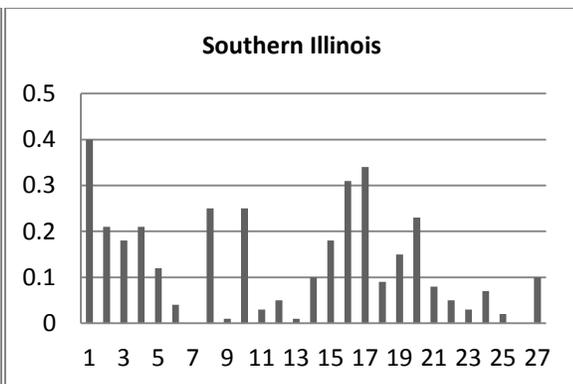
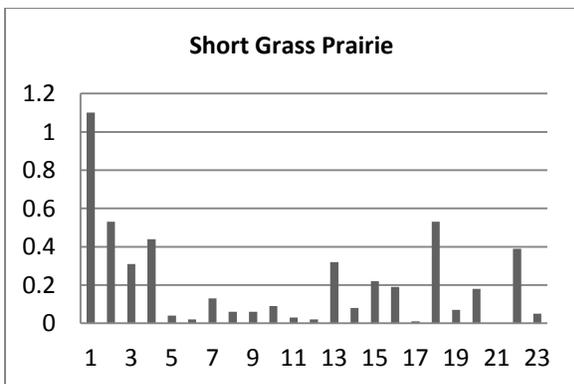
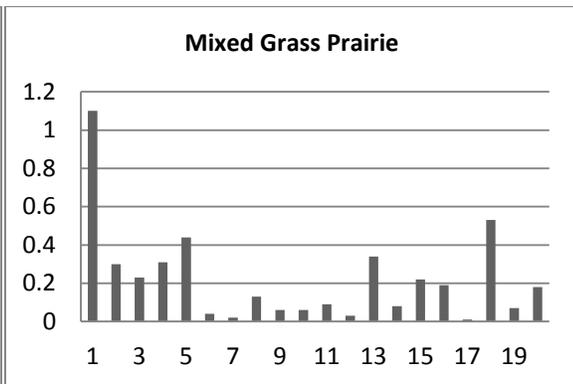
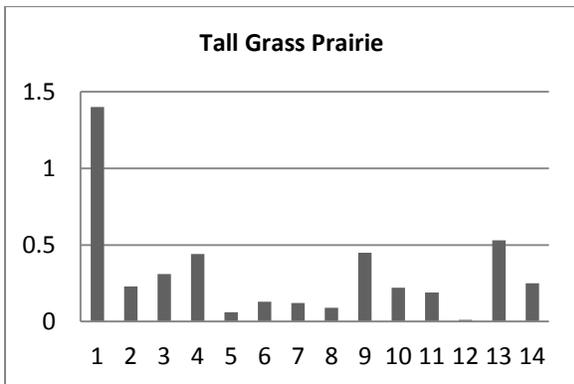
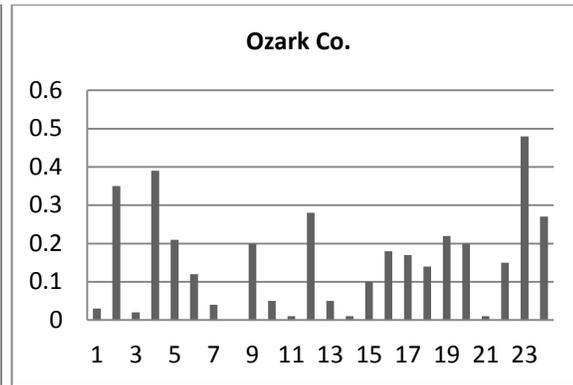
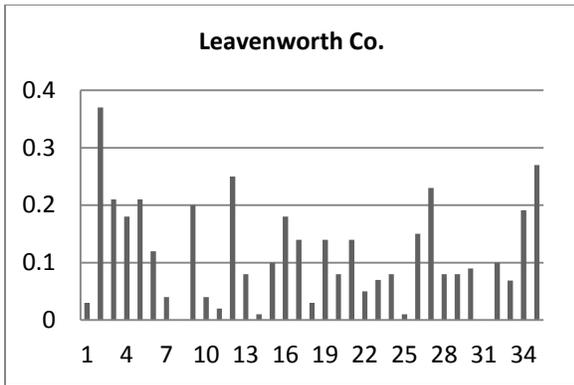
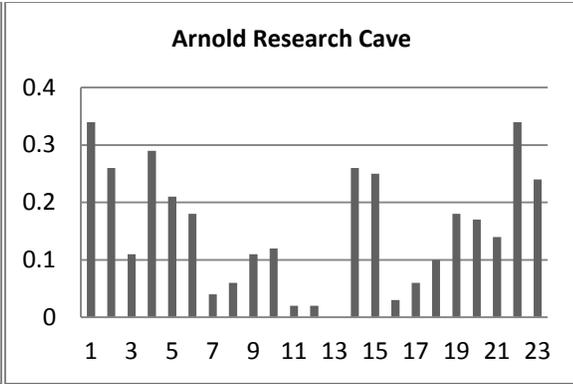
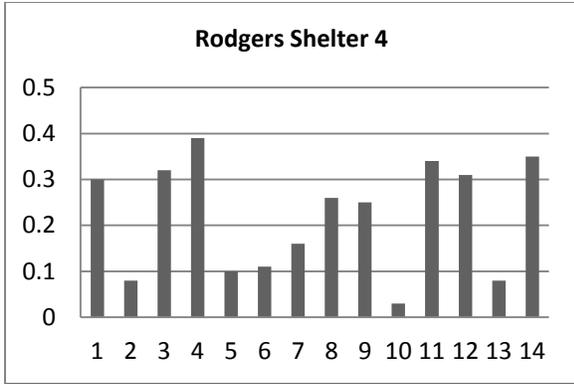
<i>Spermophilus</i>					
<i>tridecemlineatus</i>	2.12	x	x	x	x
<i>Thomomys talpoides</i>	2.11	x	x	x	
<i>Tamias striatus</i>	2.05				
<i>Sigmodon hispidus</i>	1.97				x
<i>Scalopis aquaticus</i>	1.96				
<i>Glaucomys volans</i>	1.81				
<i>Perognathus hispidus</i>	1.68				x
<i>Mustela nivalis</i>	1.67				x
<i>Microtus ochrogaster</i>	1.58	x	x	x	x
<i>Microtus pennsylvanicus</i>	1.57				
<i>Chaeotipus Perognathus hispidus</i>	1.51		x	x	
<i>Synaptomys cooperii</i>	1.5				x
<i>Blarina brevicauda</i>	1.45				x
<i>Microtus (pitymys) pinetorium</i>	1.42				
<i>Ochromys (Peromyscus) nuttalli</i>	1.35				
<i>Peromyscus leucopus</i>	1.33	x		x	x
<i>Peromyscus maniculatus</i>	1.33		x	x	x
<i>Zapus hudsonicus</i>	1.23				x
<i>Blarina hylophaga</i>	1.16				
<i>Reithrodontomys fulvescens</i>	1.06				
<i>Reithrodontomys montanus</i>	1.04				x
<i>Reithrodontomys megalotis</i>	0.97				x
<i>Perognathus flavescens</i>	0.94			x	
<i>Perognathus flavus</i>	0.89			x	x
<i>Cryptotis parva</i>	0.7				x

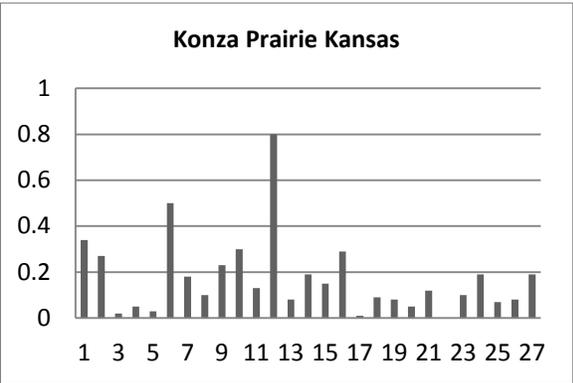
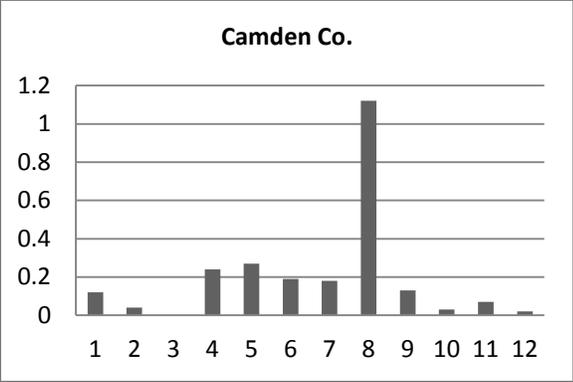
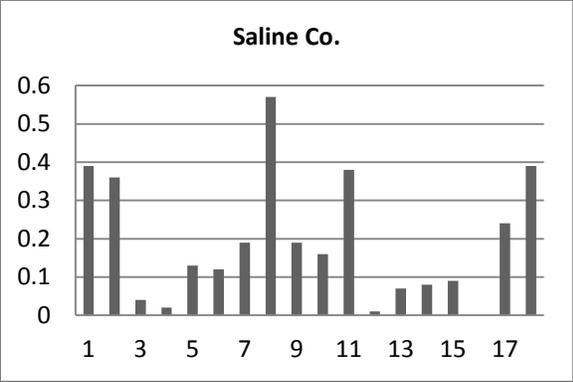
Modern Comparative Faunas Mixed Grass and Forest Edge						
Species	Log Mass	Leavenworth Co.	Ozark Co.	Southern IL.	Saline Co.	Camden Co.
<i>Bison bison</i>	5.76					
<i>Cervus elaphus</i>	5.34					
<i>Ursus americanus</i>	5					
<i>Odocoileus virginianus</i>	4.74	x	x	x		
<i>Odocoileus hemionus</i>	4.73					
<i>Puma concolor</i>	4.71	x	x			
<i>Antilocapra americana</i>	4.66					
<i>Canis lupus</i>	4.63					
<i>Canis rufus</i>	4.36		x			
<i>Castor canadensis</i>	4.34	x	x	x		
<i>Canis latrans</i>	4.13	x		x	x	
<i>Lynx rufus</i>	3.95	x	x	x		
<i>Taxidea taxus</i>	3.85					
<i>Mustela longicauda</i>	3.82					
<i>Procyon lotor</i>	3.74	x	x	x	x	x
<i>Vulpes fulva</i>	3.62	x	x	x		x
<i>Marmota monax</i>	3.58	x	x	x		x
<i>Urocyon cinereoargenteus</i>	3.58	x	x	x		x
<i>Lepus californicus</i>	3.38	x	x		x	
<i>Didelphis virginiana</i>	3.34	x			x	x
<i>vulpes velox</i>	3.34					
<i>Sylvilagus aquaticus</i>	3.33		x			
<i>Mephitis mephitis</i>	3.32	x	x		x	
<i>Lepus townsendii</i>	3.19				x	
<i>Cynomys ludovicianus</i>	3.13					
<i>Sylvilagus floridanus</i>	3.07	x		x	x	x
<i>Didephis marsupialis</i>	3.04		x	x		
<i>Ondatra zibethicus</i>	2.99	x	x	x		
<i>Mustela vison</i>	2.98	x	x	x		
<i>Sylvilagus audobonii</i>	2.95					
<i>Mustela nigripes</i>	2.93					
<i>Sciurus niger</i>	2.88	x	x	x	x	x
<i>Sylvilagus nuttalli</i>	2.88					
<i>Sciurus carolinensis</i>	2.7	x	x	x		x
<i>Citellus richardsonii</i>	2.61					
<i>Spermophilus franlinii</i>	2.56	x				
<i>Spilogale putorius</i>	2.53	x	x			
<i>Neotoma floridana</i>	2.39	x	x	x		
<i>Geomys bursarius</i>	2.31	x			x	
<i>Mustela frenata</i>	2.17	x	x			

<i>Spermophilus tridecemlineatus</i>	2.12	x			x	
<i>Thomomys talpoides</i>	2.11					
<i>Tamias striatus</i>	2.05	x		x		
<i>Sigmodon hispidus</i>	1.97	x	x			
<i>Scalopis aquaticus</i>	1.96	x	x	x	x	
<i>Glaucomys volans</i>	1.81	x	x	x		
<i>Perognathus hispidus</i>	1.68					
<i>Mustela nivalis</i>	1.67					
<i>Microtus ochrogaster</i>	1.58	x		x	x	x
<i>Microtus pennsylvanicus</i>	1.57				x	
<i>Chaetipus Perognathus hispidus</i>	1.51					
<i>Synaptomys cooperii</i>	1.5	x		x	x	
<i>Blarina brevicauda</i>	1.45			x		x
<i>Microtus (pitymys) pinetorium</i>	1.42	x		x	x	x
<i>Ochromys (peromiscus) nuttalli</i>	1.35			x		x
<i>Peromyscus leucopus</i>	1.33	x	x	x	x	x
<i>Peromyscus maniculatus</i>	1.33	x		x	x	
<i>Zapus hudsonicus</i>	1.23	x		x		
<i>Blarina hylophaga</i>	1.16	x				
<i>Reithrodontomys fulvescens</i>	1.06		x			
<i>Reithrodontomys montanus</i>	1.04					
<i>Reithrodontomys megalotis</i>	0.97	x			x	
<i>Perognathus flavescens</i>	0.94					
<i>Perognathus flavus</i>	0.89					
<i>Cryptotis parva</i>	0.7				x	

Appendix 2. Body Mass Clump Graphs



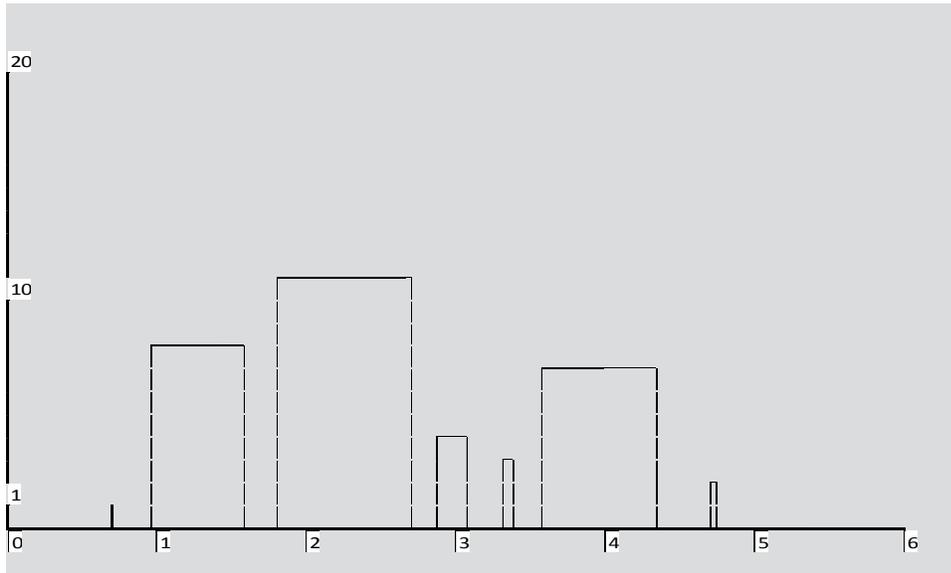




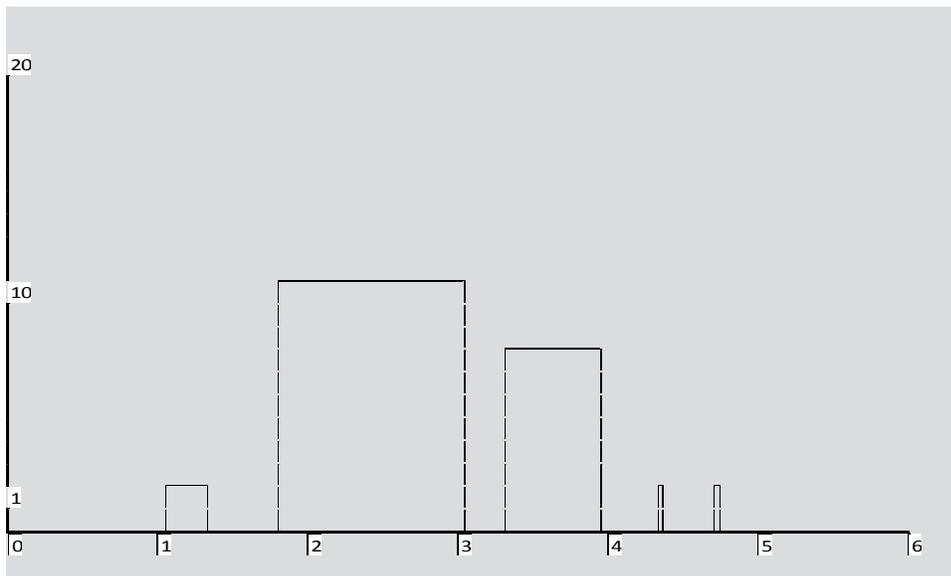
Appendix 3. Body Mass Clumps

	Body Mass Range	Taxa - 1	Uniform Interval	Gap Criterion Value
Arnold Research Cave	3.53	23	0.15	0.23
Graham IV	3.38	11	0.31	0.46
Graham III	3.29	13	0.25	0.38
Graham II	2.30	11	0.21	0.31
Graham I	3.38	11	0.31	0.46
Rodgers 1 (Early Holocene)	3.84	13	0.30	0.44
Rodgers 1 (Early Hypsithermal)	5.06	24	0.21	0.32
Rodgers 2	4.30	23	0.19	0.28
Rodgers 3	5.06	28	0.18	0.27
Rodgers 4	3.08	14	0.22	0.33
Leavenworth Co.	4.04	35	0.12	0.17
Ozark Co.	3.68	24	0.15	0.23
Southern IL.	3.51	27	0.13	0.20
Tall Grass Prairie	4.43	14	0.32	0.48
Mixed Grass Prairie	4.43	20	0.22	0.33
Short Grass Prairie	4.87	23	0.21	0.32
Saline Co.	3.43	18	0.19	0.29
Camden Co.	2.41	12	0.20	0.30
Konza Prairie	4.64	27	0.17	0.26

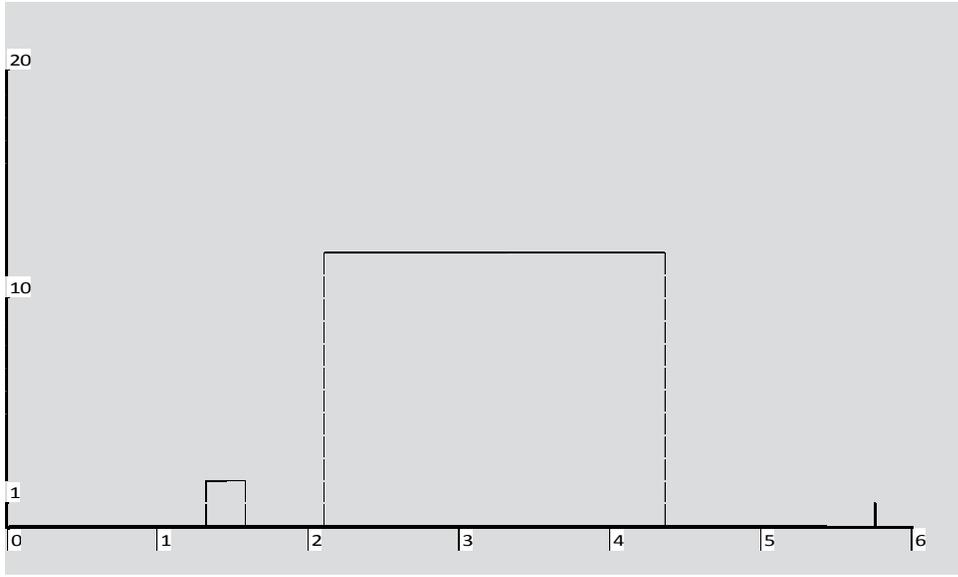
Appendix 4. Body Mass Clump Graphs



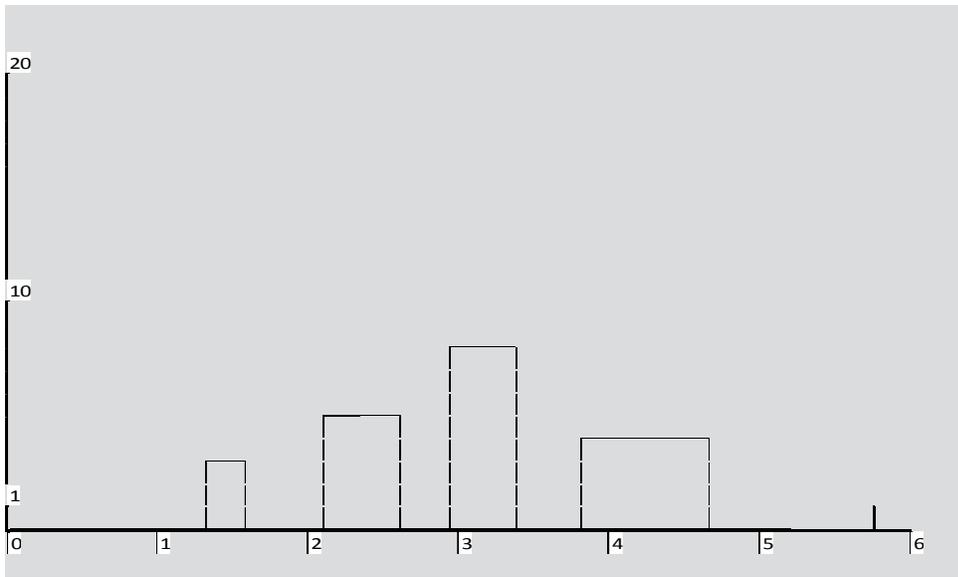
Leavenworth County Kansas.



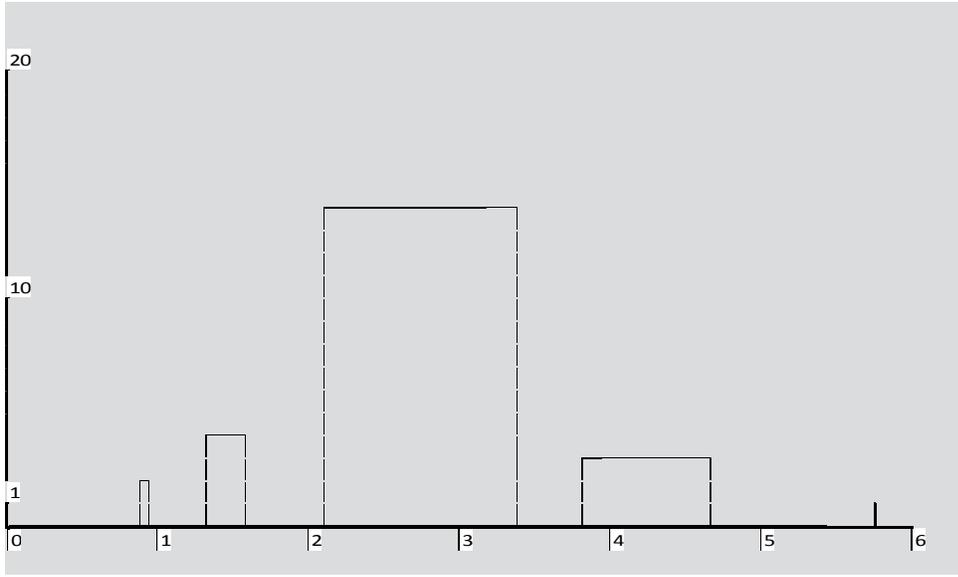
Ozark County Missouri.



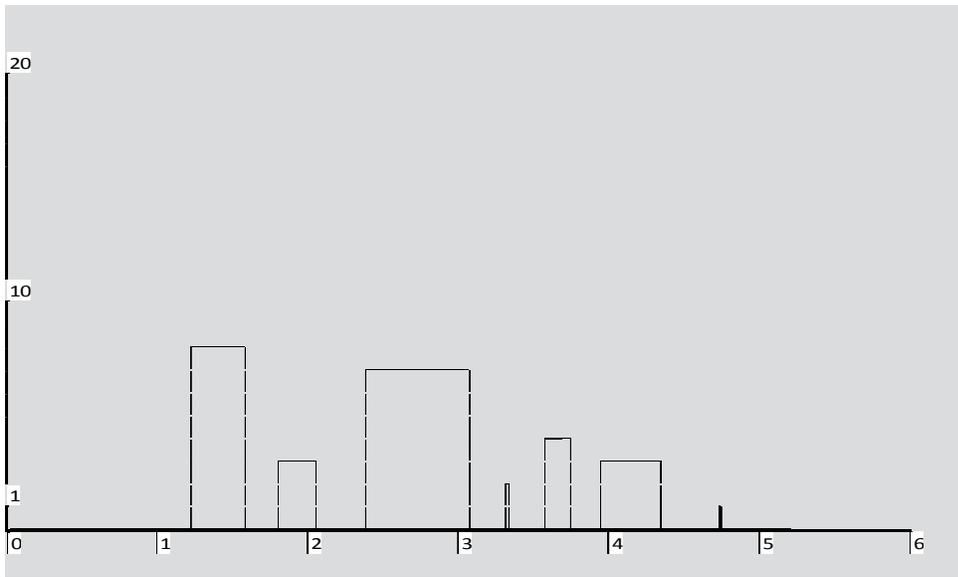
Tall Grass Prairie.



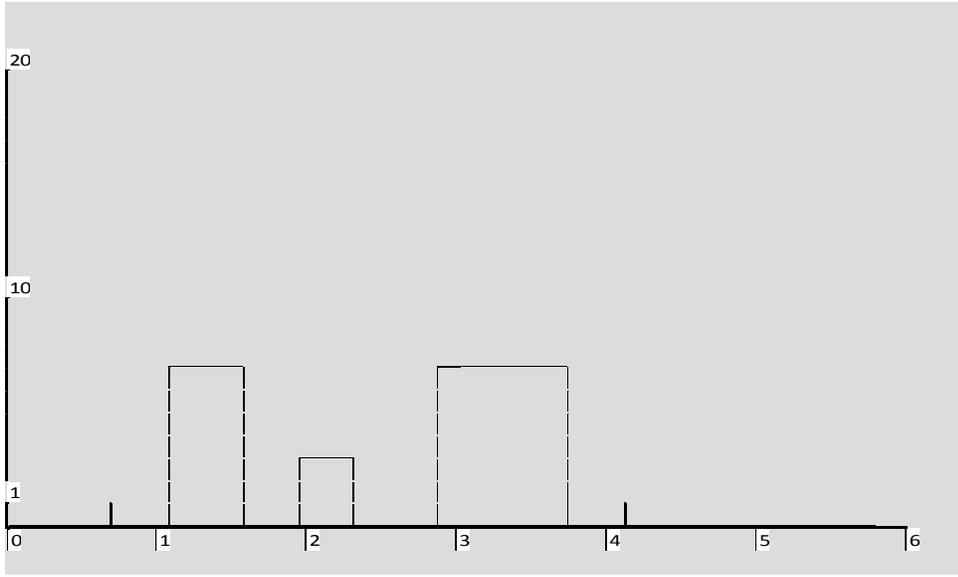
Mixed Grass Prairie.



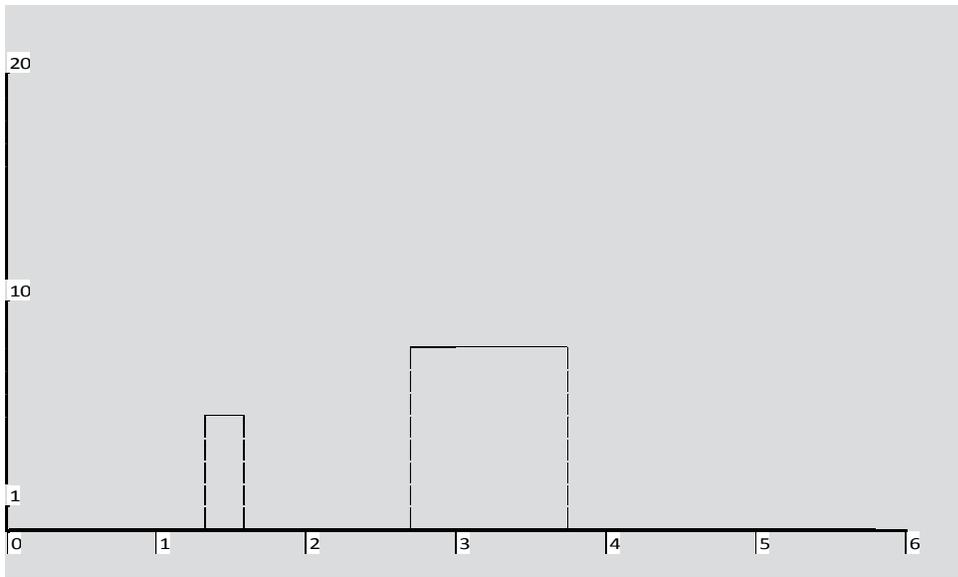
Short Grass Prairie.



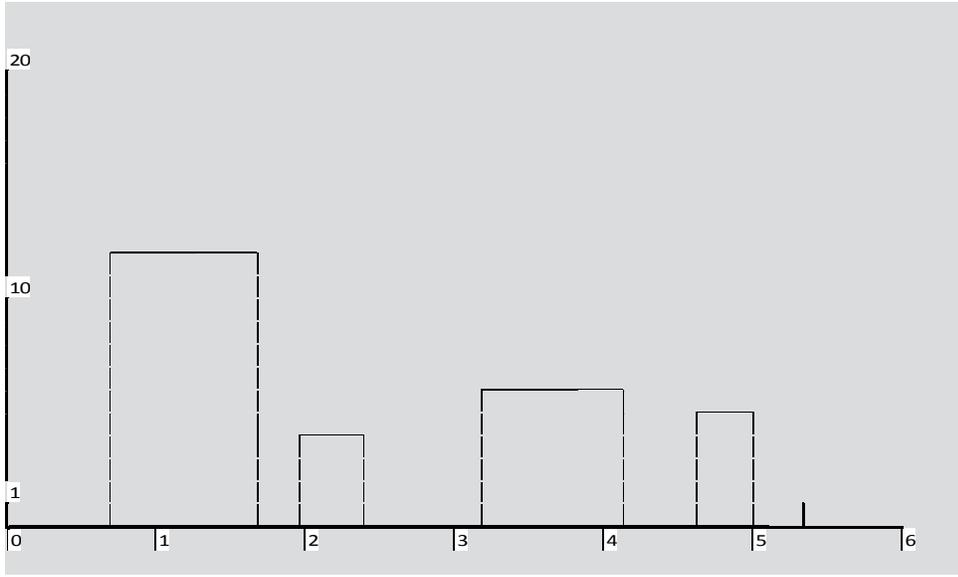
Southern Illinois.



Saline County Missouri.



Camden County Missouri.



Konza Prairie Kansas.

References

- Ahler, Stanley A.
1973 The Post-Pleistocene Depositional Change at Rodgers Shelter, Missouri. *Plains Anthropologist* 18:1 – 27
1976 Sedimentary Processes at Rodgers Shelter. In *Prehistoric Man and His Environments*, Academic Press, New York Wood, W. Raymond and R. Bruce McMillan (eds.), pp. 123 – 139.
- Ahler, Stanley A. and R. Bruce McMillan
1976 Material Culture and Rodgers Shelter: A Reflection of Past Human Activities. In *Prehistoric Man and His Environments*, Wood, W. Raymond and R. Bruce McMillan (eds.), pp. 163 – 199. Academic Press, New York
- Allen, C. R., A. S. Garmestani, T. D. Havlicek, P. A. Marquet, G. d. Peterson, C. Restrepo, C. A. Stow, and B. E. Weeks
2006 Patterns in Body Mass Distributions: Sifting Among Alternative Hypotheses. *Ecology Letters* 9: 630 – 643
- Alroy, John
2000 New Methods for Quantifying Macroevolutionary Patterns and Processes. *Paleobiology* 26: 707 – 733
- Andrews, Peter.
2006 Taphonomic Effects of Faunal Impoverishment and Faunal Mixing. *Palaeogeography, Palaeoclimatology, Palaeoecology* 241:572–589).
- Andrews, P., J. M. Lord, and E. M. Nesbit-Evans
1979 Patterns of Ecological Diversity in Fossil and Modern Mammalian Faunas. *Biological Journal of the Linnaean Society* 11: 177 – 205
- Behrensmeyer, Anna K., John Damuth, William A. DiMichele, Richard Potts, Hans-Dieter Sues, and Scott L. Wing (Eds.)
1992 *Terrestrial Ecosystems through Time: Evolutionary Paleocology of Terrestrial Plants and Animals*. University of Chicago Press, Chicago
- Brown, James H. and Paul F. Nicoletto
1991 Spatial Scaling of Species Composition: Body Masses of North American Land Mammals. *The American Naturalist* 138: 1478 – 1512
- Brumwell, Malcolm J.
1951 An Ecological Survey of the Fort Leavenworth Military Reservation. *American Midland Naturalist*, 45: 187 – 231
- Calder, William A. III
1984 *Size, Function, and Life History*. Harvard University Press, Cambridge
- Carpenter, J. Richard
1940 The Grassland Biome. *Ecological Monographs* 10: 617 - 684

- Chapman, Carl H.
1975 *The Archaeology of Missouri I*. University of Missouri Press, Columbia
- Charnov, Eric L., Gordon H. Orlans, And Kim Hyatt
1976 Ecological Implications of Resource Depression. *The American Midland Naturalist*, 110: 247 – 259
- Costeur, Loic and Serge Legendre
2008 Mammalian Communities Document a Latitudinal Environmental Gradient during the Miocene Climatic Optimum in Western Europe. *Palaios* 23: 280 – 288
- Costeur, Loic, Serge Legendre, Jean-Pierre Aguilar, and Christophe Lecuyer
2007b Marine and Continental Synchronous Climatic Records: Towards a Revision of the Mid-Miocene Mammalian Biochronological Framework. *Geobios* 40: 775 – 784
- Costeur, Loic, Sophie Montuire, Serge Legendre, and Olivier Maridet
2007a The Messinian Event: What Happened to the Peri-Mediterranean Mammalian Communities and Local Climate? *Geobios* 40: 423 – 431
- Croft, Darin A.
2001 Cenozoic Environmental Change in South America as Indicated by Mammalian Body Size Distributions (Cenograms). *Diversity and Distributions* 7: 271 – 287
- Cumming, Graeme S. and Tanya D. Havlicek
2002 Evolution, Ecology, and Multimodal Distributions of Body Size. *Ecosystems* 5: 705 – 711
- Damuth, John D.
1991 Review: Les Communautés de Mammifères du Paléogène (Éocène Supérieur et Oligocène) d'Europe Occidentale: Structures, Milieux et Évolution [The Mammal Communities of the Paleogene (Upper Eocene and Oligocene) of Western Europe: Structures, Environments, and Evolution] by Serge Legendre. *Journal of Vertebrate Paleontology* 11: 400 – 402
1992 Taxon-Free Characterization of Animal Communities. In Anna K. Beyrensmeyer, John D. Damuth, William A. DiMichele, Richard Potts, Hans-Dieter Sues, and Scott L. Wing (eds.) *Terrestrial Ecosystems through Time: Evolutionary Paleogeology of Terrestrial Plants and Animals*. University of Chicago Press pp. 183 – 197
- Damuth, John and Bruce J. MacFadden (Eds.)
1990 *Body Size in Mammalian Paleobiology: Estimation and Biological Implications*. Cambridge University Press, Cambridge
- De Bonis, L., G. Bouvrain, D. Geraads, and G. Koufos
1992 Diversity and Paleogeology of Greek Late Miocene Mammalian Faunas. *Paleogeography, Paleoclimatology, Paleogeology* 91: 99 – 121.
- Enders, R. K.
1932 Mammal Distribution in Saline and Camden Counties, Missouri. *American Midland Naturalist* 13: 114 – 123

- Escarguel, Gilles, Serge Legendre, and Bernard Sige
2008 Unearthing Deep-Time Biodiversity Changes: The Paleogene Mammalian Metacommunity of the Quercy and Limagne Area (Massif Central, France). *Geoscience* 340: 602 – 614
- Falk, Carl R.
1970 The Application of A Factor Analysis in the Interpretation of Unmodified Vertebrate Remains from an Archaeological Cave Deposit in Central Missouri. Unpublished M. A. Thesis, University of Missouri, Columbia
- Fleagle, John G.
1978 Size Distributions of Living and Fossil Primate Faunas. *Paleobiology* 4: 67 – 76
- Fleming, Theodore H.
1973 Numbers of Mammal Species in North and Central American Forest Communities. *Ecology* 54:555 – 563
- Geraads, Dennis
2003 The Middle Miocene Hominid Site of Candir, Turkey: General Paleoeecological Conclusions from the Mammalian Fauna. *Courier Forschungsinstitut Senckenberg* 240: 241 – 250.
- Gingerich, Philip D.
1989 New Earliest Wasatchian Mammalian Fauna from the Eocene of Northwestern Wyoming: Composition and Diversity in a Rarely Sampled High-Floodplain Assemblage. *Papers on Paleontology* No. 28 University of Michigan, Ann Arbor
- Gould, Stephen J.
1966 Allometry and Size in Ontogeny and Phylogeny. *Biological Reviews* 41: 587 – 638
- Gunnell, Gregg F.
1994 Paleocene Mammals and Faunal Analysis of the Chappo Type Locality (Tiffinian), Green River Basin, Wyoming. *Journal of Vertebrate Paleontology* 14: 81 – 104.
- Gunnell, Gregg F. and William S. Bartels
1994 Early Bridgerian (Middle Eocene) Vertebrate Paleontology and Paleoecology of the Southern Green River Basin, Wyoming. *Contributions to Geology, University of Wyoming* 30: 57 – 70.
- Hernandez Fernandez, M., M.T. Alberdi, B. Azanza, P. Montoya, J. Morales, M. Nieto, P. Palaez-Campomanes
2006 Identification Problems of Arid Environments in the Neogene-Quaternary Mammal Record of Spain. *Journal of Arid Environments* 66: 585 – 608.
- Holling, C. S.
1992 Cross-Scale Morphology, Geometry, and Dynamics of Ecosystems. *Ecological Monographs* 62: 447 – 502
- Jarmin, P. J.
1974 The Social Organization of Antelope in Relation to Their Ecology. *Behaviour* 48: 215 – 267

- Kay, Richard F.
1975 The Functional Adaptations of Primate Molar Teeth. *American Journal of Physical Anthropology* 43: 195 – 216
- King, James E.
1973 Late Pleistocene Palynology and Biogeography of the Western Missouri Ozarks. *Ecological Monographs* 43: 539 - 565
1981 Late Quaternary Vegetational History of Illinois. *Ecological Monographs* 51: 43 – 62
- Klippel, Walter E.
1971a Prehistory and Environmental Change Along the Southern Border of the Prairie Peninsula During the Archaic Period. Unpublished Ph.D. Dissertation, University of Missouri, Columbia
1971b Graham Cave Revisited A Reevaluation of its Cultural Position During the Archaic Period. *Missouri Archaeological Society, Memoir No. 9*
- Klippel, Walter E., Gail Celmer, and James R. Purdue
1978 The Holocene Naiad Record at Rodgers Shelter in the Western Ozark Highland of Missouri. *Plains Anthropologist* 23: 257 – 271
- Kutzbach, John E. and Peter J. Guetter
1986 The Influence of Changing Orbital Parameters and Surface Boundary Conditions on Climate Simulations for the Past 18,000 Years. *Journal of the Atmospheric Sciences* 43: 1726 – 1759
- Lambert, W. David
2006 Functional Convergence of Ecosystems: Evidence from Body Mass Distributions of North American Late Miocene Mammal Faunas. *Ecosystems* 9: 97 - 118
- Lambert, W. David and Crawford S. Holling
1998 Causes of Ecosystem Transformation at the End of the Pleistocene: Evidence from Mammal Body-Mass Distributions. *Ecosystems* 1: 157 – 175
- Layne, James N.
1958 Notes of Mammals of Southern Illinois. *American Midland Naturalist* 60: 219 – 254
- Legendre, Serge
1986 Analysis of Mammalian Communities from the Late Eocene and Oligocene of Southern France. *Paleovertebrata* 16: 191 – 212
- Leopold, A. Starker and E. Raymond Hall
1945 Some Mammals of Ozark County, Missouri. *Journal of Mammology* 26: 142 – 145
- Logan, Wilfred D.
1950 Archaeological Investigations of the Pre-Ceramic Horizon in Graham Cave, Site 23 MT-2, Montgomery County, Missouri. Master's Thesis, University of Missouri-Columbia
1952 Graham Cave, An Archaic Site in Montgomery County, Missouri. *Missouri Archaeological Society* No. 2 Columbia, Missouri

- Lyman, R. Lee
 2013 Taxonomic Composition and Body-Mass Distribution in the Terminal Pleistocene Mammalian Fauna from the Marmes Site, Southeastern Washington State, U.S.A. *Paleobiology* 39: 345 – 359
 1994 *Vertebrate Taphonomy*. Cambridge University Press
- Matthew, W. D.
 1909 The Carnivora and Insectivora of the Bridger Basin, Middle Eocene. *American Museum of Natural History* 9: 289 – 567
- McMillan, R. Bruce
 1976a Rodgers Shelter: A Record of Cultural and Environmental Change. In *Prehistoric Man and His Environments* Wood, W. Raymond and R. Bruce McMillan (eds.) pp. 111 – 122. Academic Press, New York
 1976b The Dynamics of Cultural and Environmental Change at Rodgers Shelter, Missouri. In *Prehistoric Man and His Environments* Wood, W. Raymond and R. Bruce McMillan (eds.) pp. 211 – 232. Academic Press, New York
- McMillan, R. Bruce and Walter E. Klippel
 1981 Post-Glacial Environmental Change and Hunting-Gathering Societies of the Southern Prairie Peninsula. *Journal of Archaeological Science* 8: 215 – 245
- Merceron, Gildas, Loic Costeur, Olivier Maridet, Anusha Ramdarshan, Ursula B. Gohlich
 2012 Multi-proxy Approach Detects Heterogeneous Habitats for Primates during the Miocene Climatic Optimum in Central Europe. *Journal of Human Evolution* 63: 150 – 161.
- Montuire, Sophie
 1999 Mammalian Faunas as Indicators of Environmental and Climatic Changes in Spain during the Pliocene-Quaternary Transition. *Quaternary Research* 52: 129 - 137
- Montuire, Sophie and Catherine Girard
 1998 Adaptation to Environmental Changes: Communities Need More Time Than Species. *Palaontologische Zeitschrift* 72: 241 – 248
- Montuire, Sophie and Emmanuel Desclaux
 1997 Palaeoecological Analysis of Mammalian Faunas and Environmental Evolution in the South of France During the Pleistocene. *Boreas* 26: 355 – 365
- Montuire, Sophie, and Federica Marcolini
 2002 Paleoenvironmental Significance of the Mammalian Faunas of Italy since the Pliocene. *Journal of Quaternary Science* 17: 87 – 96.
- O'Brien, Michael J. and W. Raymond Wood
 1998 *The Prehistory of Missouri*. University of Missouri Press, Columbia
- Parmalee, Paul W., R. Bruce McMillan, and Francis B. King
 1976 Changing Subsistence Patterns at Rodgers Shelter. In *Prehistoric Man and His Environments* Wood, W. Raymond and R. Bruce McMillan (eds.), pp. 141 – 161. Academic Press, New York.

- Polombo, Maria R., Pasquale Raia, and Caterina Giovinazzo
2005 Early-Middle Pleistocene Structural Changes in Mammalian Communities from the Italian Peninsula. *Geological Society, London, Special Publications* 247: 251 – 262.
- Purdue, James R.
1980 Clinal Variation of Some Mammals During the Holocene in Missouri. *Quaternary Research* 13: 242 – 258
1989 Changes During the Holocene in the Size of White-Tailed Deer (*Odocoileus virginianus*) from Central Illinois. *Quaternary Research* 32: 307 – 316
- Rodriguez, Jesus
1999 Use of Cenograms in Mammalian Paleocology: A Critical Review. *Lethaia* 32: 331 - 347
- Schmidt-Nielsen, Knut
1984 *Scaling: Why is Animal Size So Important?* Cambridge University Press, Cambridge
- Seiman, Evan and James H. Brown
1999 Gaps in Mammalian Body Size Distributions Reexamined. *Ecology* 80: 2788 – 2792
- Sen, Sevket, Genevieve Bouvrain, and Denis Geraads
1998 Pliocene Vertebrate Locality of Calta, Ankara, Turkey, 12, Paleocology, Biogeography and Biochronology. *Geodiversitas* 20: 497 - 510
- Shippee, J. M.
1966 The Archaeology of Arnold-Research Cave Calloway County, Missouri. *The Missouri Archaeologist* 28
- Simpson, E. H
1949 Measurement of Diversity. *Nature* 163: 688.
- Smith, F. A., S. K. Lyons, S. K. M. Ernest, K. E. Jones, D. M. Kaufman, T. Dayan, P. A. Marquet, J. H. Brown, and J. P. Haskell.
2003 Body mass of Late Quaternary mammals. *Ecology* 84:3403.
- Stephenson, Robert L.
1965 Quaternary Human Occupation of the Plains. *The Quaternary of the United States*, pp.685 – 696. Princeton University Press, Princeton.
- Transeau, Edgar Nelson
1935 The Prairie Peninsula. *Ecology* 16: 423 – 437
- Travouillon, K.J. and Serge Legendre
2009 Using Cenograms to Investigate Gaps in Mammalian Body Mass Distributions in Australian Mammals. *Paleogeography, Paleoclimatology, Paleoecology* 272: 69 – 84
- Travouillon, K.J., S. Legendre, M. Archer, and S.J. Hand
2009 Paleocological Analysis of Riversleigh's Oligo-Miocene Sites: Implications for Oligo-Miocene Climate Change in Australia. *Paleogeography, Paleoclimatology, Paleoecology* 276: 24 - 37

- Tougard, C. and S. Montuire
 2006 Pleistocene Paleoenvironmental Reconstructions and Mammalian Evolution in South-East Asia: Focus on Fossil Faunas from Thailand. *Quaternary Science Reviews* 25: 126 – 141.
- Valensi , Patricia, and Eleni Psathi
 2004 Faunal Exploitation during the Middle Palaeolithic in South-Eastern France and North-Western Italy. *International Journal of Osteoarchaeology* 14:256 – 272
- Wilf, Peter, K. Christopher Beard, K. Sian Davies-Vollum, and Jay W. Norejko
 1998 Portrait of a Late Paleocene (Early Clarkforkian) Terrestrial Ecosystem: Big Multi Quarry and Associated Strata, Washakie Basin, Southwestern Wyoming. *Palaios* 13:514 – 532
- Willey, Gordon R.
 1966 *An Introduction to American Archaeology. Volume 2, North and Middle America.* Prentice Hall, Inc. Englewood Cliffs.
- Wing, Scott L., Hans-Deiter Sues, Richard Potts, William DiMichele, and Anna K. Behrensmeyer
 1992 Evolutionary Paleoecology. In *Terrestrial Ecosystems Through Time* Anna K. Behrensmeyer, John Damuth, William A, DiMichele, Richard Potts, Hans-Deiter Sues, and Scott L. Wing (Eds.) pp. 1 – 13. University of Chicago Press, Chicago.
- Wing, Scott L. and David R. Greenwood
 1993 Fossils and Fossil Climate: The Case for Equable Continental Interiors in the Eocene. *Philosophical Transactions: Biological Sciences* 341: 243 – 252
- Wolverton, Steve
 2001 Environmental Implications of Zooarchaeological Measures of Resource Depression. Unpublished Ph.D. Dissertation, University of Missouri, Columbia
 2002 Zooarchaeological Evidence of Prairie Taxa in Central Missouri during the Mid-Holocene. *Quaternary Research* 58: 200 – 204
 2005 The Effects of the Hypsithermal on Prehistoric Foraging Efficiency in Missouri. *American Antiquity* 70: 91 – 106
- Wood, W. Raymond and R. Bruce McMillan (Eds.)
 1976 *Prehistoric Man and His Environments: A Case Study in the Ozark Highland.* Academic Press , New York