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Hugh H. Genoways

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The expansion and collapse of the geographic range of the Texas rice rat (*Oryzomys texensis*) in the upper Mississippi River drainage basin at the end of the Holocene was a unique event in North American mammals. In a period of about 4000 years with a point of origin near the American Bottom in Illinois, these small rodents extended their geographic range in a straight-line distance of over 950 km to the west into Nebraska and the same distance to the east into Pennsylvania. Then in less than 400 years this range expansion collapsed back to a point where the northern-most edge of the modern geographic range of these rice rats is in southern Illinois. It is concluded that no single factor lead to this geographic range expansion, but it was a complex interplay of changes in Native American populations, culture, foodways, riverine habitats, and climate along with the impact of kleptoparasitism and passive anthropochory. The collapse of the expanded geographic range of Texas rice rats appears to have occurred between AD 1400 and AD 1600, but it did not occur simultaneously throughout the geographic range. This was not an orderly range contraction, but a collapse of populations in place with many local extinction events. These rice rat populations declined beginning with the onset of the Little Ice Age, which brought a colder and wetter climate that caused crop failures resulting from droughts, cold temperatures, or shortened growing seasons. These conditions stressed the dietary reserves of the human populations and thereby the rice rat populations. These conditions, particularly droughts, were harmful to the growing of maize, which served as the primary food resource of the Native Americans and the associated populations of rice rats. It is proposed that the pre-1910 records of rice rat from unusual localities compared to the modern geographic range in southwestern Ohio, Kentucky, and Kansas represent the final extinction events of these Holocene rice rat populations.

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University of Nebraska Lincoln

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Cover image of a Texas rice rat from Port Aransas, Nueces Co., Texas,
courtesy of José G  Martínez-Fonseca.

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University of Nebraska Lincoln

# Preface

In early 2016 as I had completed the initial draft of this manuscript, I had sent it for preliminary reviews to colleagues who were familiar with the situation with Holocene rice rats. One of these people, Holmes A. Semken, Jr., quickly responded back to me, saying that he had recently reviewed a manuscript on this very topic that was about to be published. He asked if I was aware of this situation, I was not. The publication did appear soon thereafter (Vickery et al., 2016). Dr. Semken did encourage me to move forward to complete this manuscript because the focus was different from that of Vickery et al. (2016), but I chose to set it aside for later consideration. In the interim, a second paper pertaining to this topic has appeared (Tankersley and Lyle, 2019).

Although there are these two publications, I have concluded that now is the time "for later consideration." This paper is not an answer to, or critique of, the earlier two publications, but rather a statement of my ideas. These earlier papers are both strong contributions that add significantly to our understanding of Native Americans in the Mississippi River drainage basin and the Holocene history of rice rats. They have approached these issues more as archeologists and anthropologists, but I am a biologist so that has informed my approach and my particular interest in the rice rats.

Based on my understanding, the expansion and collapse of the geographic range of the Texas rice rat (*Oryzomys texensis*) in the upper Mississippi River drainage basin at the end of the Holocene was a unique event in North American mammals. In a period of about 3000 years, using a point of origin near the American Bottom in Illinois these small rodents extended their geographic range in a straight-line distance of over 950 km to the west into Nebraska and the same distance to the east into Pennsylvania. Then in less than 400 years this range expansion collapsed back to a point where the northern-most edge of the modern geographic range of these rice rats is located in southern Illinois.

In my initial search of the literature, I had identified 91 archeological and paleontological sites in the upper Mississippi River drainage basin from which Texas rice rat remains had been reported. Vickery et al. (2016) had 60 site and of these 10 were new to me and Tankersley and Lyle (2019) provided an additional five sites. This gives a total of 106 sites with Holocene rice rat remains, but this number comes with several caveats. The counting of sites within larger sites such as Cahokia, Glenwood, and southwestern Ohio can be a matter of opinion. A few of the sites in Arkansas may be from within the modern geographic range of the species. Eschelman (36LA12) site in eastern Pennsylvania was included by Vickery et al. (2016), although I have discussed this site here I do not believe that it should be included in the list. Although 106 archeological and paleontological sites in the upper Mississippi River drainage basin with rice rat remains is an impressive number, the reader needs to keep in mind that this is only a small fraction of the archeological and paleontological sites that have been studied within this region and, obviously, is even a smaller fraction of the total sites. Although this was a geographically wide phenomenon, the rice rats do not appear to have been particularly abundant, except at a few sites such as those near Chillicothe, Ohio, Cahokia, Illinois, and Glenwood, Iowa.

Much of this manuscript remains the same as my original draft that was completed in 2016, with revisions. I have included the 15 additional sites, with the most occurring in Ohio. Where it seemed appropriate, I have commented on the two earlier studies and I have added some applicable recent literature. I hope that the readers of this publication will feel that it was worth my time and theirs to have completed this third contribution on the Holocene rice rats of the upper Mississippi River basin.

*Hugh H. Genoways*
*Lincoln, Nebraska*
*January 2023*

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# Holocene Rice Rats (Genus *Oryzomys*) from the Upper Mississippi River Drainage Basin

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## Abstract

The expansion and collapse of the geographic range of the Texas rice rat (*Oryzomys texensis*) in the upper Mississippi River drainage basin at the end of the Holocene was a unique event in North American mammals. In a period of about 4000 years with a point of origin near the American Bottom in Illinois, these small rodents extended their geographic range in a straight-line distance of over 950 km to the west into Nebraska and the same distance to the east into Pennsylvania. Then in less than 400 years this range expansion collapsed back to a point where the northern-most edge of the modern geographic range of these rice rats is in southern Illinois. It is concluded that no single factor led to this geographic range expansion, but it was a complex interplay of changes in Native American populations, culture, foodways, riverine habitats, and climate along with the impact of kleptoparasitism and passive anthropochory. The collapse of the expanded geographic range of Texas rice rats appears to have occurred between AD 1400 and AD 1600, but it did not occur simultaneously throughout the geographic range. This was not an orderly range contraction, but a collapse of populations in place with many local extinction events. These rice rat populations declined beginning with the onset of the Little Ice Age, which brought a colder and wetter climate that caused crop failures resulting from droughts, cold temperatures, or shortened growing seasons. These conditions stressed the dietary reserves of the human populations and thereby the rice rat populations. These conditions, particularly droughts, were harmful to the growing of maize, which served as the primary food resource of the Native Americans and the associated populations of rice rats. It is proposed that the pre-1910 records of rice rat from unusual localities compared to the modern geographic range in southwestern Ohio, Kentucky, and Kansas represent the final extinction events of these Holocene rice rat populations.


**Key Words:** American Bottom, archeology, Cahokia, climate change, Eastern Agricultural Complex, foodways, Holocene, Illinois River, jump dispersal, kleptoparasitism, Mammalia, maize, Mississippi River, Missouri River, Native Americans, Ohio River, *Oryzomys texensis*, passive anthropochory, Rodentia

## Introduction

While surveying the archeological and paleontological literature for Holocene records of Nebraska mammals, I became aware of records of the marsh rice rat (*Oryzomys palustris*) from the state (Genoways, 2021). I was well aware that the nearest modern records for this species were in southern Illinois (Hoffmeister, 2002) and adjacent Kentucky (Barbour and Davis, 1974). My first reaction to finding these records was that they must be in error or based on misidentified material, but the records from Nebraska reached 10 localities and many of the reports were authored by scientists that I knew and respected (Bozell and Ludwickson, 1999; Graham et al., 1987; Koch and Nelson, 2002). This led to my asking the question as to how the rice rats arrived in Nebraska. A further search of the literature resulted in the discovery of scattered reports of Holocene rice rats, many times as only a line or two in large publications and archeological reports, which together presented a picture of a unique phenomenon at least for Holocene mammals. Marsh rice rats evidently expanded their geographic range to Nebraska in the west and to Pennsylvania and West Virginia in the east beginning about 2500 BC, but by approximately AD 1600 the geographic expansion had collapsed with populations of rice rats having returned to near their modern distributional pattern. This paper is an attempt to bring these data together and to explore the reasons behind the expansion and subsequent collapse. This sequence of event appears to have played out along the rivers of the upper Mississippi River Basin from the mouth of the Arkansas River northward.

Rice rats of the genus *Oryzomys* are a speciose and widespread Neotropical group of rodents (Weksler, 2006). Beginning in early 1960s (Hall, 1960) a single species, *Oryzomys palustris*, was believed to occur in the United States, with a distribution across the southern and eastern coastal areas and along the Mississippi River lowlands as far north as Illinois (Hall 1981). However, recent studies, particularly studies of molecular genetics, have shown the situation to be far more complex. Benson and Gehlbach (1979; see also Haiduk et al., 1979) argued for the recognition of *O. couesi* as a species separate from *O. palustris* based on karyotypes and differences in size. The geographic range of *O. couesi* was restricted to Cameron and Hidalgo counties in Texas and then southward into adjoining Tamaulipas, Mexico. A few years later Schmidt and Engstrom (1994) compared *O. couesi* and *O. palustris* based on genic variation as detected by protein electrophoresis confirmed the earlier arrangement considering these to be separate species and also identifying an area of overlap between the species in Kenedy, Willacy, and Cameron cos., TX, and one locality in northeastern-most Tamaulipas, with no hybrid individuals being found.

Using mitochondrial and nuclear DNA in molecular studies, Hanson et al. (2010) and Indorf (2010) presented evidence that within *Oryzomys palustris* in the United States there were two distinct species. They restricted *O. palustris* to the southeastern United States from Alabama eastward and up the east coast to New Jersey and Pennsylvania. The western-most records for this species given by these authors were from Alabama—Cherokee, Colbert Co., and Horseshoe Bend National Military Park, Tallapoosa Co. The other species recognized was *Oryzomys texensis* occurring along the Texas coast and into Louisiana and Mississippi and then northward along the Mississippi River lowlands as far north as western Kentucky and southern Illinois. Eastern records for this species were Tupelo, Lee Co., MS, and 8.02 km N Memphis, Shelby Co., TN. The focus of the current paper will be on the Texas rice rat, *O. texensis,* and to a far lesser extent *O. palustris*.

An understanding of the habitat requirements of Texas rice rats will provide insights into the factors limiting their geographic distribution. Fortunately, we have good ecological studies of the Texas rice rat from extremes in its geographic range—southern Louisiana and Texas and southern Illinois. In Louisiana (Negus et al., 1961; Goertz and Long, 1973; Wolfe, 1982), this semi-aquatic mammal inhabited meadows and marshy areas near water or in standing water with dense vegetation. The species was most abundant in sedge communities, but was also present in coastal and freshwater marshes, old fields, bottomland forests, and pinelands. At pond and lake edges, the flora was dominated by broomsedge, bulrushes, common rush, and bearded beggartick. In areas with standing water, typical plants were bagpod, cattails, and reed canary grass, with woody vegetation such as common buttonbush and black willow. Many times, the rice rats placed their grassy nests high in the dense stands of vegetation or even in the woody bushes. Important trees in these areas included loblolly pine, sweet gum, persimmon, and sassafras.

The highly aquatic nature of the habits of Texas rice rats were shown in two studies conducted in the vicinity of Galveston, Galveston Co., TX. Researchers (Abuzeineh et al., 2007:77) found that rice rats, "maintained a substantial population in a habitat that experienced long-term inundation," that is, where the ground was entirely submerged. Kruchek (2004) showed similar results working on population levels of rice rats in this area, but detected some movement of rice rats into upland habitats with dense cover provided by bushy beardgrass, Gulf cordgrass, and little bluestem in response to flooding tides and hurricanes.

In southern Illinois, Hofmann and Gardner (1987) and Hofmann et al. (1990:168) did sampling throughout the area to determine the status of *O. texensis*, which was believed to deserve a threatened status in the state. They found that the "optimal habitat for rice rats in southern Illinois has standing water with emergent herbaceous wetland vegetation." The emergent vegetation included sedges, bulrushes, rushes, spike rushes, cattails, rice cutgrass, and common reed. These authors found Texas rice rats were not confined to natural, undisturbed wetlands because they were relatively abundant in roadside ditches that lacked standing water, although the ditches were capable of holding water. More recently Eubanks et al. (2011) also working in southern Illinois confirmed the findings of the earlier studies, concluding that the Texas rice rat is a wetland-obligate species. Their advanced analyses of land cover models indicated that the habitat requirements of these rodents were early successional wetlands with emergent vegetation and associated upland grass cover.

## Methods

The literature search undertaken for this study was only possible in the digital age with the availability of the internet and the World Wide Web. The initial work was undertaken using several common search engines—Firefox, JSTOR, WorldCat, Project MUSE, and ProQuest. Copies of the identified publications with potential records were obtained online, via interlibrary loans, and by direct requests to archeological surveys and institutions involved in the studies. As copies of the reports and publications were received, I searched their literature citations and sent a second wave of requests to obtain other appropriate literature. This process was repeated in several cycles until I could no longer find new references. This should not be taken to mean that I believe that I have found all of the relevant literature, because these reports are highly scattered and a very limited number of copies were created for many of them. Many archeological survey reports are in highly organized collections and easily available, but a significant number are in personal file cabinets and are unknown to outsiders. Among the literature items received about one in four had information used in this report.

In the text and figures, the designation "R" indicates a record of a modern specimen of a Texas rice rat. The designation "H" refers to a historical record of a rice rat that is more than 100 years old and is from outside the known modern geographic range of the Texas rice rat. On the state maps of the archeological and paleontological sites, the letter designation along with the number is an indicator of the state and locality number that appear in Appendix 1.

In Appendix 1 the site names, site numbers, the localities of the sites, and number of rice rats are as given in the cited literature. Age of site is as given in the original publication or as revised in a subsequent publication by these researchers. The number of rice rats is given either as MNI (minimum number of individuals, as determined by the highest count of a unique skeletal element) or TR (total remains, which is a simple count of all bones of the species present).

The sites included in Appendix 1 are from the Mississippi River drainage basin from the mouth of Arkansas River northward. This point was chosen because it is within the modern distribution of *Oryzomys texensis*, but it is an area approaching the northern limits of the modern distribution. This point also includes all of the tributaries of the Mississippi River where extralimినal Holocene records of the rice rat have been found. The major tributaries of the Mississippi River included in this study are the Ohio, Missouri, Arkansas, and Illinois rivers.

Acronyms for museums mentioned in the text are as follows: Sam Noble Oklahoma Museum of Natural History, University of Oklahoma, Norman (SNOMNH); National Museum of Natural History, Washington, D.C. (NMNH); Sternberg Museum of Natural History, Fort Hays Kansas State University, Hays (FHSU); University of Michigan, Museum of Zoology, Ann Arbor (UMMZ). Scientific names for the common names of plant and vertebrate species used in text are given in the two glossaries following Appendix 1.

## Results

Appendix 1 is a compilation of the Holocene records for the Texas rice rat, *Oryzomys texensis*, in the Mississippi River drainage basin north of the confluence with the Arkansas River. Most of these records are from outside of the area where modern rice rats of this species occur. First, we will consider the geographic range of the Texas rice rats as it is known today within this region. This will be followed by a review of the data presented in Appendix 1 arranged by major tributary. Finally, we will explore some early modern records that seem to appear in unusual locations.

### Modern Distribution

The modern distribution of the Texas rice rat in Arkansas is nearly statewide in appropriate semiaquatic habitats (Fig. 1), with the exception of some of the north-central counties up to the Missouri boundary (Sealander 1979; Sealander and Heidt 1990; Connior 2010). These rats are known from each county adjacent to the Mississippi River and at least six counties along the Arkansas River. An early record from the northwestern-most county of the state at 8 miles east-northeast of Siloan Springs, Benton Co., was taken near Osage Creek, a tributary of the Arkansas River (Fig. 1, R1), which eventually meets the main stem of the river in Sequoyah Co., OK (Davis and Lidicker, 1954).

The majority of the records for the Texas rice rat in Oklahoma are from the southeastern portion of the state (McCarley, 1960; Caire et al., 1989) as far west as near Loco, Stephens Co. (Braun et al. 2020—Fig. 2, R2). In recent years populations of these mice also have been found in the northeastern part of the state in association with the Arkansas River and its tributaries (Fig. 2). Probably the first record of rice rats in this area was based on three specimens trapped in January 1980 near Stigler, Haskell Co. (Fig.


Fig. 1.—Map of the state of Arkansas, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). "R" labeled locality is near Siloan Springs as discussed in the text in the section on Modern Distribution.


Fig. 2.—Map of the state of Oklahoma, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). “R” labeled localities are R2) Loco; R3) near Stigler; R4) Cedar Crest Lake; R5) Eufaula Wildlife Management Area; R6) Camp Gruber Maneuver Training Center; R7) Wagoner Co. as discussed in the text in the section on Modern Distribution.


Fig. 3.—Map of the state of Tennessee, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). "R" labeled localities are R8) Reelfoot Lake; R9) Land Between the Lake National Recreation Area; R10) Cross Creeks National Wildlife Refuge; R11) Polk Co.; R12) Blount Co.; R13) near Caryville; R14) Highcliff as discussed in the text in the sections on Modern Distribution.

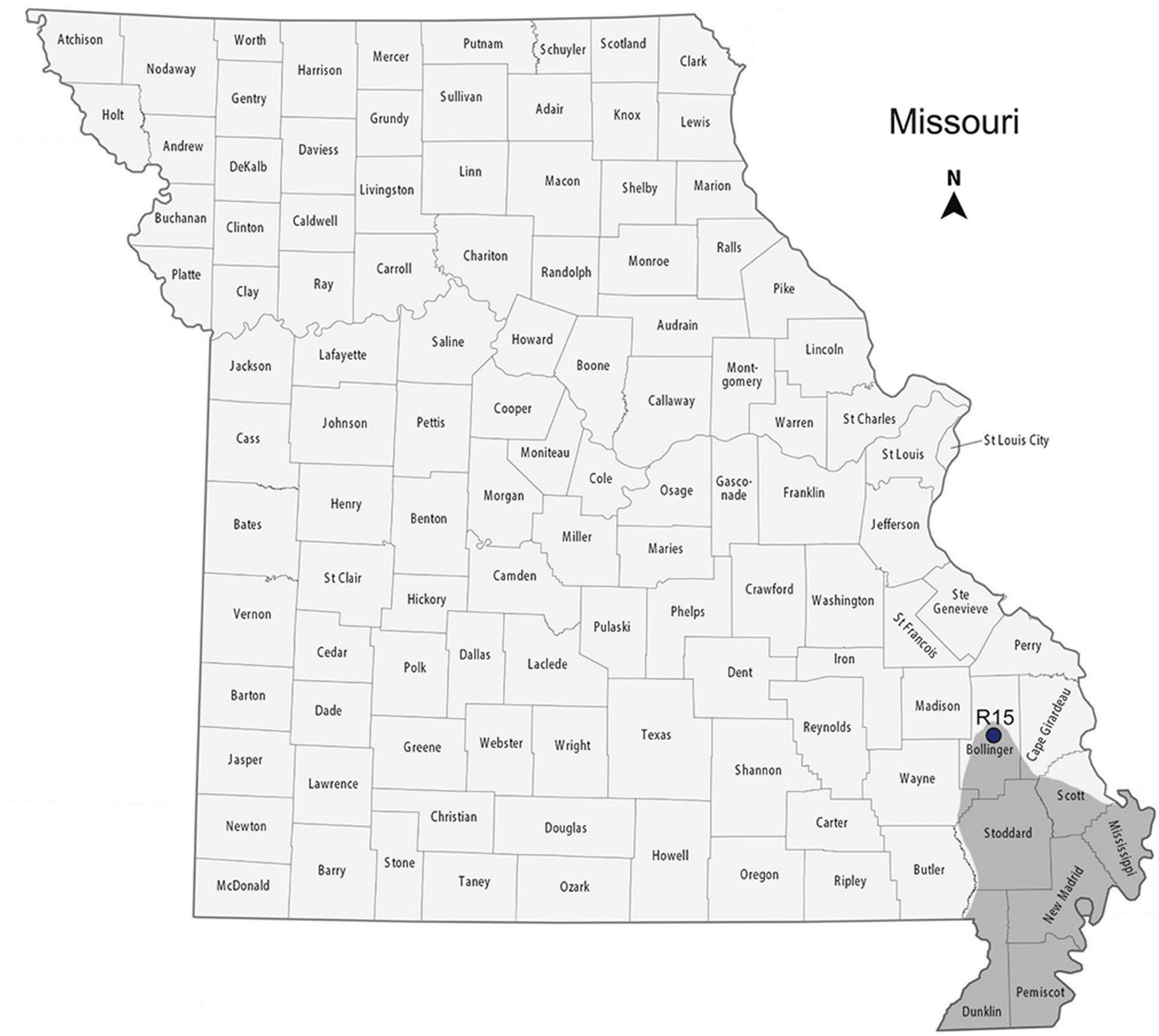


Fig. 4.—Map of the state of Missouri, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). "R" labeled locality is R15) Marble Hill as discussed in the text in the section on Modern Distribution.


Fig. 5.—Map of the state of Kentucky, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). “R” labeled localities are R 16) near Hardin; R17) near Golden Pond as discussed in the text in the section on Modern Distribution and “H” labeled locality is H1) Barbourville as discussed in the text in the section on Early Modern Records from Unusual Locations.


Fig. 6.—Map of the state of Illinois, with counties outlined, showing the modern geographic distribution (shaded area) of the Texas rice rat (*Oryzomys texensis*). "R" labeled localities are R18) Washington Co.; R19) near Norris City as discussed in the text in the section on Modern Distribution.

2, R3) (Gettinger, 1991). The northeastern-most of these new records is from Cedar Crest Lake (Fig. 2, R4), which is an impoundment on Spring Creek in Mayes Co. (Gettinger, 1991). This creek flows into the Neosho River, which in turn flows into the Arkansas River. Braun and Revelez (2005) added records from the Eufaula Wildlife Management Area in Okmulgee Co. located in the Canadian River drainage (Fig. 2, R5) not far from its confluence with the Arkansas River. Braun et al. (2020) reported a specimen taken at Camp Gruber Maneuver Training Center, Muskogee Co., in the floodplain of the Arkansas River (Fig. 2, R6). A record from a third northeastern county, Wagoner, was added by the work of McDonald et al. (2006) studying owl pellets (Fig 2, R7). This county is bordered on the east by the Neosho River and on the south by the Arkansas River.

Charting the distribution of the Texas rice rat in Tennessee is more complicated than it might appear because there is no published comprehensive treatment of the mammals of the state (Beasley and Severinghaus, 1973; Kennedy, 1991; Kennedy et al., 2012) and Hanson et al. (2010) show both *O. texensis* and *O. palustris* occurring in Tennessee. I have confined my comments here to the distribution of rice rats west of the Tennessee River, which appear to be *O. texensis* (Hanson et al., 2010). Goodpaster and Hoffmeister (1952) found rice rats to be widespread in the area of Reelfoot Lake (Fig. 3, R8) in Obion and Lake counties in northwestern-most Tennessee where their chief food items were the babies of five species of turtles. Later Beasley and Severinghaus (1973:108) reported these mice from nine additional counties where they " were collected in lowland areas subject to flooding." The collections of the Sam Noble Oklahoma Museum of Natural History has specimens of *Oryzomys* from another four counties, thus there are records from at least 15 of the 21 counties in Tennessee west of the Tennessee River (Fig. 3). The species is clearly widespread in this part of the state.

The authors of *The Wild Mammals of Missouri* Schwartz and Schwartz (2001:194) simply stated that the distribution of the rice rats in the state was "in the Mississippi Lowland." I have found specimens of rice rats from Missouri in the collections of the National Museum of Natural History and the Sternberg Museum of Natural History from five counties in the southeastern-most part of the state—Bollinger, Dunklin, Mississippi, New Madrid, and Stoddard (Fig. 4). The northern-most of these localities (Fig. 4, R15) is Marble Hill, Bollinger Co. (NMNH 159,585), but the species may be expected further to the north in Cape Girardeau and Perry cos.

Barbour and Davis (1974) reported rice rat records from five counties without specific localities in western Kentucky—Calloway, Fulton, Hickman, Livingston, and Trigg (Fig. 5). The University of Michigan, Museum of Zoology, has specimens from near Hardin, Marshall Co. (UMMZ 97,210-13), in this same part of the state (Fig 5, R16). The sites in Fulton and Hickman counties are located in the lowlands of the Mississippi River, whereas those from Calloway and Marshall counties also are from west of the Tennessee River, but may be in the drainage of that river. The specimens from 8 miles NNE of Golden Pond, Trigg Co. (UMMZ 97202-09), lie on the narrow strip of land between the Cumberland and Tennessee rivers and are in the drainage of the former river (Fig 5, R17). Finally, the material from Livingston Co. is from the furthest north modern locality in Kentucky, which is an area of the drainages of the Ohio and Cumberland rivers. There are also three specimens of rice rats from Barbourville, Knox Co. (NMNH 157,093-94, 157,303), from an apparently isolated site near the upper Cumberland River in southeastern Kentucky (Figs. 5, 11; H1). These specimens were collected on 12-13 August 1908 with no additional individuals being taken in the area since that time (Barbour and Davis, 1974).

The final state in the area under consideration to report records of *O. texensis* is Illinois where the species has been well studied (Fig. 6). These recent studies (Hofmann and Gardner, 1987; Hofmann et al., 1990; Hoffmeister, 2002; Eubanks et al., 2011; Cooney et al., 2015) have documented the occurrence of *O. texensis* in 13 counties in extreme southern Illinois—Alexander, Franklin, Hamilton, Jackson, Johnson, Massac, Perry, Pope, Pulaski, Saline, Union, White, and Williamson. In addition, there is one tentative record from an unspecified locality in Washington Co. (Fig 6, R18) where a rice rat was recorded from the stomach of a mink (Casson, 1984). This presumably would be the northernmost record for the species in Illinois. These locations lie within the drainage systems of the Mississippi and Ohio rivers and their major tributaries—Big Muddy River a tributary of the former and Cache, Little Wabash, and Saline rivers tributaries of the latter. Although the capture site at 5.5 km NE Norris City, White Co. (Fig. 6, R19) (Hofmann et al., 1990), is only approximately 18 miles [30 km] west of the Indiana state line, but there are no modern records from Indiana (Mumford and Whitaker, 1982).

## Archeological and Paleontological Records

Archeological and paleontological sites in the upper Mississippi River drainage basin from which the remains of the rice rat *Oryzomys texensis* have been reported are listed in Appendix 1. The results of archeological and paleontological studies are presented below in order as if one were moving upstream in the major river systems—Mississippi, Ohio, Illinois, and Missouri rivers.

### *Arkansas*

Six Holocene sites with remains of the Texas rice rats have been reported from northeastern Arkansas (Fig. 7). All sites date to post-AD 800. At least five of these places lie on the alluvial plain of the Mississippi embayment or along the St. Francis River, which enters the Mississippi River north of Helena, Phillips Co., AR. The McDuffer (Parmalee, 1963a) site was not exactly placed within Craighead Co. so it could be associated with Crowley's Ridge or the lowlands (A4). The remains of maize have been reported from four of the sites—Banks Village (A1—Parmalee, 1966; Perino, 1966; Guilday, 1971), Lawhorn (A5—Moselage, 1962; Parmalee, 1962b), Parkin (A2), and Upper Nodena (A3). Rice rat remains at the Parkin (Scarry and Reitz, 2005) and Upper Nodena (Mainfort et al., 2007) sites were relatively abundant representing at least a minimum of 23 and 55 individuals, respectively. The Zebree site (A6) was located on the floodplain of the Little River in northeastern Arkansas. The site included material from Late Woodland and Early Mississippian occupations, but few other details of the village are available (Guilday and Parmalee, 1971). All of these archeological sites fall within the modern geographic range of *O. texensis*.

### *Tennessee*

My literature search has found only four archeological sites in Tennessee from which rice rats have been reported; however, even this small number of sites presented some challenges in interpretation (Fig. 8). Chucalissa (T1), south of Memphis, was the only site with rice rat subfossils in the main channel of the Mississippi River in Tennessee (Cleland, 1966). The site was occupied in the Late Mississippian and prehistoric periods (Mainfort, 1996). This site is within the modern geographic range of *O. texensis*. The other three archeological sites were located on tributaries of the middle Cumberland River in the vicinity of Nashville (Mound Bottom—T2; Gordontown—T3; and Rutherford-Kizer—T4). These three sites were Mississippian in age, with Mound Bottom potentially having some older materials. These sites lie to the east of the known geographic range of modern rice rat records in Stewart Co. These rice rats may have entered this area from the south, which would potentially


Fig. 7.—Map of the state of Arkansas, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: A1 Banks Village; A2 Parkin; A3 Upper Nodena; A4 McDuffer; A5 Lawhorn; A6 Zebree. See Appendix 1 for additional information on localities.

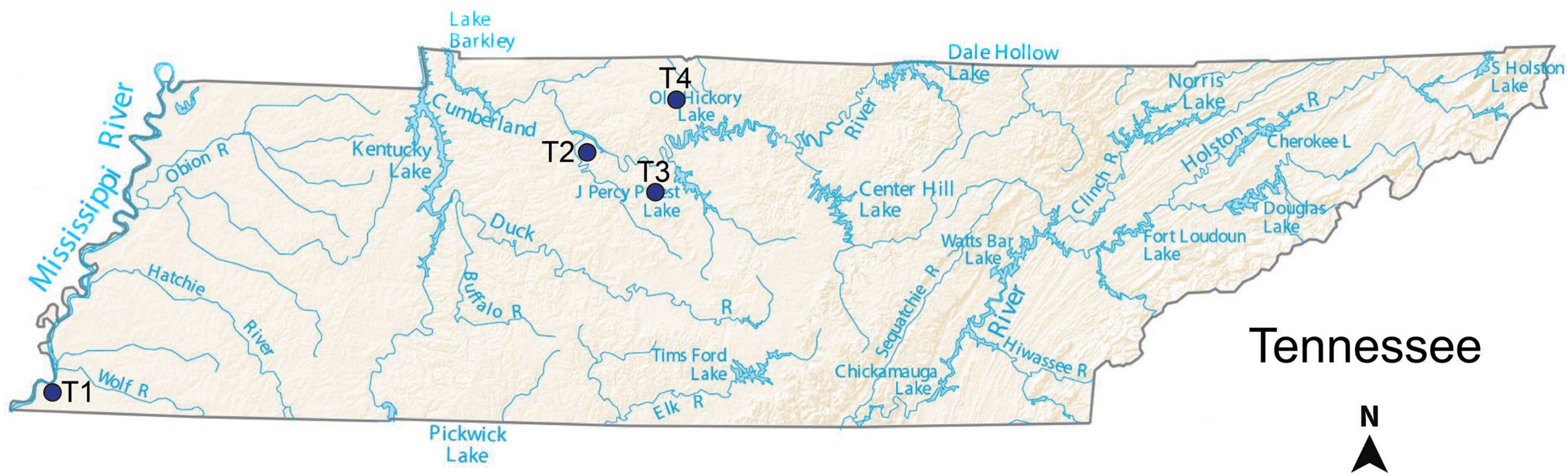


Fig. 8.—Map of the state of Tennessee, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: T1 Chucalissa; T2 Mound Bottom; T3 Gordontown; T4 Rutherford-Kizer. See Appendix 1 for additional information on localities.

associate them with *O. palustris* or they may have moved along the Cumberland River from the Ohio River drainage placing them more likely with *O. texensis*. The occupants of these three villages were involved in extensive maize-based agriculture, which also included beans and squash as well as native cultigens, such as marshelder, sunflower, and knotweed (Markuso, 1998; Moore et al., 2006; Clinton and Peres, 2011; O'Brien and Kuttruff, 2012). Clinton and Peres (2011) give a particularly interesting discussion of the Garden-Hunting Model of food procurement at the Rutherford-Kizer site.

### *Illinois*

Moving up the Mississippi River the next two states are Missouri and Kentucky, but sites in these states do not enter the main stem of the river so they will be discussed below at the appropriate points. Twenty-four archeological and paleontological sites in Illinois are known to have produced specimens of Holocene rice rats (Fig. 9). This was a higher number of sites than reported for any other state, and it was useful in illuminating a complex story. The archeological records of rice rats in Illinois appear to fall into three geographic groupings.

The first group includes records of rice rats from along the lowlands and adjacent bluffs to the east of the main stem of the Mississippi River between the mouth of the Ohio River and the mouth of Carr Creek near Columbia, IL. Four sites would be included in this group including Modoc Rock shelter (I1, I2), Waterman (I3), and Meyer Cave (I4), occurring in Monroe and Randolph cos. No modern records of rice rats are known from these counties, but modern records are available for adjoining counties of Perry and Washington to the east. The Modoc Rock Shelter provides the oldest records of rice rats from the area under consideration, with remains identified from both the Early Archaic and Middle Archaic strata (Styles, 1981b). The mammalian fauna from the site was essentially the same as would be expected today (Styles, 1981b). The high numbers of small mammals in the deposits led Styles (1981b; Styles and Colburn, 2019) to consider sources other than humans for a portion of the accumulation. Among these sources, she listed "owl pellets, stomach contents from carnivores and snakes using the shelter, and water transportation of bones during floods and rains." The series of occupations of Modoc Rock Shelter were considered to be short-term camps rather than multi-season base camps where hunter-gatherers used both local fauna, especially white-tailed deer and tree squirrels, and flora.

Meyer Cave was a fissure deposit at the end of a small cave in the bluff overlooking the Mississippi River. The site was primarily a fissure paleontological site, although a few native artifacts also were recovered (Parmalee, 1967a). Deposits from the cave were dated as originating during the Late Woodland period between AD 500 and AD 1200 and included remains from at least 15 individual rice rats.

The fourth site, Waterman, in Randolph Co. sets the other end of the time scale, because this record places rice rats near the northern limit of the modern geographic range of the species in the mid-1700s in historic times. Plant remains from the site indicated a "heavy reliance on corn" (Brown, 1991). The records from these four sites taken together would indicate that rice rats have been present near the northern limit of their modern geographic range for at least the last 10,000 years.

The second grouping of sites in Illinois (Fig 9) were those associated with the American Bottom—the lowlands east of the Mississippi River opposite St. Louis, MO, highlighted by the major archeological development of Cahokia. There are at least seven sites in this area from which rice rat remains have been identified —Cahokia, Cahokia Mound 31, Julien, Kane Village, Merrell Tract, Powell Tract, and Range. The range of the ages of these sites—AD 600 to AD 1350—covers most, if not all, of the occupation of the Cahokia and the American Bottom. The Range site falls into the Late Woodland period of AD 650 to AD 900 (J. Kelly, 1987; Kelly et al., 1987; Koldehoff and Galloy, 2006), whereas five sites cover the Late Woodland transition and the Mississippian period of AD 1000 to AD 1350 (Emerson, 2002; Benson et al., 2009), with the Powell Tract overlapping the two AD 800 to AD 1150 (O'Brien, 1972). Although none of the samples of rice rats was large, the largest was from excavations of refuse pits and kitchen middens associated with Monk's Mound and Mount 34 where 54 skeletal items were recovered (Parmalee, 1957).

The Range Site was a multicultural occupation located in the Prairie Lake meander scar of the American Bottom (I5). Cultures represented at this well studied site were Archaic through Emergent Mississippian, but the rice rat remains were from a Late Woodland occupation covering the period of AD 600 to AD 870 (J. Kelly, 1987). The site contained over 1500 pits of various sizes and shapes, with six individual rice rats being recovered from Pit Cluster 4 of Occupation Area P-3. Two additional individuals were recovered from the refuse of earth ovens of Feature 807. Material in the oven was both burned and unburned but unfortunately the condition of the rice rat material was not noted (L. Kelly, 1987). Johannessen (1987) reviewed plant remains from the Range site finding that the Eastern Agricultural Complex was well represented including seeds of maygrass, goosefoot, erect knotweed, sunflower, and marshelder. They raised squash and bottle gourds, but there was no evidence for the use of maize. Remains of hickory nuts, acorns, black walnut, butternut, hazelnut, and pecan represented gathering activities.

The Merrell Tract was a group of pithouses within the Cahokia complex in the American Bottom (I6), which was occupied from AD 850 to AD 950. Excavations demonstrated that these people were exploiting aquatic resources such as waterfowl and fishes as well as terrestrial resources, especially white-tailed deer. L. S. Kelly (1979:20) studied the animal remains from the site including the rice rats, but also concluded: "Agricultural products were available during the summer period and could be stored for later use during the winter."

The Kane Village was located in the northern portion of the American Bottom during the period AD 900 to AD 1100 (I11). It was classified as Late Woodland site with very little relationship to the developing Mississippian culture located nearby in the American Bottom including the early Cahokia. Remains of plants and animals were recovered from house structures as well as storage pits. None of the animal remains, including that of the rice rats, was attributed to any particular structures within the site (Parmalee, 1973). Based on the plant remains at the site, maize was in extensive use, with ears, cobs, and kernels present. Other plant remains indicate both gardening and gathering activities, including bottle gourd, goosefoot, hickory nuts, mallow, viburnum, and wild grapes (Munson and Anderson, 1973).

The Julien site was a Mississippian culture village (AD 960 to AD 1350) located south of the main mound complex of Cahokia (I8) in the American Bottom (Milner, 1984). The village occupied a series of sandy ridges that lay beside the now drained Goose Lake. A single mandible of a Texas rice rat was discovered in this site in Feature 24 an external refuse pit (Cross, 1984). Study of these storage/refuse pits indicated that the occupants of the Julien site were exploiting aquatic resources, with nearly 50% of the faunal component being comprised of fish remains. There was also a wide representation of waterfowl and other birds in their diets (Kelly and Cross, 1984). Johannessen (1984) examined the subsistence uses of plants at the Julien site, finding that in the cultural transition from Late Woodland to Mississippian maize was added to the diet but none of the other plants was eliminated. There was additional evidence of agricultural activities with the discovery of the rinds of squash and gourds. Among the carbonized seeds found in the pits were maygrass, goosefoot, erect knotweed, marshelder, black nightshade, wild bean, and sunflower. These people also engaged in gathering of nuts with an emphasis on thick-shelled hickory, but also including pecan, black walnut, and acorns.

A single individual of the Texas rice rat was found in premound excavations at Mound 31 (I10) in the main mound complex at Cahokia (Sullivan and Pauketat, 2007). The discovery of these remains in the deposits prior to the construction of Mound 31 places a date of AD 1050 to AD 1100 on this material. Plant remains from the same premound deposits included maize, squash, persimmon, and pecan. White-tailed deer and waterfowl were prominent among the faunal remains. Similar results were found for the Powell Tract (AD 800 to AD 1150) (I9) with white-tailed deer and waterfowl prominent in the faunal remains (Parmalee, 1963b), with maize present in the plant remains (Cutler, 1963). Remains of a single rice rat was recovered here.

Parmalee (1957) reported on the vertebrate remains resulting from the excavation of about an acre of the village site east of Monk's Mound and a section of the western slope of Mound 34 (I7). Remains were recovered primarily from refuse pits and kitchen middens. Among the mammal remains found at the site were 54 bones belonging to the Texas rice rat. This placed a population of rice rats at the heart of Cahokia at the height of its occupation, living among the refuse being generated by the village. White-tailed deer and several species of waterfowl appeared to contribute a major portion of the faunal component of the diet of occupants of the village. At AD 900 Cahokia was an ordinary village. Maize agriculture intensified after AD 800, but brought a range of agricultural and technological problems resulting in crop failures. Benson et al. (2009) attributed the "boom" at Cahokia and American Bottoms from AD 1050 to AD 1100 to 50 years of the wettest weather of the millennium. The "bust" at Cahokia from AD 1100 to AD 1250 appeared to be a result of a series of long-term droughts. By AD 1350, Cahokia and much of the central Mississippi Valley had been abandoned.

The final 13 sites in Illinois (Fig. 9) are all located in the Illinois River valley, extending as far north as southern Peoria Co. The archeological sites with rice rat remains appear to fall into two major time periods of Middle and Late Woodland (100 BC to AD 750) and Middle to Late Mississippian cultures (AD 900 to AD 1500). Whether there was a break in real time of rice rats inhabiting the valley of the Illinois River or whether this break was simply a sampling issue, can't be answered with the information available at this time. All of the Woodland sites producing rice rat remains were located in the lower Illinois River valley (Hill, *ca.* 1970; Parmalee et al., 1972; Styles, 1981a; Purdue and Styles, 1985, 1986; Styles et al., 1985; Byers, 2013). Many of the Middle to Late Woodland sites (Macoupin, Smiling Dan, Apple Creek, Guard, Carlin, Newbridge, and Scovill) were judged by their investigators as falling in the transition time from late Middle Woodland to early Late Woodland.

The Smiling Dan (I18) site was a Middle Woodland Hopewellian site located in the broad valley of the Illinois River where prairie predominated with timber skirting the river. Remains of a minimum of five rice rats were recovered from this site, which was more than any of the other Woodland sites along the Illinois River. Asch and Asch (1985; see also Smith, 1985) studied a large collection of archeobotanical materials that gave a broad understanding of the diet of the people who occupied the Smiling Dan site. These authors found extensive evidence of horticultural activity as well as gathering of wild plant resources. The remains of nuts were well represented in the archeobotanical materials, with at least seven species of nuts being present, having hazelnuts and thick-shelled hickory nuts the most abundant. Seven plants characteristic of the seed crop complex of eastern North

America were present—starchy seeds (maygrass, erect knotweed, little barley, goosefoot) and oily seeds (marshelder, sunflower, squash). Tubers of the ground nut and seeds from wild grapes were present, indicating the broad range of wild food items that were gathered. Remains of plant material were found concentrated in pit features indicating the storage of these resources for later consumption. A large trash midden was found in a gully at one edge of the camp. Both of these sources would have provided rich picking for rice rats, especially in the winter months.

The Scovill site (Munson et al., 1971) was typical of the transition phase sites (I22). It was a seasonal camp occupied in spring and early summer for planting of gardens and revisited in late summer through early winter for harvesting the gardens, gathering of other food items such as various nut species, and hunting for a selection of animal species. The camps were located on river terraces or at the base of bluffs along the Illinois River and its tributaries. At the Scovill site, 92 in-ground storage/refuse pits were discovered and sampled (Munson et al., 1971). The gardens were used for growing of local plants as well as plants introduced from outside the areas, such as squash, sunflower, sumpweed, goosefoot, and gourds. If maize was present in these Woodland period gardens, it was not a major component and not part of inhabitants diet (Ford, 1981; Smith, 2011). These plants would certainly have provided a food source for rice rats, but the location of the camps away from the marshy lowlands along the river would have placed them only at the periphery of prime rice rat habitat. This would explain at least in part the low number of rice rats recovered from these sites (Appendix 1).

For the five remaining sites of late Middle Woodland to early Late Woodland villages along the Illinois River (Fig. 9), there was a variable amount of information available on the horticultural practices—Apple Creek (Struever, 1968; Struever and Vickery, 1973—I13); Carlin (Asch and Asch, 1981); Guard (no information found—I19); Macoupin (Struever and Vickery, 1973); Newbridge (Maina, 1967; Struever and Vickery, 1973; Asch and Asch, 1981). These sites were a variation on the theme for horticulture discussed for the Smiling Dan and Scovill sites. There was a clear emphasis on the fall gathering and storage of nuts of at least eight species, including several species not recorded from other sites—pecan, bitternut, and butternut. The seven seed crops of Eastern Agricultural Complex were present but in varying amounts depending on the site. Sunflowers were rare and were not reported from the Carlin site (I15). Marshelder was present at all the sites, but Munson et al. (1971) believed that the few seeds found at Scovill were not from a domesticated plant. Other garden plants or gathered resources at one or more of the sites included grape, pawpaw, plums, and wild rice. Maygrass seeds were particularly abundant at the Carlin site. Although rare, maize was reported from the Macoupin (Struever and Vickery, 1973—I12]), Newbridge (I16), and Carlin sites (Asch and Asch, 1981, 1985), but it does not appear to have formed any significant part of the diet of the inhabitants of these villages. Maina (1967) identified three types of beans at the Newbridge site and thought that at least two were cultigens. It appears that non-perishable food items were stored in earthen pits, which subsequently in many cases became refuse pits. Just as at the Smiling Dan site, rice rats would have found the shelter and food needed for survival in these five semi-permanent villages.

Four (Emmons—I20; Kingston Lake—I23—Kingston Kitchen Midden—I24; Norris Farms No. 26—I21) of the six Mississippian sites were located along the central Illinois River valley. The other two Mississippian sites (Hill Creek—I17; Schild—I14) were from Greene and Pike cos. in the lower Illinois River valley in the same area as the Woodland sites. The Emmons (Parmalee, 1967b; Guilday, 1971) and Schild (Parmalee, 1971b) sites were cemeteries with 83 and

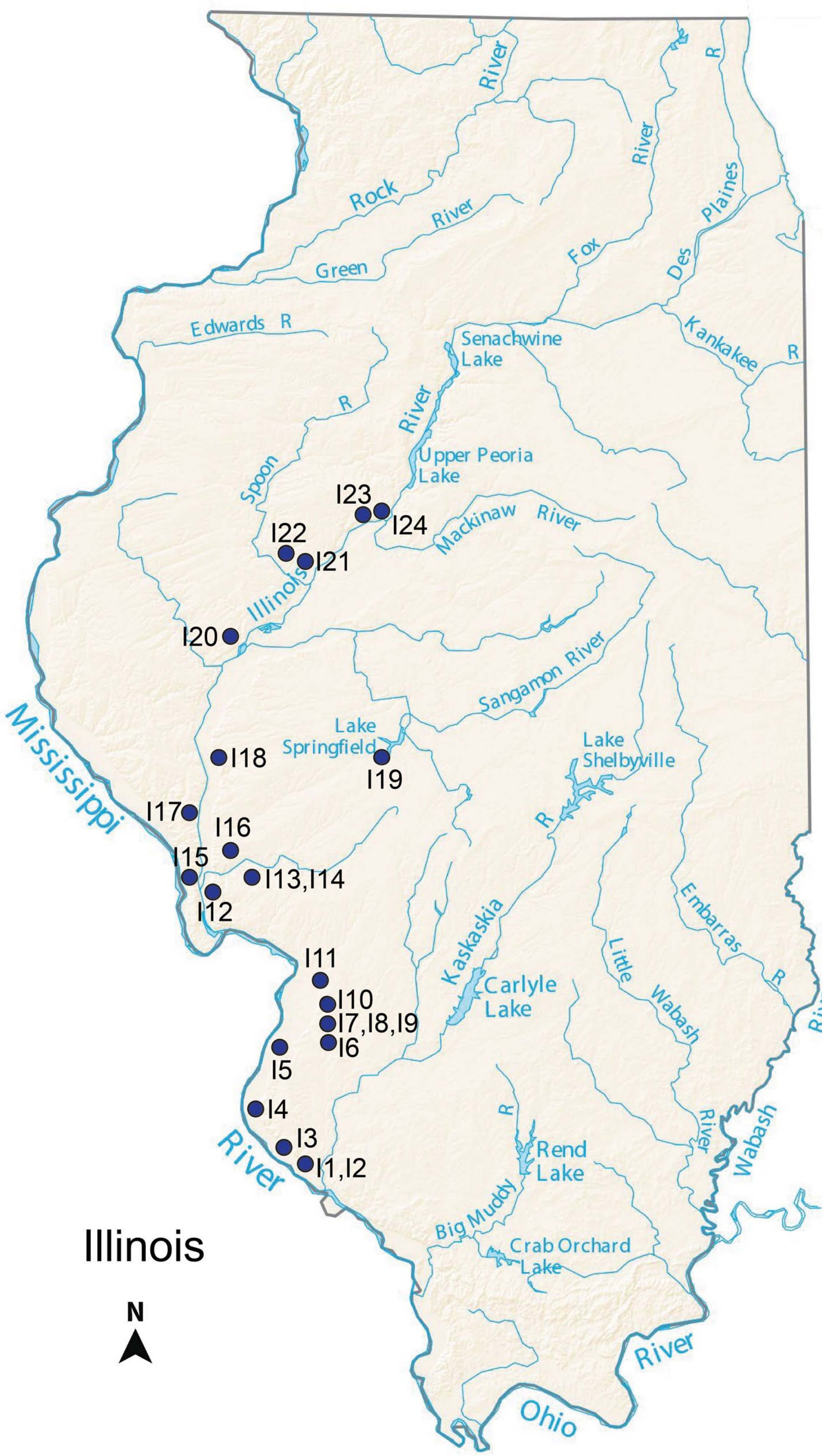


Fig. 9.—Map of the state of Illinois, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1: follows:
I1 Modoc Rock Shelter, Levels 4-5;
I2 Modoc Rock Shelter, Level 15;
I3 Waterman;
I4 Meyer Cave;
I5 Range;
I6 Merrell Tract;
I7 Cahokia Mounds;
I8 Julien;
I9 Powell Tract;
I10 Cahokia Mound 31;
I11 Kane Village;
I12 Macoupin;
I13 Macoupin;
I14 Schild Cemetery;
I15 Carlin;
I16 Newbridge;
I17 Hill Creek;
I18 Smiling Dan;
I19 Guard;
I20 Emmons;
I21 Norris Farms No. 26;
I22 Scovill;
I23 Kingston Lake;
I24 Kingston Kitchen Midden.
See Appendix 1 for additional information on localities.


Fig. 10.—Map of the state of Indiana, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows:
D1 Anderson Pit Cave;
D2 Angel;
D3 Passenger Pigeon Cave;
D4 raptor roost;
D5 Jennison Guard.
See Appendix 1 for additional information on localities.

300 burials, respectively (Strezewski, 2003). The two cemeteries set the earliest potential dates for this series of archeological sites at AD 900 and AD 1000, respectively. There was apparently no data on food ways of the people associated with the cemetery sites. However, there was a brief mention of plant materials recovered from the Kingston Lake (Baker, 1936; Parmalee, 1962a) site, which was the northern-most site for rice rats remains in Illinois. Simpson (1939) reported plant material from this site—maize, butternuts, walnuts, pawpaw seeds, and squash seeds.

The most individual rice rats represented from these sites were four at Norris Farm No. 26 (Woodman, n.d.). This does not indicate very high populations in these areas given that these four individuals accumulated over a period of as much as 300 years. It does not appear that rice rats were present along the Illinois River valley after AD 1500. The subsistence system was similar to that of the Late Woodland except that maize production intensified around AD 1100 after having been introduced into the valley 300 years earlier (VanDerwarker et al., 2013). The Hill Creek (Colburn,1985) location was where archeobotanical research has been conducted indicating: “Maize was of course an important element of the diet, as were various cultivated native seeds and wild nuts” (Conner, 1985). Among the latter species were acorns, hazelnuts, and thick-shelled hickory nuts.

It is impossible to prove that any species is absent from an area; however, it is of note that there were no archeological or paleontological records of rice rats found along the main stem of the Mississippi River north of the mouth of the Illinois River. However, there were two interesting areas in the greater Cahokia region that lacked rice rat subfossils that may give some insights into places where rice rats may or may not be found. In the Driftless Area of southwestern Wisconsin, there were what is believe to be religious shrines associated with Cahokia. Here in the area of Trempealeau and Little Bluff the Cahokians through terraforming reshaped the bluffs along the Mississippi River. Pauketat et al. (2015, 2017) believed that the Cahokians occupied the area in the warmer months and not throughout the year, but they returned multiple times between approximately AD 1050 and AD 1100 to carry out religious activities. To reach these sites, the Cahokians traveled either 900 river km north on the Mississippi River or by way of the Illinois River, then overland to the Rock River, and final to the Mississippi River to complete the journey. There was little evidence of agricultural activities and few storage or refuse pits associated with the shrines, suggesting that all items to sustain these visits were brought with the voyagers. No rice rat subfossils have been reported from these sites. There was another shrine 24 km east of Cahokia now known as the Emerald Acropolis. Skousen and Huber (2018:218) believed that “Recent research has revealed that the Emerald Acropolis was a pilgrimage center, a place periodically visited by Cahokians and individuals from more distant locales . . . .” There was a terraformed ridge associated with this site as well as numerous mounds, and special spiritual buildings, but few storage pits, little domestic debris, or permanent houses. Again, no rice rats subfossils have been reported from these excavations. These sites without rice rats subfossils shared characteristic, which may help in our understanding of the conditions that were necessary for the rice rats to be present and survive. These sites lacked a permanent population of Native Americans, little or no local agricultural/horticultural activities, only a few storage or refuse pits, and no elaborately constructed village or homes.

### *Indiana*

Although there are only five sites in Indiana from which Holocene remains of rice rats have been reported, they were diverse in age and origin (Fig. 10). The single individual reported from Anderson Pit Cave (Richards, 1980) is from one of the oldest sites (7550 BC) from which there are rice rat remains in the upper Mississippi River drainage basin (D1). The Anderson Pit Cave was near Bloomington, which placed it among the upper tributaries of the east fork of the White River. This site was at a considerable distance from the Ohio River so potentially the warmer, moister climate in the mid-Holocene provided rice rats more freedom to move away from major river ways. Rice rat fossil material recovered from Anderson Pit Cave was a portion of a left dentary, paired maxillae, and a left premaxilla, all with teeth absent. These were found deep within the cave in the sediments of an ancient woodrat nesting area, in general association with a late Pleistocene-early Holocene fauna that included the giant armadillo (Richards, 1980).

The remains of 19 rice rats from the Angel site (D2) were recovered from only a small sample of the zooarcheological material available from the site southeast of Evansville in Vanderburgh Co., IN (Adams, 1950; Richards, 1980; Monaghan and Peebles, 2010). Angel site was the remnants of a major Middle to Late Mississippian settlement that was occupied from AD 1000 to AD 1400. The Angel site was a palisaded village and associated ceremonial mounds occupying an area of about 47 ha situated along the Ohio River. Pits for storage of food and refuse were located at many places throughout the site. Subsistence was based on hunting and maize agriculture. In addition to the storage pits, the investigators found evidence of the construction of cribs to hold the maize within house structures (Black, 1944). Adams (1950:21) suggested that the rice rats may have been transported to this area “perhaps as pets.”

Passenger Pigeon Cave (D3) was described as “a shallow ‘shelter-like’ limestone cave and crawlway” and the nearby raptor roost (D4) was said to be a “bluff cove” (Richards, 1980:426). These sites were on the bluffs adjacent to the Ohio River. The deposits were composed primarily of raptor refuse, such as disintegrated owl pellets, and were dominated by remains of Passenger Pigeons. From the cave, 14 fragmented bones representing a minimum of three individual Texas rice rats. Only one dentary bone of a rice rat was recovered from the bluff cove, whereas over a thousand dentary bones of the vole, *Microtus,* were recovered from the same deposit (Richards, 1980). This gives a good indication of the relative scarcity of rice rats at this location because the voles would have occurred in a similar habitat. Richards (1980) gave no age for these two deposits, but the comments in his text indicate that these bones were recovered from the top 12 and 6 inches, respectively, of the dusty deposits. This indicates to me that these rice rat remains may be from a late prehistoric time.

The Jennison Guard site (D5) was located “on a terrace at the confluence of the Great Miami and Ohio River” in extreme southeastern Indiana (Cook et al., 2015:95). Influences from Mississippian material culture and architecture were evident in this large Fort Ancient tradition village. Maize dominated the dietary plant assemblage, because by Fort Ancient/Mississippian period it had replaced native cultigens. Other plant food items included squash/gourds, native nuts, and small possibly oily seeds. Animal remain that would have formed part of diet included white-tailed deer, elk, and raccoon among the larger mammals and eastern woodrat (the most individuals represented), eastern gray squirrel, fox squirrel, and Virginia opossum among the medium-sized mammals. Turkeys, fishes, and turtles were most abundant among the non-mammal fauna remains.

### *Kentucky*

Seven sites in Kentucky have yielded rice rat remains (Fig. 11), with Salts Cave Vestibule (Y1) producing the oldest artifacts, resulting from an Early Woodland occupation dating from 720 BC to 190 BC (Gardner, 1987). This site is located in central Kentucky and is part of Mammoth Cave National Park. The Green River, which is located about 2.5 km from the Cave, is a tributary of the Ohio River, but Salts Cave is over 300 river km upstream from its mouth near Evansville, IN. It is not clear if the Green River from the Ohio River was the route followed by this rice rat population because the main stem of the Cumberland River is only about 75 straight-line km to the southeast of Salts Cave and certainly the tributaries of the Green and Cumberland rivers are in even closer proximity. Rice rats could have crossed the intervening upland and entered central Kentucky from the south. The early mixed gardening-foraging subsistence horticulture practiced at Salt Cave near the Green River has been extensively studied (Watson and Yarnell, 1966; Watson, 1974; Gardner, 1987). Watson and Yarnell (1966) identified 17 species of plant foods associated with human occupation of the cave. As much as 66% of the total bulk of food was from "cultivated" species, including squash, sunflower, gourd, marshelder, and goosefoot seeds. These foods were supplemented with gathered items including hickory nuts and acorns. These species were harvested in the fall and most were capable of being stored through the winter. There was indication of reduced human activity at the cave during the spring and summer, with the residents potentially working in gardens along the Green River, which could have been the source of the rice rat subfossil. Salts Cave was a longer distance from a waterway than many sites from which rice rat subfossils have been found; however, there was evidence that the human occupants were exploiting resources from riparian habitats, such as fish, turtles, and mussels (Watson, 1974). There was no evidence of cultivation of maize. These plant materials were supplemented by hunting for such species as whited-tailed deer, raccoon, turkey, and eastern cottontails (Duffield, 1974).

The remaining six localities in Kentucky were Fort Ancient sites, which were clustered along and near the Ohio River in the northeastern part of the state (McCord, 1953; Henderson and Turnbow, 1987; Breitburg, 1992; Pollack and Henderson, 2000). The Bintz site was located in two places—one along the flood plain of the Ohio River and the second was nearby on the first terrace above the flood plain—not far from Ross in Campbell Co. (Y2). McCord (1953) attributed the site to the Madisonville Focus of the Fort Ancient culture, which would date to AD 1500 to AD 1650. McCord does not give counts of the animal and plant remains recovered from the site, but he does present a long list of species of vertebrate, invertebrates, and plants used by residents of this village. Among the plant remains recovered were maize and pignut hickory.

Breitburg (1992) reported remains of rice rats from four Fort Ancient sites along or near the Ohio River in northeastern Kentucky—Augusta, Fox Farm, Snag Creek, and Thompson (Henderson and Turnbow, 1987). The Fox Farm site was located about 10 km south of the Ohio River on one of its tributaries (Y5), the Thompson site was located on the south bank of the Ohio River across from the mouth of Scioto River (Y7), the Augusta site also was located on the south bank of the Ohio River (Y4), and the Snag Creek site was found along the creek of the same name about 0.4 km south of the Ohio River (Y3). Breitburg (1992) was one of the few authors that systematically recorded burned and unburned bone from all of these sites. The data for rice rats were as follows: Augusta, 22 individual bones found with 2 burned; Fox Farm, 66 bones, 2 burned; Snag Creek, 6 bones none burned; Thompson, 23 bones, 2 burned. This gives a total of 117 rice rat bones of which six, or about 5%, were burned.

The Bentley site was a 1.2-ha Late Fort Ancient village on the second floodplain terrace of the Ohio River, located across from the mouth of the Scioto River (Y6). The Late Fort Ancient archeological site were overlain by a well-known 18th-century Shawnee village, Lower Shawneetown, which was occupied from 1750 to 1758 (Henderson and Pollack, 1985). The excavations at this site uncovered a number of pits containing carbonized maize, indicating its extensive use in the diets of the inhabitants of the village (Henderson, 2008). Among the faunal remains listed by Tankersley and Lyle (2019) were white-tailed deer, opossum, beaver, woodchuck, raccoon, black bear, eastern cottontail, turkey, Passenger Pigeon, and a variety of mussels.

Henderson and Turnbow (1987) studied the subsistence patterns of the occupants of Fort Ancient villages in this part of Kentucky. In general outline, they followed a hunter-gatherer-gardener pattern, with the plant component resulting from collecting nuts and wild plants and plant cultivation. Such nuts as black walnuts, butternut, hazelnut, acorns, and hickory nuts were gathered but this activity appeared to have made only a minor contribution to the subsistence of these villages. Gathering of wild plants such as pawpaw, wild grape, bedstraw, smartweed, and pokeweed represented "an important secondary Fort Ancient food source." Cultivated plants including maize, squash, and beans appeared to be the major food source for Fort Ancient people, with an emphasis on maize. Goosefoot was the only "member of the starchy-oily seed complex of Eastern North America that was documented" in this study and this was only at Fox Farm. It was only found at one other Fort Ancient site, clearly indicating that these people had "abandoned the use of native North American cultigens almost wholesale" (Henderson and Turnbow1987:217).

### *Ohio*

The 21 locations from which Holocene rice rats were reported in Ohio were primarily associated with the Ohio River and four of its tributaries—from west to east: Great Miami, Little Miami, Scioto, and Hocking (Fig. 12). The number of sites in Ohio with Holocene rice rat remains is second only to 24 sites found in Illinois. Three sites in Ohio were associated with the Great Miami River (DuPont, State Line, and Incinerator), with one in the extreme southwestern Ohio, another a few kilometers up stream straddling the Indiana-Ohio state line, but the third was located about 110 km up the river. Two of the sites were associated with the Fort Ancient tradition, but the other was a Late Archaic village from an earlier period.

The DuPont site was an unstratified middle Late Archaic village (O1) situated along "a southwest-northeast-trending promontory overlooking the confluence of the Ohio and Great Miami Rivers" (Dalbey, 2007:51). The site had been partially destroyed by industrial expansion and road development (Starr, 1960; Dalbey, 2007) so the full extent of the village was not determined. Similar to other archaic sites, white-tailed deer and elk formed the primary protein sources, but there was more extensive use of aquatic resources, such fishes, mussels, migratory birds, beaver, and muskrat, than at other archaic sites in the region. This was possible because of the proximity of the broad flood plain, marshes, and backwater lakes formed by the confluence of the rivers (Vickery 2008; Tankersley and Lyle, 2019). No use of cultigens was detected at the site. A wide range of edible plants were use, with heavy reliance on nuts, such as black and white walnuts, hickory nuts, acorns, and hazelnut, whereas lesser amounts were taken of fleshy fruits, such as pawpaw, black cherry, wild plum, and sumac, and wild seeds, such as chenopods and wild beans (Dalbey, 2007; Vickery, 2008).

The State Line site straddles the Indiana-Ohio state line (O2), with the largest portion situated in the Ohio. The site sat on a terrace about 10 m above the flood plain of the Great Miami River appropriately 10 km above its confluence with the Ohio River (Starr, 1960; Vickery et al., 2000). There appeared to be some mixed archeology, but the primary site was a Middle Fort Ancient village. Before excavation the site had been extensively disturbed, but the investigators estimated that it covered 4 to 6 ha. There was no other site in the Great Miami Valley that matched the complexity and size of the State

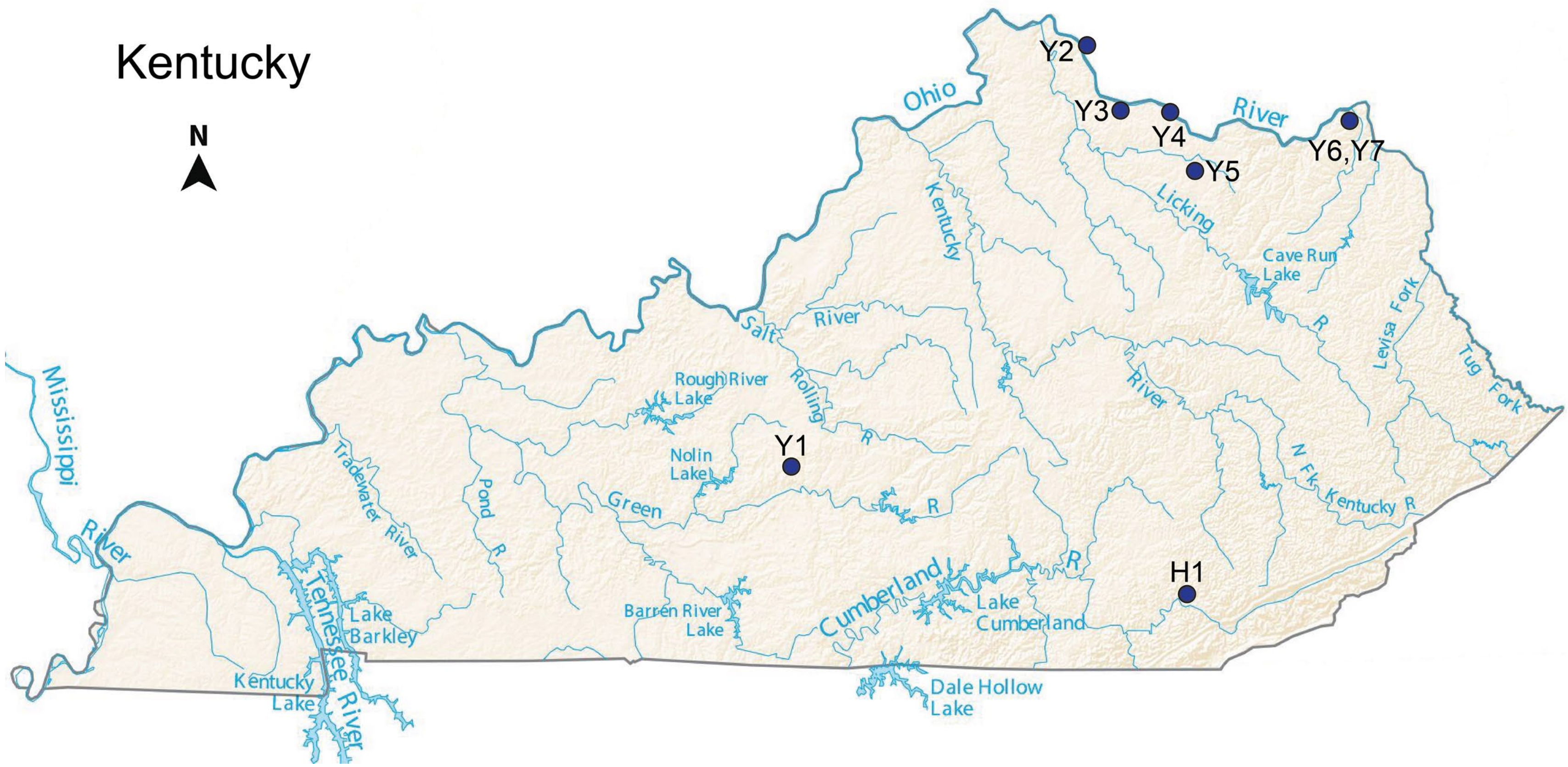


Fig. 11.—Map of the state of Kentucky, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: Y1 Salts Cave Vestibule; Y2 Bintz; Y3 Snag Creek; Y4 Augusta; Y5 Fox Farm; Y6 Bentley; Y7 Thompson. See Appendix 1 for additional information on localities. The "H" labeled locality is Barbourville as discussed in the text in the section on Early Modern Records from Unusual Locations.


Fig. 12.—Map of the state of Ohio, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: O1 DuPont; O2 State Line; O3 Incinerator; O4 Clough Creek; O5 Turpin (Late Woodland component); O6 Turpin (Fort Ancient component); O7 Madisonville; O8 Sand Ridge (2); O9 Sand Ridge (1); O10 Anderson Village; O11 Maple Creek; O12 Bullskin Creek; O13 Feurt Village; O14 Baum Village; O15 Blain Village; O16 Seip Earthworks; O17 Cramer; O18 McCune; O19 Gabriel; O20 Raven Rocks Rockshelter; O21 Gillie Rockshelter. See Appendix 1 for additional information on localities. The "H" labeled locality is Madisonville as discussed in the text in the section on Early Modern Records from Unusual Locations.

Line site, with an estimated 500 to 800 inhabitants (Vickery et al., 2000). White-tailed deer and elk accounted for about 80% of the faunal remains as was typical of Fort Ancient sites. Other important contributions to the diet of the village was provided by black bear, raccoon, Wild Turkey, Canada Goose, and several species of larger ducks. Freshwater invertebrates also were exploited, including a number of species of mussels, snails, and crayfish. Among the cultigens recovered was a large quantity of maize, as well as beans, squash, and sunflowers. Gathered plant material represented in the diet included purslane, butternut, black walnut, hickory nuts, and acorns (Vickery et al. 2000).

The Incinerator site was a Middle Fort Ancient village located on the floodplain of the Great Miami River (O3) in modern day Dayton, Montgomery Co., OH (Allman, 1968; DeAloia, 2004). The village was highly organized and stockaded, with storage and refuse pits preserving many of the artifacts and food related items. The village consisted of 20 to 30 structures arranged in a circular pattern with a central plaza. The population was estimated to be between 200 and 500 inhabitants (DeAloia, 2004). Based on faunal remains from the Incinerator site, Shane (1988) estimated inhabitants were deriving useable meat in the following percentages from animals in the area: white-tailed deer, 76%; elk, 10; Wild Turkey, 4; fish, 3; black bear, 1; raccoon, 1; fox and gray squirrels, 1. Red-horse, buffalo, and common sucker were the species of fishes most commonly taken. Shane (1988) identified 52 taxa of birds from the site, but Wild Turkey accounted for 71% of the bird bones, which probably included birds taken for food and those taken for feathers. Mammals were represented by at least 33 taxa in the faunal remains, being, as previously stated, dominated by white-tailed deer and elk. Shane (1988:163) remarked on the presence of rice rats, stating “rice rat (*Oryzomys palustris*), whose remains are abundant in the Incinerator site.” Maize was found in 93% of the features tested by Wagner (1988). The primary type of maize grown by the inhabitants of the Incinerator site was “Eastern Eight-Row,” a flint type, but higher row count maize was also found, which may have represented popcorn (Wagner, 1988:94). The domesticated bean and sunflowers were the other cultigens found at the site. Small seeds gathered for use included purslane, sumac, nightshade, and a chenopod (Wagner, 1988).

Of seven sites along the Little Miami River, six (Clough Creek; Madisonville; Sand Ridge 1, 2; Turpin 1, 2) were in eastern Cincinnati near the Ohio River, but the fifth site, Anderson Village (Goslin, 1951), was located about 60 km up the river near Fort Ancient in Warren Co. All of these sites represent the Fort Ancient culture or have a component of Fort Ancient.

At the Turpin site (O5, O6), Late Woodland cultural material was found including a single rice rat as well as two rice rats associated with the Fort Ancient material. The (Theler and Harris, 1988) site was characterized as a stratified site, including Late Woodland and Early to Middle Fort Ancient villages and an Early Fort Ancient burial mound (McCall, 2013). Late Woodland subsistence included hunting and gathering as well as gardening (Railey, 1996). The intensification of horticulture became the focus of Late Woodland period subsistence practices (Railey, 1996). The main game sources included white-tailed deer, raccoon, elk, Wild Turkey, and other forest mammals, although at Sand Ridge (O8, O9) there may have been a greater use of fishes, such as suckers, channel catfish, and freshwater drum (Breitburg, 1992; Railey, 1996; McCall, 2013). Between AD 1000 and AD 1650, Fort Ancient peoples, including those at the Turpin site and the other four sites along the lower Little Miami River valley, focused subsistence efforts on maize, squash, gourds, and beans, particularly to survive through the meager winter and spring months. A comparison of the plant remains from the Madisonville (O7) and Sand Ridge (Theler and Harris, 1988) sites showed great similarity in seed, nut, squash, and maize usage, except remains of beans were not found at Sand Ridge (Drooker, 1997). Maize was the single most important Fort Ancient agricultural product. Maize-based subsistence systems in the Ohio Valley abruptly appeared about AD 900. The rapidity of maize integration into the diet was one reason the archeological record of the Ohio River valley has been of particular interest (McCall, 2013). The Clough Creek site (O4) was only about 0.5 km from the Sand Ridge site along a creek of the same name just before its confluence with the Little Miami River. This site covered about 0.8 ha and like several other sites in the area it was built on top of an earlier Late Woodland settlement.

Langdon (1881:307) described his early discovery of rice rat subfossil material as being the result of "the recovery of two well-preserved crania from the 'ash-pits' in the Madisonville ancient cemetery." Madisonville (O7) was a protohistoric site so these rice rats may have been among the last to occur along the Ohio River valley (Drooker, 1997). The rice rat remains from the other Fort Ancient sites along the Little Miami River were equally low or the numbers were unreported. The species was certainly present throughout this area during this time period, but it does not seem to have been present in large numbers.

The Anderson Village site (O10) was located on the low floodplain on the eastern bank of the Little Miami River at its confluence with Randall Run in Warren Co. It was situated less than 1 km from the Fort Ancient archeological site, which is the type site for this tradition (Barber, 1978; Essenpreis, 1978). Essenpreis' (1978:161) evaluation of the site was it "covers a rectangular area of approximately 500 m × 100 m, it actually consists of a number of discrete occupations, with evidence for fairly rapid use-abandonment-reuse of the area." The plant and animal remains were limited in the areas that were excavated, but the resource use appeared to be typical of Fort Ancient sites.

Two sites in southern Ohio (Maple Creek and Bullskin Creek) were located near the mouths of two smaller streams at their confluence with the Ohio River. Both of these sites dated to the Late Archaic. The Maple Creek site was situated at the confluence of Maple Creek and the Ohio River in extreme southern Clermont Co. (O11). Vickery (2008) placed this village's occupation in the late Archaic and as being characteristic of several other villages in southern Ohio and adjacent areas during this period. Vickery (2008) recognized three horizons at this site with the rice rats associated with the Horizons 1 and 2. The first Horizon was a hard-packed living floor unique among Late Archaic sites, with five or six refuse pits and three earthen ovens originating in this horizon. Horizon 2 was a discontinuous layer of heat-cracked rocks probably resulting from aboveground cooking. Like other archaic sites white-tailed deer were the primary source of protein, but unlike other sites, elk remains were not found at Maple Creek. Among the faunal remains, riverine sources were not as well represented here as at other similar age sites, with only three species of mussels and turtles present, the freshwater drum was the only fish species, and Blue-wing Teal was the only waterfowl. The other proteins sources were more associated with forest and forest-edge habitats, with such species as opossum, porcupine, woodchuck, raccoon, fox and gray squirrels, eastern cottontail, and Wild Turkey. No cultigens were identified among the plant remains, but heavy use was made of nuts and fleshy fruits (Vickery, 2008; Tankersley and Lyle, 2019).

The Bullskin Creek site, which sat atop a terrace above Bullskin Creek, near its mouth on the Ohio River (O12), appeared to have been a base camp for nomadic groups during the Late Archaic period. The site covered about 2.25 ha containing burials, ovens, trash pits, and postmolds. Remains of dietary plant material heavily favored nuts, such as walnut, hickory nuts, acorns, and hazelnut, but also included fleshy fruits and wild beans. No evidence of cultigens was found (Vickery, 2008). Heavy use was made of large- and medium-sized mammals such as white-tailed deer, elk, beaver, opossum, muskrat, and fox and gray squirrels (Tankersley and Lyle, 2019). Wild Turkey and some waterfowl also were used and there was evidence of use of other aquatic resources, including several species of fishes, but not nearly as extensive use of mussels as at other sites. Vickery (2008) pointed out the significant number of raptor species represented in the faunal remains at this site, but he suspected that they had been taken for ceremonial purposes rather than as food.

There were five archeological sites associated with the Scioto River in Ohio where remains of rice rat have been reported. The river runs north and south through central Ohio, with its mouth on the Ohio River at Portsmouth. Just on the south bank of the Ohio River at this point were two sites discussed above in South Portsmouth, KY—Bentley (15GP15) and Thompson (15GP27). The Feurt Village (O13), a Fort Ancient cultural site, was situated on the east side of the Scioto River about "5 miles north of Portsmouth" (Goslin, 1950; Guilday and Mayer-Oakes, 1952). The occurrence of rice rats was documented by: "Only a few bones of this animal were found, consisting of skulls, innominata and leg bones" (Goslin, 1950).

The other four sites (Baum Village, Blain Village, Cramer, and Seip Earthworks) were located about 100 km up the Scioto River in the vicinity of Chillicothe Ross Co., OH. The Seip Earthworks (O16) were considered to represent the Hopewell culture from the time period of 100 BC to AD 500. This would be an early record of rice rats in Ohio, but Lee (2009:77) warns that the identification of the rice rat "was not conclusive" and was based on one individual. This is the only rice rat known from any of the Ohio Hopewell sites. The specimen came from a large pit within Structure 7 that contained secondary deposition bones from an unknown primary source. The Seip mounds were used for a series of burials that contained copper and other material burial goods that resulted from long distance trade. Plant material from the site was very limited, but Wymer (2009) was able to identify seeds of goosefoot, erect knotweed, and little barley as well as rind from squash. Evidence of gathering was the presence of the nutshells of walnut, hazelnut, and thick-shelled hickories.

The remaining three sites in the vicinity of Chillicothe—Baum Village (O14), Blain Village (Parmalee and Shane, 1970; Prufer and Shane, 1970; Schambach, 1971) (O15), and Cramer (Goslin, 1951) (O17)—were occupied periodically during the Fort Ancient period of AD 1000 to AD 1400 (Guilday and Mayer-Oakes, 1952). These villages were based upon a food economy of gardening, raising maize, and hunting local game. Mills (1906:31) described the situation at the Baum Village where: "The rice field mouse is found in great numbers in the refuse pits, attracted there evidently by the grain and nuts stored for food."

Progressing eastward two sites (McCune, O18; Gabriel, O19) where rice rat remains have been recorded were located in the vicinity of Athens along the Hocking River. The villages were located at a little more than 50 km above the mouth of the Hocking River on the Ohio River. Both villages date from the late Fort Ancient culture in the Feurt Phase in which maize was heavily used (Murphy, 1989).

The final two sites in Ohio differ from all others in the state, being small, temporary, seasonal camps associated with rocky outcrops or overhangs, and not directly associate with any large rivers. Shane and Parmalee (1981:71) "hypothesized that the Raven Rocks site was a seasonal camp or hunting station to which a small group of hunters returned after the hunt in order to process deer and a limited number of other animals." They believed that the probability was that these activities at Ravens Rocks (O20) occurred in the fall or winter. Although a large amount of bone was recovered from site, Shane and Parmalee (1981) believed that many of the remains, including those of the single rice rat, were incidental to the human occupation. The bones of animals that they did associate with human activity included those of the white-tailed deer, beaver, raccoon, bobcat, woodchuck, elk, eastern cottontail, gray fox, red fox, and Virginia opossum. However, it was the white-tailed deer that dominated the diet of these Late Woodland inhabitants, providing approximately 63% of the useable meat.

The Gillie Rockshelter site was a Late Woodland temporary camp similar to Ravens Rocks, located in Summit Co. in northeastern Ohio (O21). There were some unique characteristics of the site, including being about a 0.5 mile [0.8 km] from a permanent creek down a steep slope. The site was located in a beech-maple forest, but the investigator noted that the area was rich in springs (Bernhardt, 1973). This would not be prime habitat for rice rats, but the water resources would have been important. Tinkers Creek was the stream nearby, which was a tributary of the Cuyahoga River, placing this site in the drainage basin of the Great Lakes and not the Ohio River. It is the only site included here that is outside the Mississippi River Basin, but it is not more than 5 km from that basin. The area excavated was approximately 900 square ft [83.5 square m] under an overhang that was 20 ft [6 m] to 30 ft [9 m] high. Shane (1973) identified at least 23 species of vertebrates among the animal remains at the site. White-tailed deer remains again were dominant, representing about 70% of the meat harvested. Fur-bearing species of mammals such as muskrat, beaver, bobcat, and raccoon were the other group that was emphasized. Shane (1973) believed that the remains of small mammals species, including the single rice rat, were intrusive to the site's human occupation. Based on the animal remains, Shane placed the occupation of the site during the summer months. The charred fragments of hickory nuts and walnut shelled were found in a trash pit, indicating that the shelter could have been used into the fall months.

### *West Virginia*

Six archeological sites in West Virginia have had reports of rice rats among the recovered animal remains (Fig. 13). Two of the sites (Buffalo Village and Mount Carbon) were located in association with the Kanawha River, with the sites being 35 and 135 km, respectively, from its mouth on the Ohio River. Buffalo Village (V1) was located on the floodplain of the river with relatively sedentary occupants engaged in farming and hunting. The economy revolved around farming maize and hunting of white-tailed deer. The site was occupied by a peripheral group of the Fort Ancient culture during the Late Prehistoric period (Guilday, 1971). Guilday (1971) compared measurements of subfossil rice rats from several sites to those of modern specimens finding that they did not significantly differ from each other in size. Although much further upstream, Mount Carbon Village (V2) was a Fort Ancient site that shared many characteristics with Buffalo Village. The site, which was occupied by a sedentary agricultural people, was situated on the bank of the river. Guilday and Tanner (1965:6) describe how: "The exceptional preservation of the rice rat skeletons as well as the presence of burrow systems associated with them in the pit areas is evidence that the rice rats were living in the Indian refuse pits."

The remaining four sites in West Virginia where rice rats subfossils were known occurred on or near the Ohio River in the Mid-Ohio Valley and Northern Panhandle of the state. In the Mid-Ohio Valley, the Miller site was a small circular-shaped village of the Fort Ancient tradition located on a high alluvial terrace above the Ohio River near its confluence with Turkey Run (V3). The shallow surface debris middens, lack of large storage pits, and scarcity of postmolds suggested to the investigator "that the site represents a year-round encampment of short duration" (Wilkins, 1981:17). Murphy (1981:28) concluded: "The absence of any trace of cultigens or nuts and seeds is ambiguous . . .," suggesting the site may have only been occupied seasonally. Compared to other Fort Ancient sites, the Miller site showed little diversity in faunal resource use, with white-tailed deer and elk proving a substantial portion of the protein diet. Raccoon and Wild Turkey contributed small amount of protein. The site did include abundant remains of as many as 21 species of freshwater mussels of the family Unionidae, which probably were available in the adjacent Ohio River. Only a single left femur of a rice rat was recovered from the site (Murphy, 1981).

A short distance further upstream the Neale's Landing site was located on Blennerhassett Island in the Ohio River between Parkersburg, West Virginia, and Belpre, Ohio (V4). The village was located on the lower end of the island, adjacent to the main channel. The proto-historic Fort Ancient settlement was relatively small, covering no more than 1 ha and was located on a 10-meter bluff, which offered defense on two sides (Hemmings, 1977). Individuals in this village received approximately 88% of the meat in their diets from white-tailed deer, black bear, and elk. These were supplemented by Wild Turkey and fishes, with those species with more than one individual represented in the faunal remains being freshwater drum, channel catfish, suckers, and buffalo. Tanner (1977:A16) commented on rice rats from this site stating: "At least 12 rice rats were documented at Neale's Landing, including one immature example, possibly a nestling. West Virginia records this small rodent as early as the Middle Woodland/Fairchance Mound fauna. The rice rat's long period of residency in the state was terminated by dispersal of sedentary agricultural villages . . ." Fragments of maize kernels and cobs, common beans, hickory nutshells, walnut shells, butternut shells, pawpaw seeds, and grape seeds were the identifiable plant remains from the site. Maize was by far the most important plant food used by the village. The maize was Northern Flint, which was primarily an eight-row count, but 20% were ten-row (Yarnell, 1977).

In the Northern Panhandle, Fairchance Mound (V5) was situated on Middle Grave Creek, which joined Grave Creek and then the Ohio River over a river distance of 2.5 km on the eastern edge of Moundsville, Marshall Co., West Virginia. Fairchance Mound was a unique site because it was the only Middle Woodland Hopewellian site on the upper Ohio River where rice rat subfossils have been discovered. The remains of at least seven individual were discovered (Guilday and Tanner, 1968:44). They believed that rice rats were occupying the same ecological niche that is filled today by introduced rats (*Rattus ratttus,* and *R. norvegicus*) by "living off stored foodstuff." The occupants of this site living about AD 500 were engaged in hunting, gathering, and probably gardening. Nuts, including black walnut, shagbark hickory, bitternut, pignut hickory, and shellbark hickory, as well as acorns and wild plums were among the wild food plants that were gathered. The presence of cultigens was questionable but the carbonized remains of either wild or semi-domesticated amaranth and a small sunflower were recorded (Cutler and Blake, 1984; Hemmings, 1984).

Further north in the panhandle, Speidel Farm (V6) was located on Short Creek, which flows northward into the Ohio River in about 9 km, not far from Oglebay Park, Ohio Co. The site dates from the Late Prehistoric period and was associated with the Fort Ancient culture. Concerning the bones from Speidel Farm, Guilday and Mayer-Oakes (1952:254) stated: "The bones showed no evidence of having been used by man. They are complete and unburned."

***Pennsylvania***

Pennsylvania is the final state in the Ohio River basin from which Holocene rice rats have been reported with the records being confined to the southwestern corner of the state (Fig. 14).

Probably the best known of these sites is the Meadowcroft Rockshelter in Washington Co. (P1). It sits on Cross Creek, which flows to the west for about 15 km into Boone Co., WV, where it meets the Ohio River. Meadowcroft Rockshelter was a stratified multicomponent site that may extend as far in the past as 17,000 BC. Only two right tibiae of rice rats were found. Guilday et al. (1980) postulated that this very low representation of rice rats was because the site was only occupied sporadically and probably not year-around. This site has been extensively radiocarbon dated, but the dates for Level IV (1100 BC to 250 BC) where the rice rats were found has a date that is much older than other sites in Pennsylvania and in fact, one needs to go as far west as Bullskin Creek and Maple Creek in southern Ohio to find older dates. The dating of material from Meadowcroft has been controversial and the issues involved have not been fully resolved (Adovasio et al., 1978, 1980, 1990; Guilday et al., 1980; Carlisle and Adovasio, 1984; Guilday and Parmalee, 1984).

Three sites in Pennsylvania with rice rat remains were located on the floodplain or bank of the Ohio River. The Ohioview (Alam, 1961; Mrozoski, 1966; Guilday, 1971; Guilday et al., 1980) and Shippingport (Mrozoski, 1966; Guilday et al., 1980) sites (P2, P3) were located on the north bank of the Ohio River in Beaver Co. north of Pittsburgh. The McKees Rocks (Crane and Griffin, 1972; Guilday et al., 1980) site (P4) was on the south bank of the river just below the confluence of the Allegheny and Monongahela rivers forming the Ohio River in Pittsburgh. All of these sites fall into the Monongahela Tradition of the Late Woodland period in Pennsylvania (AD 1000 to AD 1500).

The Monongahela Tradition, which was established throughout the upper Ohio River basin by AD 1000, was characterized by small, palisaded villages that increased in size over time. Maize-based agriculture increased in intensity (Hemmings, 1984), by Middle Monongahela reaching the levels where storage of maize was above ground and associated with individual dwelling while by Late Monongahela the amount of above ground storage had increased and appeared to be stored as community resource. Chemical analyses of skeletons from a large Late Monongahela village revealed that maize contributed 70% to 80% of their diets (King, 1999; Richardson et al., 2002). Gilmore (1946:231) studying faunal remains from three Monongahela sites concluded: "The deer was doubtless the staple meat-food of the Indians and certainly was very abundant." White-tailed deer of all ages and both sexes were represented in the faunal remains from these villages, indicating a year-round taking of this species. Secondary sources of protein in the Monongahela diet were elk, black bear, fox and gray squirrels, and Wild Turkey. In some villages, aquatic resources such as fishes and freshwater mussels received sporadic use (Guilday, 1955, 1961).

About 50 km upstream on Chartiers Creek, which empties into the Ohio River beside the McKees Rocks Mound, was located the Boyle (Nale, 1963) site (P5) along the southern edge of modern day Canonsburg in Washington Co. The site was located on a ridge, but with easy access to Chartiers Creek and other water sources. This village was contemporaneous with those along the main stem of the Ohio River.

The Allegheny and Monongahela rivers join in Pittsburgh to form the Ohio River and Holocene rice rat subfossils have been found at archeological sites along both of these river systems. Only a single site with subfossils rice rats has been found along the Allegheny River (Johnston), whereas six sites have been found in the Monongahela drainage. The Monongahela River and its principal tributary, the Youghiogheny River, both arise in the mountains of West Virginia, western Maryland, and southwestern Pennsylvania, flowing in parallel in a northward direction to a confluence in McKeesport, only a short distance before the confluence with the Allegheny River. Four sites were within the Monongahela


Fig. 13.—Map of the state of West Virginia, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: V1 Buffalo Village; V2 Mount Carbon; V3 Miller; V4 Neale's Landing; V5 Fairchance Mound; V6 Speidel Farm. See Appendix 1 for additional information on localities.

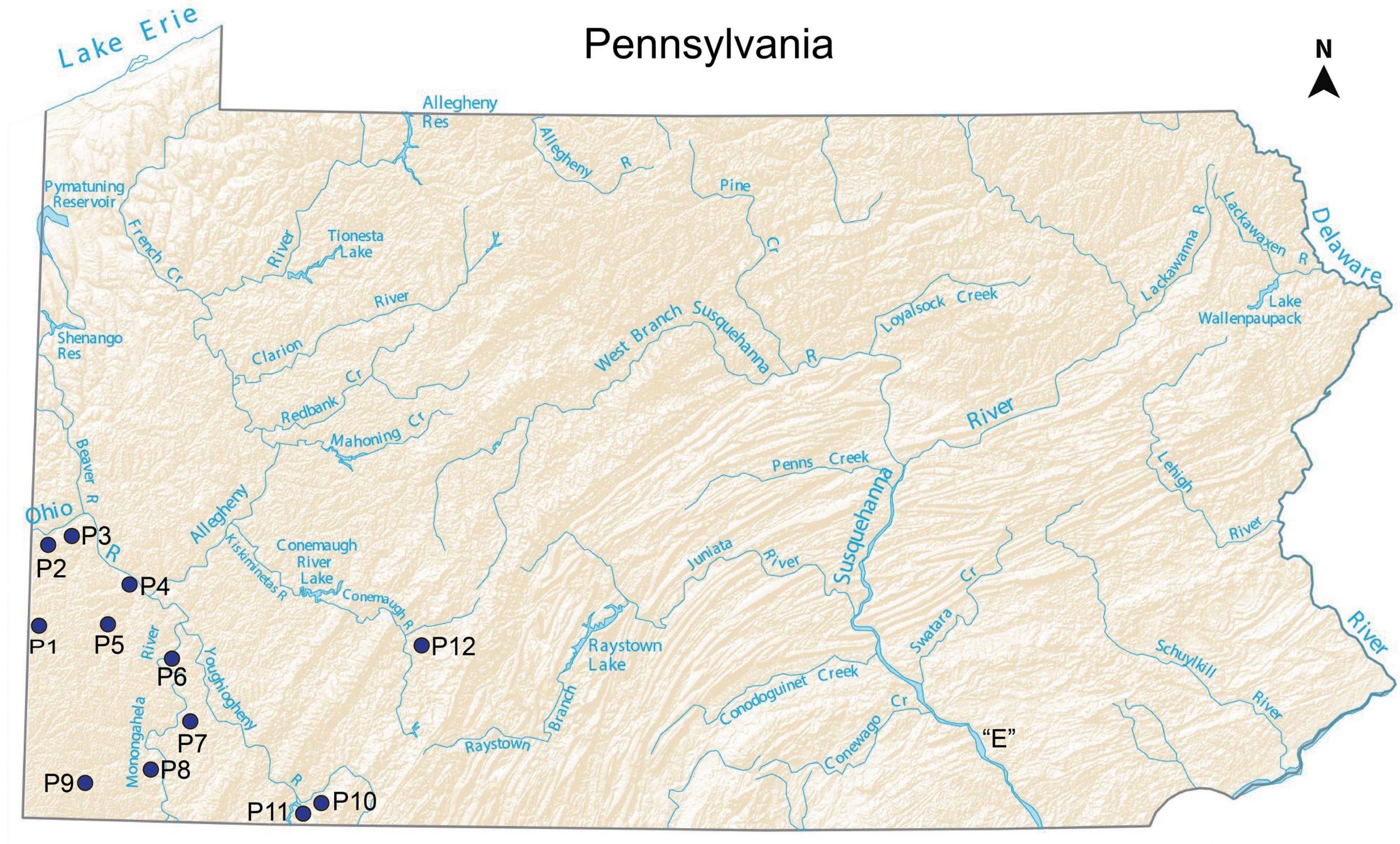


Fig. 14.—Map of the state of Pennsylvania, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: P1 Meadowcroft; P2 Shippingport; P3 Ohioview; P4 McKees Rocks; P5 Boyle; P6 Bunola; P7 Campbell Farm; P8 Hartley; P9 Varner; P10 Fort Hill; P11 Martin; P12 Johnston; "E" Eschelman. See Appendix 1 for additional information on localities.

drainage (Bunola, Campbell Farm, Hartley, and Varner) and two were in the Youghiogheny drainage (Fort Hill and Martin).

The Monongahela culture people occupied the four Monongahela basin sites at various times between AD 1000 and AD 1500. Their villages were located in a variety of places, such as the Bunola (Crane and Griffin, 1972; Guilday et al., 1980) site (P6) situated on the floodplain of a bend in the Monongahela River not distant from the confluence with the Youghiogheny. Two others sites—Campbell Farm (Crane and Griffin, 1972; Guilday et al., 1980) (P7) and Harley (Guilday et al., 1980; Zimmerman and Randolph, 1986) (P8)—were located along smaller tributaries a short distance from the main stem of the Monongahela—respectively, 5 km upstream on Redstone Creek and 6 km upstream on Muddy Run. The unique situation of the Varner site (Fig. 14, P9) was noted in some detail by Guilday (1961) who believed that it demonstrated a strong commensal relationship between native peoples and the rice rats. The village was located on a forested isolated hilltop several kilometers from the nearest stream, which was Whiteclay Creek a tributary of the Monongahela River.

Gilmore (1946) described the two villages located in the Youghiogheny drainage. The Fort Hill site (P10) was situated on top of an elevation rising to a height of 150 m, being circled on three sides by the Casselman River. The Casselman River joins the Youghiogheny in about 13 km, which then reaches its confluence with the Monongahela in approximately 112 km. Although the Fort Hill site was not as extreme as the Varner site, it was another demonstration that rice rats could be found at some distance from aquatic habitats. Both of these sites were of similar age and represent the Monongahela Tradition. The Martin site (P11) was located on floodplain along the west bank of the Youghiogheny River just north of the modern border with Maryland and approximately 127 km from its confluence with the Monongahela.

The only site in the Allegheny River basin from which rice rat remains were known was the Johnston (Guilday. 1955) site (P12), which was located on the Conemaugh River in Blairsville from where it flows about 75 km to the northwest to the enter the Allegheny River nearly 50 km upstream from its confluence to form the Ohio River. This was a very Late Prehistoric permanent village of the Monongahela culture.

Two sites listed by Vickery et al. (2016) in Pennsylvania (Guffey and Mingo Rock Shelter) were identified only by county (Allegheny and Beaver, respectively). I have been unable to find additional information on these sites so they are not plotted on Fig. 14. Rice rat remains are known from other sites within both of these counties. The last site to consider from Pennsylvania was Eschelman (“E”), even though it was from outside of the Mississippi River drainage basin. The site laid along the Susquehanna River not far from where it empties into the upper Chesapeake Bay. This large Susquehannock village was occupied during the early contact period around AD 1600 to AD 1625. There are no well-documented modern reports of the rice rats from Pennsylvania and only two sketchy reports from Delaware Co. (Genoways, 1985), but the species is abundant in southern New Jersey and Delaware. Under the current systematic arrangement of rice rats in the United States, the rice rats from the Eschelman site would be *Oryzomys palustris* and not *O. texensis* as in the Mississippi River drainage basin. Guilday et al. (1962) believed the Eschelman site demonstrated the close relationship been rice rats and the native people before full contact and the introduction of European rats.

***Missouri***

The final river basin in which Holocene *O. texensis* have been found is that of the Missouri River. There are only three sites known from the state of Missouri (Fig. 15). Two of these sites were combination archeological and paleontological sites—Graham Cave and Brynjulfson Cave

No. 2. Graham Cave (M1) had both an Archaic and Woodland component and the placement of the rice rat subfossils within this complex has not been published (Klippel, 1971; Parmalee and Oesch, 1972). The material from Brynjulfson Cave No. 2 (M2) was more precisely dated, falling in the period 510 BC to AD 560 representing the Boone Focus of the Late Woodland culture (Parmalee and Oesch, 1972). Both sites lie near tributaries of the Missouri River—Graham Cave was about 25 km away along the Loutre River and Brynjulfson Cave was about 10 km along Little Bonne Femme Creek. The circumstances under which rice rat subfossils were discovered in Graham Cave are sketchy (Parmalee and Oesch, 1972). There had been mixing of the layers from the Archaic and Woodland periods by domestic animals and burrowing rodents (Klippel, 1971). Parmalee and Oesch (1972) believed that even though these caves were archeological sites the presence of rice rats was unrelated to their use by native peoples. Their conclusion was based on the facts that the caves were used only sporadically, the use may have never been year-round, and there was no evidence of cultivation of food plants near the caves.

West of the Brynjulfson Cave No. 2 site, Middle Woodland villages were scattered along the Missouri River and into the Kansas River valley. Reid (1976) believed that these western sites were founded "by Illinois Valley Hopewell people migrating west along the Missouri River." These sites from the time period of AD 1 to AD 500 along the Missouri and Kansas rivers in the vicinity of Kansas City were termed the Kansas City Hopewell culture (E. Johnson, 1975; A. Johnson, 1976; Adair, 1977). Of a number of these sites (A. Johnson, 1976), rice rat subfossil remains have been reported from only two—Trowbridge in Kansas (E. Johnson, 1975) and Young in western Missouri (Adair, 1977). The Kansas City Hopewell complex villages appeared to center around the junction of the Kansas and Missouri rivers and extended northward along the Missouri to the Nebraska border and westward along the Kansas River to central Kansas (E. Johnson, 1975; A. Johnson, 1976). These people were hunter-gatherers who practiced horticulture with gardens in the flood plains of the smaller tributaries of the main river systems. Most plant foods were gathered and harvested in the late summer and fall and could be stored for later use. These food items were stored in earthen pits, which were repurposed into refuse pits. These two sites show evidence of the being part of the "Hopewell Interaction Sphere" in which finished tools and artifacts and unique raw materials were transported over long distances (Reid, 1976).

The third site in Missouri was the Young site (M3) in Platte Co. just north of Kansas City and the confluence of the Missouri and Kansas rivers. The site was located along Brush Creek within 1 km of its mouth on the Missouri River. The diet of these people consisted of wild animals, fish, and a variety of seeds and nuts. The Young site (Adair, 1977) presented a much broader use of plant foods than the nearby Trowbridge site based on the 29 earthen pits that were excavated, with 21 genera of plants among the recovered remains. Adair (1977) explained: "Many of the seeds of fruits represented at Young, including hickory, walnut, hazelnut, grape, blackberry, chokecherry, sunflower, raccoon grape, and amaranth, could easily be dried and stored for winter use." Also present were domesticates known from the east, including marshelder, knotweed, and goosefoot, but with a very limited use of maize or squash.

### *Kansas*

There were two archeological sites in Kansas where subfossils of rice rats were recovered (Fig. 16). The Trowbridge site (K1) was located near the head of Brenner Heights Creek in a suburb of present-day Kansas City, KS. Following the course of the creek, it was about 3.5 km to its mouth on the Kansas River. This Kansas City Hopewell site was occupied in the period of AD


Fig. 15.—Map of the state of Missouri, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: M1 Graham Cave; M2 Brynjulfson Cave No. 2; M3 Young. See Appendix 1 for additional information on localities.

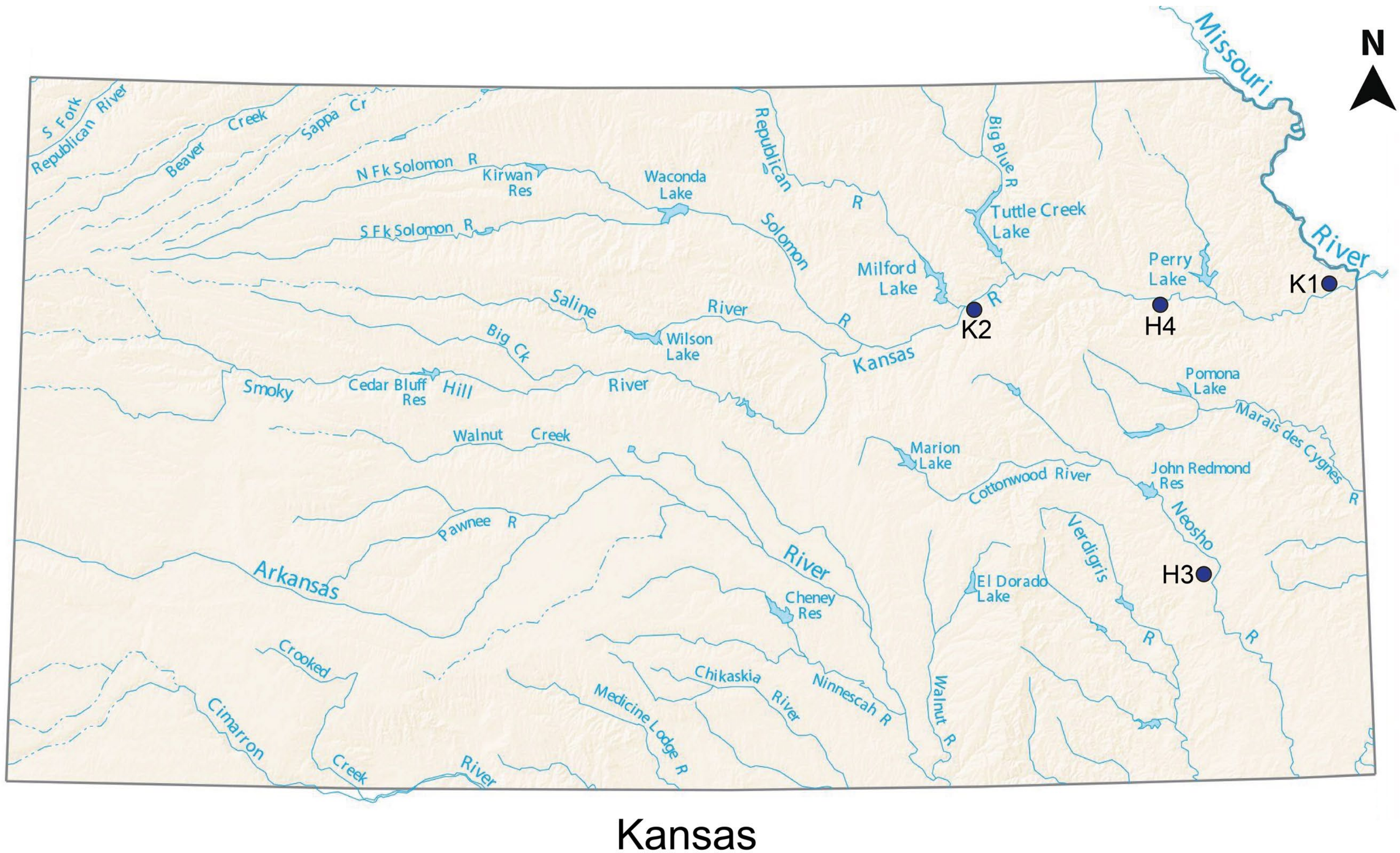


Fig. 16.—Map of the state of Kansas, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: K1 Trowbridge; K2 Witt. See Appendix 1 for additional information on localities. The two "H" labeled localities are H3 Neosho Falls and H4 Topeka as discussed in the text in the section on Early Modern Records from Unusual Locations.

25 to AD 500. Only a portion of a mandible from a rice rat was recovered here. A wide range of vertebrate and invertebrate animals was consumed by these peoples (E. Johnson, 1975). Not many plant remains (E. Johnson, 1975) were found at the Trowbridge site with only two cultigens being found—squash and marshelder. There was some evidence from earlier excavation that maize and bean may have been grown, but more recent work at the site has not supported these discoveries. Gathering efforts must have focused on nuts and acorns, although these items were rare in the site, with black walnut, hazelnut, hickory, and pecan also being represented. Also present were remains of amaranth as well as pawpaw, persimmon, and grape, which would not have been stored for winter use.

The Witt site (K2) was located in central Kansas on a ridge top overlooking the Smoky Hill River just east of Junction City, Geary Co. The site was approximately 2.5 straight-line km south of the confluence of the Smoky Hill and Republican rivers to form the Kansas River. A single earthlodge measuring 10 m by 10 m with internal cache pits comprised this site. Brown (1982) placed this site as a Smoky Hill variant of the Central Plains tradition, with occupation at some point between AD 1100 and AD 1400. The subsistence economy for people at this site was "divided about equally between maize horticulture and hunting" (Brown, 1982). Twenty bones of rice rats were found here representing a minimum of six individuals.

The Central Plains tradition referred to a cultural group that occupied areas of Nebraska, Kansas, and Iowa from AD 1000 to AD 1800. This group was characterized by having small permanent villages usually consisting of earthlodges. These earthlodges were large and sunken about 30 cm below the ground surface, with posts and a framework that was covered in earth and stucco. The lodges normally were placed on primary terraces of the river systems. These areas provided futile agricultural lands for their primary crop of maize, with squash and beans. These foods were supplemented with hunting a variety of game, including American bison and gathering of native seeds, berries, nuts, and roots (Peregrine, 2001).

### *Iowa*

Iowa archeological sites with remains of rice rats are concentrated in two counties—Crawford and Mills (Fig. 17). The Mill Co. sites (W1) were a series of earthlodges located on the top and western slopes of the loess hills overlooking the Missouri River from the east. From approximately AD 900 to AD 1250, these lodges were occupied by people of the Glenwood Focus of the Nebraska Culture associated with the Central Plains Tradition (P. Johnson, 1972; Bardwell, 1981; Croft and Semken, 1994; Pugh, 2009). There were an estimated 240 known earthlodges in Mills Co. and probably two to four times as many in total. Game taken was fairly diverse, including American bison, elk, white-tailed/mule deer, beaver, and eastern cottontail. Bardwell (1981) and P. Johnson (1972) studied a group of 14 earthlodges along Pony and Keg creeks where rice rat subfossils were found in each lodge, with a minimum of 128 individuals being identified (13ML121, 124, 126, 128-33, 135-6, 138-9, 155). Croft and Semken (1994) examined the isolated Wall Ridge Earthlodge (13ML176) where the remains of a minimum of 41 rice rats were identified (W2). These remains were retrieved from the overburden, house fill, and refuse pit fill, indicating to the authors that rice rats lived contemporaneously with the native people. These lodges were built by a semi-sedentary farming people who raised such cultigens as maize, beans, squash, gourds, sunflowers, goosefoot, knotweed, and marshelder (P. Johnson, 1972; Perry, 1996).

Remains from the M.A.D. 1 and 2 sites (W3, W4) in Crawford Co. were the oldest from the mid-Missouri River region and were two of only three sites north of the mouth of the Platte River along the Missouri (Pyle, 1981). This mixed cultural site was located along the Boyer River about 80 km from its mouth on the Missouri River. An alternative route to these sites could have been via the main stem of the Mississippi River then northwest along the Des Moines River and then along the Raccoon River to a point that was only about 80 km overland east of the M.A.D. sites. Rice rat remains were recovered from the Valley Variant of the Middle Woodland culture with a date falling in the period of 50 BC to AD 300 and in the Boyer Variant of the early Late Woodland cultural period of AD 300 to AD 900 (Benn, 1981a). There was evidence of gardening at the site with the remains of sunflower, goosefoot, squash, and gourds being recovered, but no maize or beans were found. Residents of the site also engaged in gathering as indicated by the presence of black walnut and acorn remains in the excavated refuse and storage pits (Benn, 1981b).

### *Nebraska*

The final state from which *O. texensis* subfossils are currently known is Nebraska where 10 archeological sites have been identified (Fig. 18). All of these sites pertain to the Central Plains Tradition and date to post AD 1000. These sites lie in four major drainage basins—Missouri, Platte, Big Blue, and Republican rivers. The two Rulo Southeast sites (N1, N2) were located on the bluffs west of the Missouri River just north of where the Big Nemaha River joins the Missouri in extreme southeastern Nebraska (Nelson, 2006). These sites fill the geographic gap between the Young site in Missouri and the Glenwood sites in western Iowa. The time period of the occupation of these Rulo Southeast sites also matches that of the latter two sites. A minimum of 12 rice rats were represented in the remains from pits in two house structures. Proceeding northward along the river, the Parker site (N3) was located on the bluffs at the western edge of the Missouri River floodplain (Ewing, 2000). It was the only site with rice rat remains located along the main stem of the Missouri River north of the Glenwood sites in western Iowa and was about 60 km north of the mouth of the Platte River.

Although four sites were located in the Platte River drainage, only the Patterson site (N4) was near the main stem of the river, being located along a small tributary. Bozell and Ludwickson (1999) reported more than 20 species of mammals from the site including a minimum of two individuals of Texas rice rat. The site was composed of four known earthlodges associated with extensive agriculture, with an emphasis on maize along with beans and squash. Some cultigens such as goosefoot, sunflower, and marshelder were also available and nuts and fruits were gathered. There also was an emphasis on hunting with remains of mollusks, fishes, turtles, and birds, as well as mammals being represented at the site.

The remaining three sites are located in the drainage of the Loup River, which enters the Platte River near Columbus, Platte Co. The Beaver Creek site (Koch and Nelson, 2002) was located along Beaver Creek about 65 km north of its mouth on the Loup River near Genoa in Nance Co. (N5). A minimum of 11 individuals of rice rats was recovered primarily from storage/refuse pits. This site is the northern-most locality from which rice rats remains have been recorded. The subsistence for occupants was based on the use of wild plants and agricultural crops, with an emphasis on maize. Hunting included taking of large mammals such as bison, pronghorn, and deer (Koch and Nelson, 2002).

The Cunningham site (Ludwickson, n.d.) was located near Fullerton in Nance Co. (N6) on a terrace of the main stem of the Loup River. Three rice rat subfossils were recovered from pits, but none from the houses that were excavated. Ludwickson (n.d.) was able to document only the use of maize and wild plum at this site. A wide range of mollusks and vertebrates were taken, including the large mammals, such as American bison,

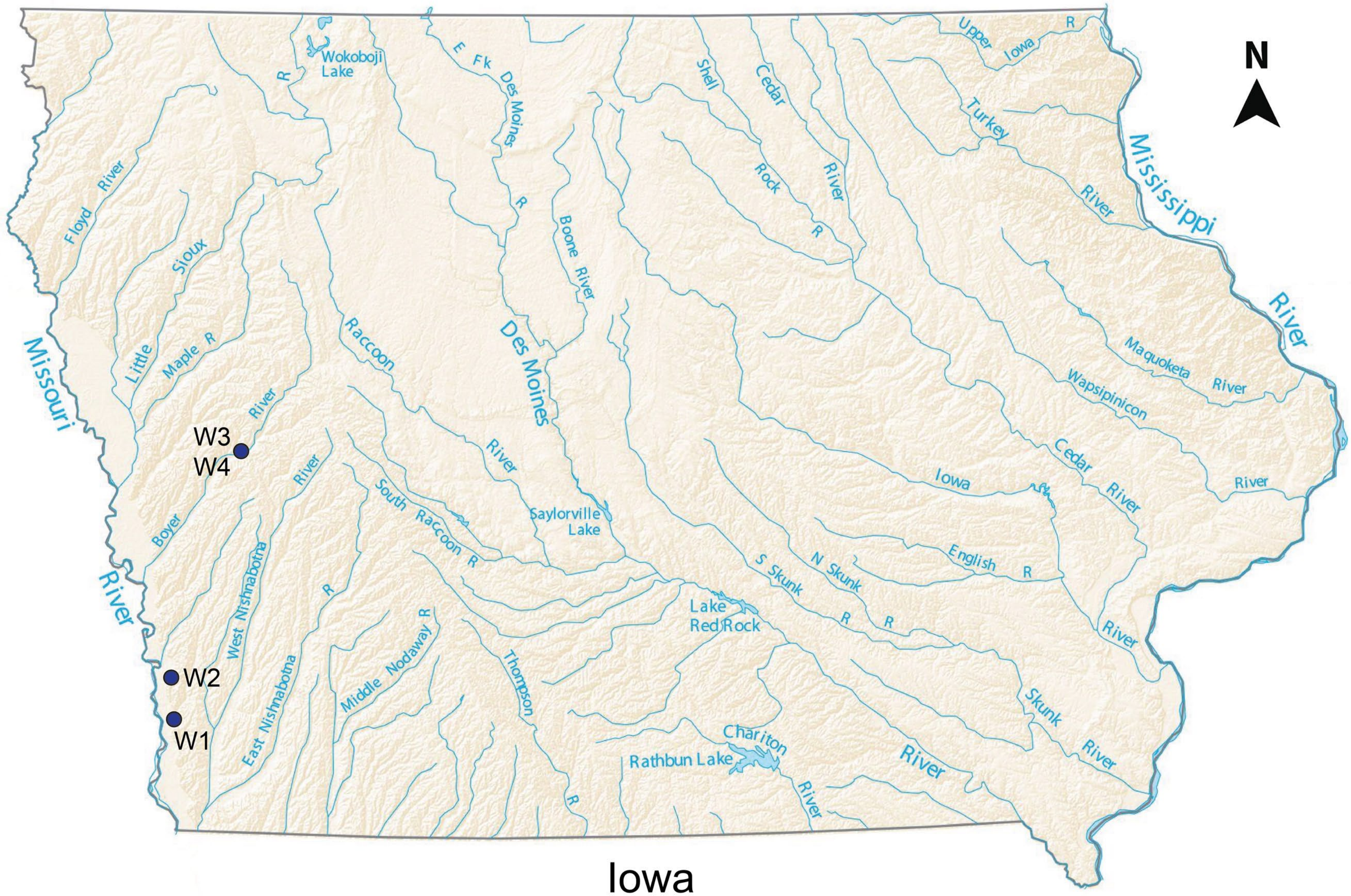


Fig. 17.—Map of the state of Iowa, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: W1 Glenwood; W2 Wall Ridge Earthlodge; W3 M.A.D. Valley variant; W4 M.A.D. Boyer variant. See Appendix 1 for additional information on localities.

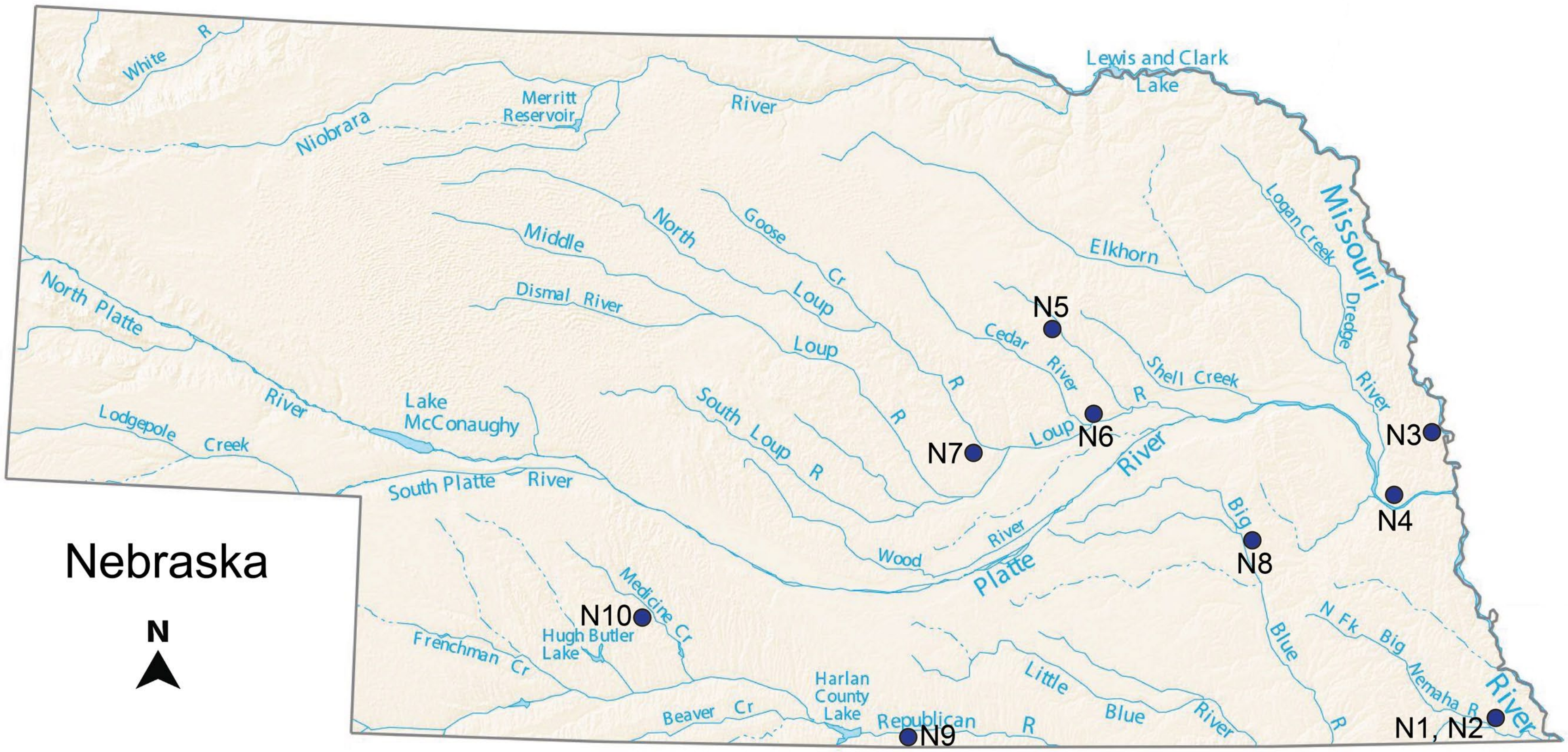


Fig. 18.—Map of the state of Nebraska, with major river systems indicated, showing the archeological and paleontological sites where the remains of the Texas rice rat (*Oryzomys texensis*) have been recovered. The site numbers match those in Appendix 1 as follows: N1 Rulo Southeast (H70) ; N2 Rulo Southeast (H69); N3 Parker; N4 Patterson; N5 Beaver Creek; N6 Cunningham; N7 Schmidt; N8 Palmer Johnson; N9 Shipman; N10 25FT22. See Appendix 1 for additional information on localities.

pronghorn, white-tailed deer, and elk.

The Schmidt site (Satorius-Fox, 1982) in Howard Co. (N7) was located on a terrace of the North Loup River, about 15 km from it confluence with the main river. It was an interesting site in that it has the largest count of individual rice rats, 37, of any site in Nebraska and Satorius-Fox (1982) identified both juveniles (14) and adults (23) in the sample. This population of rice rats was clearly established and reproducing. Riverine and floodplain resources were used by the inhabitants of this Loup River site with seasonal hunting of American bison and deer and growing of maize and other garden plants.

The final three archeological sites in Nebraska were located in the drainage basin of the Kansas River, but they were on separate tributaries far from the main stem of the river in north-central Kansas. The Palmer Johnson site (Bozell and Koch, n.d.) was situated east of Ulysses in the drainage of the Big Blue River (N8), which is over 500 km from its confluence with the main stem of the Kansas River at Manhattan in Riley Co. On the other hand, the site is only 35 km south of the Platte River, but is not part of that drainage system. This is a good indication that rice rat populations west of Missouri River were not traveling strictly along watercourses. There were at least three individuals of rice rats here based on three right tibias as well as a cranium, two right maxillae, and one left mandible. The rice rat remains were recovered from pit structures within two house features. The subsistence pattern here was American bison procurement, agriculture/gardening, and a broad range of hunting and gathering (Sounders, 1994; Bozell and Koch, n.d.).

The final sites that need to be considered are Shipman in Webster Co. and 25FT22 in Frontier Co. Shipman site (N9) was located on the southern bank of the Republican River just west of Guide Rock and just north of the Kansas state line (Graham et al., 1987). The site was 145 km south of the nearest archeological site in Nebraska with rice rat subfossils. It shared many characteristics with the Witt site near Junction City, KS, and could be related to it. Along the Republican River to the Shipman site was about 320 km from its confluence with the Smoky Hill River near Junction City, but the straight-line distance was only 175 km. Whether or not the traveling Native Americans would have followed the course of the river or gone overland in the grassland area west of the dense forests of the East, would be useful to know. Certainly, the Republican River would have carried enough water to be only seasonally navigable, if at all. There were a number of other Smoky Hill culture archeological sites in Kansas between Witt and Shipman sites and no rice rats have been reported from them (O'Brien, 1984). However, about 150 km west near the Medicine Creek Dam in Frontier Co., Turnmire (1996) tentatively identified a single lower right first molar as that of a rice rat (N10). Medicine Creek is a tributary of Republican River so rice rats may have moved even further west along the river. The tooth was recovered from a pit in a house structure. Turnmire (1996) described the diet of residence of this house as having fish as a staple supplemented with horticulture.

### Early Modern Records from Unusual Locations

There are a few records of rice rats from the nineteenth and early twentieth century from unusual sites in the Mississippi River drainage basin. These records have been questioned or even discounted by researchers because the localities did not fit with the modern distribution of rice rats and renewed collecting at the sites failed to yield additional specimens. However, given the archeological and paleontological records that we have examined here, it seems appropriate to review these unusual records to determine if they provide any insights into the Holocene history of rice rats. All of these records have been published and discussed under the name *O. palustris*, but those discussed here are believed to relate to *O. texensis*.

The three specimens from Barbourville, Knox Co., KY, may fall into this category (Fig. 5, Fig. 11; H1). A. Brazier Howell took these specimens on 12-13 August 1908. These specimens are from an isolated area far from modern populations along the Tennessee and Cumberland rivers and no subsequent specimens have been captured in this area of Kentucky (Barbour and Davis, 1974). However, looking at archeological records from along the Cumberland River in north-central Tennessee (Moore et al., 2006; Clinton and Peres, 2011; O'Brien and Kuttruff, 2012) the Barbourville location does not appear to be so isolated. There are also modern records of rice rats along the Cumberland River in Stewart Co., TN, in the collections of the Sam Noble Oklahoma Museum of Natural History (Land Between the Lake National Recreation Area: SNOMNH 52409-11—Fig. 3, R9); Cross Creeks National Wildlife Refuge: SNOMNH 52402-03, 05-08—Fig. 3, R10). As discussed previously, there are records from near the mouth of the Cumberland River on the Ohio River in Kentucky. Clearly, the Cumberland River could have provided a wetlands corridor to allow rice rat populations to reach the Barbourville location in southeastern Kentucky. There was an alternative route for this population to have reached the Barbourville area along the Appalachian front from Tennessee where there are records from Polk Co. (SNOMNH 52356-57—Fig. 3, R11), Blount Co. (SNOMNH 53360-62—Fig. 3, R12), and Campbell Co. where the northern-most specimens are from near Caryville (SNOMNH 52363—Fig. 3, R13) and Highcliff (NMNH 157095—Fig. 3, R14).

The specimen of *O. texensis* from Madisonville, Hamilton Co., OH had an unusual origin as documented by Langdon (1881). Langdon (1881) reported that on 18 December 1876 he recovered the posterior half of a rice rat from the stomach of a Red-shouldered Hawk that he had just shot (Fig. 12, H2). He could find no other modern rice rats in the area, but he reported the skulls of two rice rats from an archeological site in the same area (Appendix 1). Brayton (1882:141) reported subsequently examining this specimen finding "the feet and tail agree, in the minutest details, with the full description given by Dr. Coues." Hine (1906, 1910; see also Enders, 1930) reviewed the history of the Madisonville specimen noting that there was growing archeological evidence that rice rats had occurred in Ohio in the past and pondered why the species had become extinct in the state. Madisonville, now a neighborhood in Cincinnati, lies in the drainage of the Little Miami River only about 8 km from its mouth on the Ohio River.

Elliot Coues (Coues and Allen, 1877; see also Knox, 1875) in his monographs of North American rodents listed three specimens of rice rats (NMNH 3701-02, 3327) from Neosho Falls, Woodson Co., KS, collected by B. F. Goss (Fig. 16, H3). One of these specimens (NMNH 3327) remains in the collections of the National Museum of Natural History where it was submitted as a mounted specimen that has been changed to a standard museum skin. Lantz (1904, 1905) included the rice rat on the list of Kansas mammals based on the Neosho Falls specimens, but then in 1906 Lantz (1906:216) questioned the validity of the record stating "whether there was an error as to the locality from which the Goss specimens came will probably never be known." However, a few years later Lantz (1916:242) retracted his concerns about the Goss specimens after the broader distribution of the species became clearer stating, "there is, therefore, no reason to doubt that it also ranges into Kansas." However, Cockrum (1952) in his monograph on the mammals of Kansas again raised a question about the authenticity of the specimens that Goss submitted from Neosho Fall. Cockrum (1952) does supply a useful piece of information—at least one of the specimens from Neosho Falls was captured in January 1859.

The strongest case for the validity of the record from Neosho Falls record may lie with the collector, Benjamin F. Goss (Cunningham, 1893; Nehrling, 1894). Goss was a resident of Waukesha Co., WI, until his departure in 1855 when he left to join his brother, Nathaniel S. Goss (Anonymous, 1891; Taylor, 1932), in several business interests ending ultimately in the area of Neosho Falls, KS, in 1857. The brothers purchased land, platted the city of Neosho Fall, and built several local business, as well as pursuing their mutual interest in natural history, particularly in birds. The brothers remained in Neosho Falls until the outbreak of the Civil War in which they both served. Following the war, B. F. Goss returned to Wisconsin to pursue business interests, and his brother returned to Kansas to do the same. They jointly continued to collect birds around the United States resulting in large collections with Benjamin donating his to the Milwaukee Public Museum and Nathaniel donating his to the state of Kansas after completing his monograph on the *History of the birds of Kansas*. The point of this narrative was to establish that B. F. Goss was an educated collector of natural history specimens and his time between 1857 and 1860 was spent in the Neosho Falls area when and where the rice rats were collected. Certainly, the modern records of rice rats from Arkansas and Oklahoma along the Neosho and Arkansas rivers would lend credibility to the records as well. Finally, although there were no archeological records of rice rats in this region of Kansas, the overall pattern of range expansion and contraction shown by the archeological data would certainly fit here.

In addition to mentioning the Neosho Falls material, Lantz (1905:335) stated that *Oryzomys* had been "Taken . . . at Topeka by Charles Popenoe" (Fig 16, H4). There is no further documentation of this Topeka record, but Charles Popenoe was a graduate from the Kansas State Agricultural College [= Kansas State University] in 1905, had a career with the Bureau of Entomology in the U. S. Department of Agriculture, and was said by his biographer J. S. Wade (1937:573) to possess "a broad knowledge of general natural history and related subjects . . ." Furthermore, the archeological record of rice rats at the Witt site just east of Junction City near the Kansas River (Brown, 1982; Logan, 1998) would support the idea that rice rat populations could have occurred downstream along the Kansas River as it flowed passed Topeka.

## Discussion

When the Laurentide Ice Sheet retreated to the north as the Pleistocene was ending, it opened areas previously occupied by ice allowing plants and animals to shift their geographic ranges to the north in individualistic patterns (Davis and Shaw, 2001). Mayewski et al. (2004) studying Holocene global climates concluded that their variability was under the control of multiple factors, but their impact on various sites did not occur at the same time or with the same intensity. Mean July temperatures increased in North America by 3 to 4°C between 12,000 to 8000 BC, but the increase slowed in the early Holocene (Viau et al., 2006). Changes in annual precipitation were most obvious in the west and the south of the northern Midwest where the precipitation decreased in the early Holocene and increased in the late Holocene (Bartlein et al., 1984). This climatic variability in the late Pleistocene and Holocene has impacted mammals and their geographic ranges leading to their modern distributions, which are still undergoing shifts as modern global climate changes continue (Benedict et al., 2000; Roehrs et al., 2021).

The mammalian faunal changes concomitant with the end of the Pleistocene and the retreat of the continental glacier in North America has been well studied. Much of the Pleistocene megafauna was becoming extinct and the survivors were shifting their geographic ranges. The

FAUNMAP Working Group (1996:1601) concluded that mammals during the late Quaternary responded to the changing environmental condition in a Gleasonian manner, that is, species reacted to climate change "in accordance with their individual tolerance limits, resulting in range shifts with varying rates, at different times, and in divergent directions." As the temperatures warmed at the end of the Pleistocene and into the Holocene, many mammals moved northward but not as a group but as individual species. Other species moved eastward and others westward, whereas some species remained in their exiting geographic ranges. Lyons et al. (2010; Lyons, 2003) found that the size of these geographic range shifts was related to the body size, lifespan, and the topography the species encountered. Larger-bodied and longer-living species tended to expand their geographic ranges more than those species that were small bodied, with short lifespans. By late in the Holocene, most mammalian species were occupying their modern geographic ranges.

Although the Holocene climatic changes were not as radical as those at the end of the Pleistocene, there were shifting climatic conditions, which resulted in the recognition of at least nine post-glacial episodes (Wendland, 1978; Bartlein et al., 1984; Graham et al., 1987; Bozell, 1995): *Pre-Boreal* (approximate time scale 8030 BC to 7300 BC)—in the east climate zones were moving to the north and in the Great Plains the grasslands were extending to the east as precipitation decreased and summer temperatures increased; *Boreal* (7300 BC to 6490 BC)—climate borders still moving north and eastward as modern biomes were becoming organized, with the Laurentide glacier in Great Lakes area; *Atlantic* (6470 BC to 3060 BC)—maximum aridity and temperatures for the Holocene, with the conifer-hardwood forests nearing modern positions and the ice sheet centered over Hudson Bay; *Sub-Boreal* (3060 BC to 760 BC)—Laurentide ice wasting and by 2000 BC the ecotones were in modern positions; *Sub-Atlantic* (760 BC to AD 320)—deteriorating climate north of 40° N and cooler than Sub-Boreal; *Scandic* (AD 320 to AD 740)—a warming and drying trend; *Neo-Atlantic* (AD 740 to AD 1250)—somewhat more moist in summer, approaching modern moisture scheme; *Pacific* (AD 1250 to AD 1600)—drying climate; *Neo-Boreal* (AD 1600 to AD 1850)—Little Ice Age, with cooler and moister climate.

These climatic episodes applied broadly across North America, but did vary in timing and impact depending on the location under consideration. One of the important regional vegetational changes of possible importance to the expansion of rice rat populations was the development of the Prairie Peninsula in Iowa and Illinois, which began between 6500 BC and 5900 BC (King, 1981). This time (Atlantic climate episode) corresponded to the final breakup of the Laurentide ice sheet and the development of the modern atmospheric circulation in North America, with a warmer and drier climate. This caused the replacement of the deciduous forests of Iowa and Illinois with prairie vegetation or a parkland with prairie interspersed with stands of trees. About 3000 BC, the southern margins of the peninsula experienced increased moisture and the return of forests, but central Illinois has remained prairie parkland.

Not surprisingly, there are a number of challenges in interpreting and understanding the changes in geographic distribution displayed by *Oryzomys texensis* in the Mississippi River drainage basin. One of the most complex issues to resolve is the impact the recent changes in the systematics of rice rats. Recognition of three species (*O. couesi*, *O. palustris*, and *O. texensis*) of rice rats in the United States raises questions as to which of these species were involved in this geographic range expansion (Benson and Gehlbach, 1979; Schmidt and Engstrom, 1994; Hanson et al., 2010; Indorf, 2010). The nexus of this expansion appeared to be the middle Mississippi River in the area between the mouths of the Ohio River and Missouri River. This seems to fit the model of expansion by a single species from this center. The appropriate species would be *O. texensis* with verified modern records from near Memphis, Shelby Co., TN, and Tupelo, Lee Co., MS, but this leaves an open question about the relationship and distribution of *O. texensis* and *O. palustris* in central and eastern Tennessee. The Memphis record in southwestern Tennessee and records from around Reelfoot Lake in northwestern Tennessee strongly indicate that at least the Mississippi River valley in this area was inhabited by *O. texensis*. There are old records (Goldman, 1918) indicating that *O. palustris* has populations occurring in the Ridge-and-Valley Province and the Appalachian Plateau to the west of the Blue Ridge Mountains of Tennessee, Mississippi, Alabama, and probably Georgia. The northern-most of these sites is Highcliff, Campbell Co., TN. This location is not far from Barbourville, KY, which brings into question the specific identity of the early modern specimens from this place. The archeological records from the vicinity of Nashville, Davidson Co., TN, could potentially pertain to *O. palustris*, but we may never know this precisely.

Data provided by archeological and paleontological research have some inherent challenges. In spite of the fact that a site can be placed in a chronological range, the precise time that the rice rats remains were deposited can't be determined. This makes it difficult to understand movement timing and patterns. The geography of the placement of capture sites (or specimen recovery) can't be planned or controlled so there are instances of clumping of sites and other sites appear to occur in isolated locations. Semken (1983) discussed a bias in the mammalian Holocene record toward archeological over paleontological reports. Because the Holocene mammalian fauna was basically modern in nature, paleontologists have tended to not prepare publications on these studies, whereas archeologists' work was concentrated in the Holocene and they have prepared numerous publications and reports on their studies. Finally, because it is impossible in science to prove a negative, the following discussion will be focused on where the rice rats were known to have occurred and will not try to conclude where the rice rats did not occur. Notwithstanding these limitations, I believe there is enough evidence to gain an understanding of the geographic range changes undertaken by populations of *Oryzomys texensis* during late Holocene. This late Holocene major range expansion and rapid collapse of this extended geographic range was unique among North American mammals.

Earlier researchers have noted and discussed this geographic range expansion and collapse by the Texas rice rat during the late Holocene. Most of these researchers were concerned with a single or a group of related sites so that their discussion was limited in scope. However, Bardwell (1981), Satorius-Fox (1982), Vickery et al. (2016), and Tankersley and Lyle (2019) have summarized many of these studies and compared their reasoning to explain this phenomenon. The explanations fall into two broad categories—climatically controlled or moved by Native Americans as a commensal pest and/or a potential dietary item.

Vickery et al. (2016:62) favored the former explanation using rice rats as climate proxy stating that the: " . . . hypothesis accounts for the rice rat's former distribution in terms of climates differing from those of the present day. We favor such a hypothesis and pursue the relationship between climatic variables and the rice rat's past and modern range . . . ." Semken (2016) raised some interesting issues about these ideas, such as precision of radiocarbon dating of sites, that population eruptions could not account for changes in the distribution of rice rats in Late Holocene, and the lack of rice rat subfossils occurring in Holocene non-cultural sites. Tankersley and Lyle (2019) found that the climate in the Ohio River valley was stable enough that a large suite of the same terrestrial vertebrates was procured throughout the Holocene, but they concluded that the presence of rice rats in this region from the Archaic through the Fort Ancient cultural period was more likely associated with the domestication of seed-bearing cultigens rather than climatic conditions.

Guilday et al. (1964) believed rice rat remains in archeological sites north of the present limit of the species were not likely to be the result of warmer temperatures during the climatic optimum. The subfossil records of rice rats that Guilday and his co-workers (Guilday and Mayer-Oakes, 1952; Guilday, 1955, 1961, 1971:18; Guilday and Tanner, 1965, 1968; Guilday and Parmalee, 1971) were studying in Pennsylvania and West Virginia were associated with the cultivation of prehistoric maize and all the records post-dated the climatic optimum. They believed that the rice rats were living as "common commensal pests" in the village sites eating stored food items.

P. Johnson (1972) working at Glenwood Culture sites in Mills Co., IA, took a different view of why the rice rats had moved northward, stating: "rice rats may have expanded northward into the prairie peninsula in response to the amelioration of the climate, which took place at the beginning of the Scandic climatic episode." He also made the point that many of the sites where rice rats had been recovered were from times prior to the extensive cultivation of maize.

Because native peoples have been a part of this rice rat story, it is important to have at least a basic understanding of the cultural traditions of the broad area of the North American midlands under consideration here. There is general agreement on the cultures involved, but the details of timing and sequences in various areas are still being settled. Yerkes (1988) gave a summary of prehistoric cultural development and some of the controversies involved in midwestern North America. The generally accepted cultural sequence was Paleo-Indian, Archaic hunter-gathers, Woodland period, and Mississippian period. Many of the cultures and their definition were based upon ceramic development and changes, with many authors placing them as successive developments, but Yerkes (1988; Kidder, 2006) believed that the transition from Late Archaic to Early Woodland occurred over a period of 3000 BC to 0 BC. Yerkes (1988) placed Middle Woodland from AD 0 to AD 500 and Late Woodland and Mississippian co-existing from AD 500 to AD 1600. Bozell (1995) working in Nebraska recognized the following sequence of cultural traditions: Middle Woodland, 100 BC to AD 500; Late Woodland, AD 500 to AD 1000; Central Plains, AD 1000 to AD 1500; Coalescent/Historic, AD 1500 to AD 1750. Later, Fortier et al. (2006) presented a revised chronology for the American Bottom based on calibrated radiocarbon sequences. The cultural traditions they (Fortier et al., 2006) document showed the cultural periods occurring in sequence with the following timing: Early Archaic, 8100 BC to 7000 BC; Middle Archaic, 7000 BC to 4000 BC; Late Archaic, 4000 BC to 900 BC; Early Woodland, 900 BC to 100 BC; Middle Woodland, 100 BC to AD 350; Late Woodland, AD 350 to AD 1050; Mississippian, AD 1050 to AD 1675; Historic, AD 1675.

Vickery et al. (2016) used a slightly different chronology—late Middle Woodland, AD 150 to AD 450; Late Woodland, AD 450 to AD 950; Early Mississippian, AD 1000 to AD 1400; Late Mississippian–Historic, AD 1500 to AD 1650—in their assessment of the rice rat range expansion. Tankersley and Lyle (2019) followed a different more detailed scheme in which the Holocene Climatic Optimum was characterized by global warming and increased moisture, which occurred 5000 BC to 2000 BC during the Archaic cultural period. This was followed during 500 BC to AD 1000 by global cooling and drying during the Woodland cultural period. The Ohio River valley underwent increased moisture and mean annual temperatures during AD 850 to AD 1400, which was known as the Medieval Warm Period, with a peak around AD 1250. This climatic regime spanned the Prehistoric Fort Ancient cultural period (AD 1000 to AD 1400). The Ohio River valley experienced another significant cooling and drying event known as the Little Ice Age between AD 1400 and AD 1850, with a peak between AD 1500 and AD 1600. This climatic downturn occurred during the Protohistoric to Historic Fort Ancient cultural period. With these evolving concepts of cultural traditions and chronology in mind, I have attempted in the following discussion to honor the original investigators interpretations of the cultures involved and place emphasis on the most recent chronology of sites.

Many of the earlier studies have treated the rice rat dispersal phenomenon as if it were a single event, for example, plotting the many localities with subfossils on a single map (Cleland, 1966; Bardwell, 1981; Satorius-Fox, 1982) or have treated the expansion as the result of a single factor such as climate (P. Johnson, 1972) or growing of maize (Guilday, 1955, 1961, 1971). As with many situations, this dispersal event was far more complicated than previously understood, involving all of the elements proposed in the earlier studies as well as several others. The movement of these rice rats out of the area of the central Mississippi River valley began as much as 10,000 years ago, but was primarily undertaken in the past 2500 years before beginning to collapse by AD 1500. Chronology is a primary factor in understanding this event. There are issues with chronology of archeological sites, including the improving technology of radiocarbon dating causing refinement of settlement dates (Fortier et al., 2006) and improving excavation controls allowing better dating of sites. Nevertheless, the dating associated with the archeological materials and the rice rat subfossils are precise enough, I believe, to allow an outline of progression of this dispersal event.

It is important to emphasize the habitat requirements of rice rats in riverine habitats. Water is the dominant feature of the required habitat, which can be in rivers, streams, lakes, ponds, and tidal zones and can be moving or stagnant. In the upper Mississippi River basin, these rats almost certainly were confined to marshes, sloughs, wetlands, swamps, backwaters, side channels, oxbow lakes, cattail ponds, and tributaries of the major rivers, and they could be expected to venture out on associated mudflats and grasslands. One of the preferred nesting sites for these animals was in vegetation above standing water. These are not animals to move into mature deciduous or coniferous forests, unless water was readily available. These habitats preferences placed the rice rats into the same areas generally used by Native American for their riverine village sites.

Six sites with rice rat subfossils were from a time period earlier (8000 BC to 1000 BC) than the remaining sites. The Modoc Rock Shelter, the oldest of these sites, was located along the Mississippi River in Randolph Co., IL, which is situated at the northern limit of the modern geographic range of the Texas rice rat (Fowler, 1959; Styles, 1981b). The second of these sites was Graham Cave located near the Missouri River in Montgomery Co., MO, which was about 160 km to the northwest of Modoc Rock Shelter. The single specimen dating to 7550 BC from Anderson Pit Cave, near Bloomington, IN, came from the drainage of the Ohio River, but was located approximately 135 km north of the river. The three remaining Archaic sites also were from the Ohio River drainage but were close to the main river in southwestern Ohio—DuPont, Maple Creek, and Bullskin Creek. The first three of these Archaic sites were generally paleontological in nature with some scattered archeological items associated with them. The last three and somewhat younger sites were definitely village sites with significant numbers of people and lengthy occupation.

These sites fall in the Middle Holocene during the Atlantic and Sub-Boreal climatic episodes—the former characterized by "both maximum aridity and maximum temperatures for the Holocene" (Graham et al., 1987:185), whereas the latter was a time of environmental conditions moving toward the modern conditions. Globally the time 5000 BC to 2000 BC during the Archaic cultural period was Holocene Climatic Optimum characterized by warming and increased moisture. Richards (1980) hypothesized that rice rats had extended their geographic range to the north to Anderson Pit Cave during a period with a mild-winter, moist climate, as indicated by the presence of the extinct giant armadillo, *Dasypus bellus*. This armadillo also was present at Brynjulfson Cave No. 2 in Missouri (Parmalee and Oesch, 1972), geographically close to Graham Cave but from a younger time period (510 BC). The association of these rice rats with any human activity at three sites was transitory at best, with the Archaic peoples only using the site occasionally. The Anderson Pit Cave population of rice rats appears to have been a dead end with no other populations in the state until AD 1020 and then they were confined along the Ohio River valley.

This initial expansion of Texas rice rats in the upper Mississippi River basin in the Archaic period has characteristics of a natural expansion caused by changing environmental conditions (Lyons, 2003; Trakhtenbrot et al., 2005; Lyons et al., 2010). The Mississippi River valley would be expected to be the source of these populations and one of the oldest sites is in southern Illinois near the river. To the east, sites appear along the Ohio River drainage in the contiguous states of Indiana and southwestern Ohio. Along the Missouri River to the west, the Graham Cave site is the nearest to proposed dispersal center along the Mississippi River. Populations were expanding in two directions and in both, it was areas near the presumed source that were being colonized. The regional impacts of the Holocene Climatic Optimum could have provided environmental changes instigating this movement.

The next locality in chronological sequence was Meadowcroft Rockshelter in Pennsylvania where rice rat remains were found in Level IV. Material from this level was considered to be from 1100 BC to 250 BC (Carlisle and Adovasio, 1984; Adovasio et al., 1990). There is no clear explanation other than human involvement for rice rats to be present at this site during this time period because the site was distant from the main body of the rice rat population in southwestern Ohio, with no intermediate sites. The rockshelter was located in a situation similar to those where rice rat remains have been found—along a small stream near a major river (Ohio)—but this record was at least 1000 years out of chronology. There has been controversy about the radiocarbon dates from this site (Adovasio et al., 1980; Haynes, 1980; Tankersley and Munson, 1992; Sturdevant, 1999; Goodyear, 2005), but it is still considered to be one of the oldest archeological sites in North America (Goebel et al., 2008). Another possibility is the rice rat remains could be intrusive from a more recent time by the burrowing of the rodents or from human activities; however, Falk and Semken (1998:309) in reviewing the taphonomy of rodents in archeological sites believed that rice rats were “a poor candidate as a recent intrusive.” For the time being, I believe that we accept there were rice rats at Meadowcroft Rockshelter, but when they were present must be reserved for future research.

Beginning around 500 BC, rice rat subfossil remains appeared in archeological sites beyond the core of the distribution during the Archaic period. This movement of rice rats appeared to continue until just before AD 500 when we find a break with only a few new sites with subfossil remains. In the drainage system of the Ohio River, there were two sites with dates in the range of 500 BC to 0 BC, which were Salt Cave Vestibule in Kentucky and the Seip Earthworks Complex in Ohio. These both were extensive sites but the evidence for rice rats was based on single individuals. Salt Cave was an Early Woodland site about 300 km upstream on the biodiverse Green River from its mouth on the Ohio River across from Evansville, IN. There were Archaic sites further upstream on the Ohio River so populations of rice rats could be expected at the mouth of the Green River. However, there were no other known village sites in the Green River drainage where rice rat subfossils have been found. The Seip Earthworks were located about 120 km east of the Archaic site Bullskin Creek along the Ohio River and then about 100 km north on the Scioto River to the vicinity of modern Chillicothe. As discussed previously, there are some questions about the provenience of this specimen, but clearly rice rats were present in more recent sites in the Chillicothe area, along the main stem of Scioto River, and at its mouth on the Ohio River.

In the Missouri River drainage, rice rats dating as early as 500 BC were found in Brynjulfson Cave No. 2 along with the remains of a large extinct Pleistocene armadillo. This site located along Little Bonne Femme Creek was only a short distance west from Graham Cave where rice rats from the Archaic period were recorded. Much further up the Missouri River basin, the M.A.D. 1 site in Crawford Co. in west-central Iowa may belong with this group, if the earliest date (50 BC) for this site is used. However, M.A.D. 1 was a long distance upstream from Brynjulfson Cave No. 2, which was the nearest site at a minimum distance of 750 km. Other sites in Iowa along the Missouri River were much younger, with the oldest date at AD 900 and those on the Nebraska side of the river date from AD 1000 and more recent.

Just prior to the beginning of the first millennium, the first sites with rice rat subfossils appeared along the Illinois River. The first of these was Macoupin in Jersey Co. near the mouth of the river on the Mississippi River. The second site was Smiling Dan in Scott Co. situated about one third of the way toward the northern limit reached by rice rats along the Illinois River.

In the second half of this time period (AD 0 to AD 500), five new village sites with rice rat subfossils were occupied along the Illinois River valley during the period of AD 200 to AD 450, including Apple Creek, Carlin, Guard, Newbridge, and Scovill. The Scovill site in Fulton Co. was the furthest north of these sites and near the northern limit of rice rats along this river valley. Approaching AD 500 rice rats appeared at Fairchance Mound on the upper Ohio River near Moundsville in West Virginia. This was a major movement upstream of at least 400 km along the Ohio River. Subfossils of at least seven individual rice rats were recovered at this site being "represented by a partial skeleton and isolated mandibles and limb bones. The perfect condition of these tiny elements left little doubt that rice rats were living and burrowing through the village debris" (Guilday and Tanner, 1968:44).

Beyond Brynjulfson Cave No. 2 upstream on the Missouri River and just onto the Kansas River was located the Trowbridge site and on the Missouri River northward toward Nebraska, the Young site was located on the bluffs to the east. These were the two Kansas City Hopewell sites from which rice rat subfossils have been reported. Native people occupied these sites essentially throughout this 500-year period from AD 1 to AD 500. Finally, far upstream on the Missouri and then on the Boyer River, the M.A.D. 2 site near Denison, IA, was occupied through this period, with the Young site being nearest occupied site at over 400 km downstream. Some of the movements made by rice rats during the 1000-year period (500 BC to AD 500) appeared to be long distance dispersal or jump dispersal where there was not a continuous population connecting all sites (Hengeveld, 1989; Armitage, 1993).

So what happened about 2500 years ago that allowed this population of rice rats to explosively expand and maintain a new geographic range? Yerkes (1988:312) placed 500 BC in a period of cultural transition from Late Archaic to Early Woodland traditions in midwestern North America. Cultural characteristics of this transition were the first use of ceramics, expanded use of riverine resources, beginning of domestication of regional plants, growth of "existing interregional exchange networks" (see for example, Jefferies, 1997), and a more permanent settlement pattern, with summer and winter encampments. Many of these changes would have created ideal situations for rice rats—concentration of activities along rivers, a new food resource, and a food resource at a semi-permanent location. Smith (1989, 2011; Smith and Yarnell, 2009:6561) has documented the history of the domestication of seed crops in eastern North America. By 1400 BC "at least four indigenous seed-bearing plants were brought under domestication," including pepo squash, sunflower, marshelder or sumpweed, and goosefoot. All four of these plants were pioneer "weed" species of the disturbed floodplain riverbanks. These species especially favored the sandy and exposed banks created annually by spring floods (Smith, 2011). This made these species under domestication pre-adapted to the habitats in which they were being formed into semipermanent gardens. In addition to these four domesticated native plants, there is evidence that Native Americans planted at least three other native species in their gardens, although these did not evince the characteristics of domestication: erect knotweed, little barley, and maygrass. Prentice (1986) included the bottle gourd among plants domesticated in eastern North America, but it was not raised as food but rather as an all-purpose container for food items. These "crop" plants were termed the "Cultural Complex" or the "Eastern Agricultural Complex" (see Smith and Yarnell, 2009:6561).

The planting of these seven species of "crops" in riverine gardens resulted in the initial appearance of "food-producing economies" about 500 BC in the mid-latitudes of eastern North America. These initial economies spread across a much larger region between 250 BC and AD 200 (Smith 1989, 2011). In addition to these plant materials, hickory and black walnuts as well as acorns were gathered and could be stored for as much as a year (Smith, 2011).

My hypothesis (also that of Tankersley and Lyle, 2019) is that the concordance of the beginning of horticulture (see Fritz, 1990, for terminology) in eastern North America at about 500 BC and the second pulse of outward migration of the Texas rice rat was not a coincidence but a key portion of the coming together of conditions that allowed this dispersal. Horticulture brought together in gardens several plant species that would be ideal food items for the rice rats as well as humans. This made a new, concentrated source of food available in a predictable place in an ideal habitat for the rice rats. As these "crops" were harvested and stored in pits in the ground in the villages along with other food items gathered from local forests, especially nuts, it made a source of food readily available to the rice rats throughout the winter no matter the climate conditions. With the human population becoming more sedentary with only one or two village sites being used, the "house" construction became more elaborate and more permanent creating places where the rice rats could find some refuge (Yerkes, 1988; Smith, 2011). At several sites, rice rats subfossils have been recovered from inside the remnants of houses and lodges. Although earlier researchers have proposed maize as the underlying factor for this expansion of the geographic range of rice rats, it appears not to have been a factor during this period. Maize may have reached eastern North America at approximately this time, but it did not become an important part of native agriculture until around AD 800 to AD 1000 (Ford, 1981; VanDerwarker et al., 2013).

P. Johnson (1972) and other earlier researchers attributed the geographic range expansion to climatic changes occurring in the Scandic episode. However, this range expansion started in the Sub-Atlantic climatic episode and extended into the beginning of the Scandic. The Sub-Atlantic was one of the cooler Holocene climatic episodes, with the Scandic representing a warming, but also a drying trend at the end of the period.

Kidder (2006:198, 216) characterized the climate change of the period of 1000 BC to 500 BC as "involving cooler summer temperatures and increased winter precipitation." Her research indicated that during this time period the Mississippi River basin was subjected to "massive floods" resulting in landscape changes, abandonment of part of the basin by native people, and cultural changes. These flood events occurred in much of the basin and were "of historically unprecedented size and duration."

The presumption has been that warmer temperatures, with perhaps moister conditions, would have been necessary for rice rats to move north of their modern geographic range, but the warmer conditions did not arrive until the beginning of the Scandic episode around AD 300 well after the expansion had started. The massive flooding leading up to 500 BC could have been beneficial to rice rat populations because they remodeled the floodplains increasing their size and creating new habitats with more marshes, sloughs, oxbow lakes, and backwaters, allowing rice rat populations to increase. Texas rice rats would have easily tolerated the restriction of flooding to the spring season beginning around 500 BC because the species is adapted to shifting its local distribution from lowlands to uplands. I believe it is difficult to determine if climate change was a trigger for the rice rat movement because the broad episodic climate descriptions are not fine grained enough to describe conditions in the restricted areas along the river courses where the rice rats were confined. One positive impact the climate had was that it allowed native horticulture to begin and develop.

There are some additional observations from this 1000-year period of geographic range expansion by Texas rice rats that should be kept in mind as we examine the next 1000 years (AD 500 to AD 1500) of this phenomenon. The expansion occurred in all three river basins—Illinois, Missouri, and Ohio—that were involved in this 2500-year dispersal event. None of the sites was at the end point of the expansion, but it was close in the Illinois River valley. In the Missouri and Ohio drainages, the rice rat populations do not appear in a regular progression upstream. Rice rats appeared to have jumped long distances along the river systems. The distances to Fairchance Mound and M.A.D. 1 and M.A.D. 2 seem too far for rice rats to have covered in normal geographic range dispersal in the time available. The highest number of individual rice rats recovered from any of these sites was seven from Fairchance Mound in West Virginia. Although there is no known direct relationship between population size and the number of subfossils recovered from a site, the numbers of rice rats does seem low with most sites having the species represented by single individuals.

The next 500-year period of AD 500 to AD 1000 appeared to be a transition time with major changes occurring in the diets of people and by extension the rice rats. Eleven new sites with subfossil remains of Texas rice rats have been identified during this time. In addition there were six sites that were first occupied prior to this 500-year period, but continued to be occupied into the AD 500 to AD 1000 period. Five of these sites (Apple Creek, Carlin, Guard, Macoupin, and Newbridge) were located in the lower Illinois River valley. Except for Macoupin, the other four sites were first occupied by AD 200 to AD 400, and were abandoned by AD 700 to AD 750. The remaining site that spans two time periods was the M.A.D. 2 site in west-central Iowa in the Missouri River drainage, which was occupied from AD 300 to AD 900. It is impossible to determine when or how long rice rats were present during occupancy of these villages. There was no evidence of change of human subsistence at any of these village sites. The Eastern Agricultural Complex dominated the diet, which was supplemented by hunting of local wildlife, fishing, and gathering of local plant resources with emphasis on nuts and acorns. There was no evidence of maize adding to the food economy of these villages.

Six of the new villages established during the 500-year period from AD 500 to AD 1000 were located along the main stem of the Mississippi River in western Illinois. The earliest of these was Meyer Cave located in Monroe Co., which was primarily a paleontological site, although a few native artifacts were also recovered (Parmalee, 1967a). This site along with Modoc Rock Shelter and Waterman site in Randolph Co. document that rice rats have occurred in this area near the northern edge of their modern geographic range almost continuously since at least 6500 BC.

The remaining five Illinois sites were associated with Cahokia and the American Bottom, but predate the boom of Cahokia (Benson et al., 2009). The Range site was the oldest of the villages, being occupied from AD 600 to AD 870. The residents were engaged in gardening-gathering-hunting, with emphasis on the crops of the Eastern Agricultural Complex, with no evidence of the growing of maize. Unfortunately, the Merrill Tract occupied from AD 850 to AD 950 has little plant subsistence data that I was able to find. I did not find any reports of maize being grown here. At the Powell Tract (AD 800 to AD 1150), Kane Village (AD 900 to AD 1100), and the Julien site (AD 960 to AD 1350) maize had been added to the crops that were being grown, indicating that these sites were in the emergent Mississippian tradition. As one looks ahead in time, it can be seen that maize became a primary part of diet of the residents of Cahokia and the surrounding areas.

Of the 10 archeological sites beyond the American Bottom occupied between AD 500 to AD 1000, eight were in the Ohio River valley and one each in the Illinois River and Missouri River valleys. Turpin in southwestern Ohio was a multicultural site with the Late Woodland settlement covering this entire 500-year period. Subsistence here was gardening-gathering-hunting with no evidence of maize agriculture until after AD 1000. Sand Ridge also located in southwestern Ohio directly followed the cultural and horticultural succession of the nearby Turpin site. The origins of the other six sites dated from later in the period starting around AD 900. All of these sites appear to have had maize-based subsistence diets with an increasing emphasis on maize and squash and later beans. Mound Bottom in Tennessee has been assigned to Mississippian culture. Blain Village in Ohio and Speidel Farm in West Virginia were considered to be Fort Ancient culture, whereas Boyle in Pennsylvania was assigned to be Monongahela Tradition of the Late Woodland period. Mound Bottom lay in the middle of the Cumberland River valley to the east of the modern distribution of rice rats in Tennessee. Two later sites, Gordontown and Rutherford-Kizer, with rice rat subfossils were located nearby. Blain Village was located along the Scioto River near Chillicothe, OH, in the same area as the earlier Seip Earthworks Complex that contained a rice rat subfossil. The two sites furthest up the Ohio River drainage system before AD 1000 were Speidel Farm in West Virginia and Boyle in Pennsylvania. The latter was at this time the furthest point upstream along the Ohio River that rice rat subfossils had been recorded. The village was located along a ridge overlooking the relatively small Chartiers Creek. Speidel Farm was also located along a small stream, but it was only a short distance from the main channel of the Ohio River.

I consider the final two sites from the Ohio drainage between AD 500 and AD 1000 to be the most unusual sites from which rice rats subfossils were reported in this study. Raven Rock and Gillie Rockshelter shared several characteristics: 1) distant from the Ohio River; 2) temporary or seasonal hunting sites; 3) relatively distant from stream or other the significant water sources; 4) relatively open rock shelters; 5) rice rats believed not to be associated with human activity at the site; 6) no evidence of agricultural activities at the sites; 7) rice rat presences at these sites may be result of raptor activity bringing remains to shelter. Although these sites do not elucidate the archeology/rice rat relationship, they may be evidence of free-ranging populations not associated with human activity.

The Emmon Cemetery along the Illinois River was not directly associated with a village but grave goods clearly associate the cemetery with the Mississippian culture. Finally, far west along the Missouri River in southwestern Iowa the Glenwood site was a series of earthlodges located on the top and western slopes of the loess hills east of the river. Occupants of these earthlodges were members of the Glenwood Focus of the Nebraska Culture associated with the Central Plains Tradition (P. Johnson, 1972; Bardwell, 1981; Croft and Semken, 1994). These were semi-sedentary farming people who raised such cultigens as maize, beans, squash, as well as some of the crops of the Eastern Agricultural Complex (P. Johnson, 1972; Perry, 1996).

My interpretation of the information for the period from AD 500 to AD 1000 was that the residents of the Mississippi River basin as typified by the American Bottom made a major shift in agriculture practices. At the beginning of the period, all were cultivating crops of the Eastern Agricultural Complex as well as gathering forest resources such a nuts, acorns, and fruit to supplement hunting of local wildlife. By AD 900, in all villages where rice rat subfossils have been recovered agriculture included the raising of maize. Progressing over the next 500 to 600 years, agriculture became dominated by the raising of maize, squash, and beans—the three sisters—and most of the Eastern Agricultural Complex crops were dropped or limited in the diet.

Cahokia, which became the largest urban settlement of the Mississippian culture, was only an ordinary village in AD 900. With the introduction of maize, the village underwent growth that reached a maximum in the period of AD 1050 to AD 1100. Benson et al. (2009:468; VanDerwarker et al., 2013) attributed this "boom" to one of the "wettest 50-year periods of the past millennium." During this time, farming in the Mississippi lowland had been reorganized and the Richland farming complex was developed on the uplands to the east of Cahokia where maize was raised. Benson et al. (2009) believed that this wet period was followed by 150 years of droughts causing the "bust" of the Cahokia area. By AD 1200 Cahokia had lost nearly 50% of its population and by AD 1350 the central Mississippi Valley had been nearly abandoned. It is tempting to attribute the spread of the Texas rice rats after AD 1000 to the collapse of Cahokia and the resulting emigration of its population. However, it must be remembered that maize and rice rats were already present at the Glenwood site in Iowa, the Turpin site in Ohio, and Boyle in Pennsylvania while Cahokia was experiencing its "boom." Tracing the emigration of the Cahokians has been difficult as their cultural traditions faded as they exited the area (Benson et al., 2009; Buchanan, 2020; Emerson et al., 2020).

It is clear in the data that over the next 500 to 600 years (AD 1000 to AD 1500-1600) rice rats in the Mississippi River drainage basin reached their zenith. Of the 106 sites listed in Appendix 1 (Eschelman excluded) where subfossil rice rats have been found, 64 (60.4%) were founded after AD 1000 and if the sites that were founded before AD 1000, but continued to exist after that date are added, the number is 77 or 72.6% of all sites. As stated previously, there is no direct correlation between rice rat population size and the number of individual subfossils recovered from a site; however, the 20 sites where remains of 10 or more individuals (MNI) were recovered all were in existence after AD 1000. In the Illinois, Ohio, and Missouri river basins, rice rat distribution reached furthest upstream during this time period. In the Illinois River valley this extension was not very far, being about 50 km to the northeast from the Emmons Cemetery to Kingston Lake southwest of Peoria. However, in the Ohio River valley rice rats advanced beyond the river's formation into three of its major tributaries.

Although the airline miles from Fairchance Mound in Moundsville, WV, to the terminal locations are not far, following the river courses certainly increases the distances. The furthest site from Moundsville appears to be the Martin site in Fayette Co. just north of the Maryland-Pennsylvania border along the Youghiogheny River, which is a distance of at least 310 km; along the Monongahela River the furthest site is Varner in Greene Co., PA, which is a distance of at least 290 km; and in the Allegheny River drainage the furthest place is the Johnston site, which was the along the Conemaugh River a distance of at least 280 km from Moundsville. In Nebraska where all sites date from after AD 1000, the Schmidt site on the North Loup River is about 280 km from the mouth of the Platte River on the Missouri River across from the Glenwood sites in Iowa. As indicated here, Glenwood and Fairchance may have acted as secondary centers of dispersal for these distant upstream villages; however, there may have been many secondary dispersal sites as the rice rats moved up the river systems from one village to the next. Almost certainly, the center for dispersal for these far sites was not the original center on the Mississippi River in Illinois.

One feature that all of the archeological sites founded after AD 1000 had in common was maize agriculture. It is hard to dispute the idea that having maize available as a food source and all of the cultural changes that occurred in the human population along with maize agriculture benefitted the rice rats. John Guilday and his coworkers (Guilday, 1955, 1961, 1964, 1971; Guilday and Tanner, 1965, 1968; Guilday and Mayer-Oakes, 1971; Guilday and Parmalee, 1971) long contended that the expansion of rice rat populations beyond their modern geographic range was associated with the cultivation of prehistoric maize. In a sense, they were correct for the archeological sites that they studied in West Virginia and Pennsylvania where rice rats did not arrive until after the introduction maize into area, with the exception of Fairchance Mound near Moundsville, WV. This Middle Woodland Hopewellian site from around AD 500 demonstrates the sequence outlined here with rice rats' first range geographic expansion being a response to the development of a gardening culture based on the crops of the Eastern Agricultural Complex, but the final burst of expansion was in response to development of a culture based on maize agriculture.

An additional consideration is whether or not there was any environmental enhancement to post-AD 1000 expansion of the geographic range of Texas rice rats. Guilday et al. (1964) downplayed the impact of the environment during this time because it post-dated the climatic optimum of the Holocene. Two or three of the Holocene climatic episodes would be involved during this time, including the Neo-Atlantic (AD 740 to AD 1250), Pacific (AD 1250 to AD 1600), and possibly the Neo-Boreal (AD 1600 to AD 1850), although this period may have been too late. The last half of the Neo-Atlantic episode would have been characterized by somewhat moister summers, which approached the modern moisture scheme. This was also the time period of the Medieval Warm Period (AD 900 to AD 1300) when at least some parts of the northern hemisphere were 1° to 2° C warmer than present (Richardson et al., 2002). As discussed previously, the "boom" at Cahokia resulted from 50 of the wettest years (AD 1050 to AD 1100) in the second millennium (Benson et al., 2009), which must have been favorable for the rice rats. This was followed by a 150-year series of repeating droughts as the drying climate of the Pacific episode took hold. These alternating moist and dry periods almost certainly impacted other portions of the geographic range of rice rats beyond the American Bottom.

The expansion of the geographic range of Texas rice rats appeared to have collapsed between AD 1400 to AD 1600, but it did not occur simultaneously throughout the geographic range. I believe that this was a collapse of populations in place with many local extinction events and not an orderly range contraction. This collapse may have continued as late as Neo-Boreal (AD 1600 to AD 1850) episode. The occurrence of this collapse was in the time frame of the major climatic event of the second millennium—Little Ice Age. The Little Ice Age has been a controversial topic in the scientific literature (Cobb and Butler, 2002; Matthews and Briffa, 2005; Pompeani et al., 2021), with questions about its reality, exact timing, duration, decline in temperatures, and changes in precipitation. Much of the research on the Little Ice Age has been conducted on changes in alpine glaciation in Europe where the event seems to be better documented than in North America (Matthews and Briffa, 2005). The standard interpretation from the northern hemisphere-wide studies was that the climate was cooler and moister during the Little Ice Age. However, there is a growing body of research indicating that there was regional heterogeneity during the Little Ice Age leading Matthews and Briffa (2005:21) to comment: "the temperature trend in one region of the hemisphere may be the opposite of that in another region."

Fortunately, there are a number of recent studies of the conditions during the Little Ice Age in the Mississippi River basin and some adjacent areas that are useful in understanding its impact on the native peoples and by extension on the rice rat populations occurring here. The "boom" and "bust" of Cahokia and the American Bottom between AD 1050 and AD 1250 has been documented as resulting from a major period of precipitation followed by drought that drove down the human population of the region (Benson et al., 2009; Pompeani et al., 2021). To the south of the American Bottom and at a somewhat later date, Cobb and Butler (2002; Buchanan, 2020) presented evidence concerning the development of the "Vacant Quarter," which was a designation for the area from the confluence of Ohio and Mississippi rivers to the lower Ohio River valley possibly as far as the Angel site in eastern Indiana where rice rat subfossils were documented. This area of southern Illinois and Indiana was abandoned by Mississipian culture people between AD 1450 and AD 1550 (Monaghan and Peebles, 2010; Buchanan, 2020). Cobb and Butler (2002:637) potentially connected this movement of people to the conditions of the Little Ice Age, such as "shortfalls in precipitation and severe climatic oscillation," but they believed that more research was needed in the lower Ohio Valley to be certain of the connection. Dendrochronological studies by Stahle et al. (1985) using bald cypress trees in the Mississippi lowland of Arkansas identified 10 drought periods of 10 years or more between the years of AD 1531 to AD 1980. Some of the earliest drought periods occurred around years AD 1555, AD 1570, AD 1595, and AD 1670, with the most severe drought period of the 450-year period being from AD 1549 to AD 1577. Another characteristic of this climate reconstruction was severe oscillations in precipitation throughout the period studied.

In the central Ohio River valley of Ohio, Kentucky, and West Virginia, Warren (2014) commenting on the Fort Ancient people stated: "After 1400, the Little Ice Age made the Ohio Valley colder and wetter than it had been for hundreds of years. Corn remained the foundation of Fort Ancient diets. But climate change meant that farming became increasingly hazardous . . . ." Warren (2014) stated that the diet of Fort Ancient people was composed of 68% maize, with each person requiring nine bushels of maize per year and "with the Little Ice Age, Fort Ancient farmers turned to Eastern Eight Row corn. An early maturing corn, Eastern Eight Row lessened the anxiety that came with relying on agriculture in northern climates prone to early frost." Certainly, the cooling weather would not have favored the rice rat populations in this area. Also as the climatic conditions deteriorated, the Fort Ancient people took up a more nomadic lifestyle moving between summer and winter camps, forming larger villages while abandoning others, palisading villages, and moving villages from riverine situations into the uplands for better defense. This would have reduced the reliability of food resources and loss of protected wintering sites in the villages, which would have again caused stress to the rice rat populations of the central Ohio River valley.

Richardson et al. (2002) presented evidence and causes for the disappearance of the Monongahela culture of the upper Ohio Valley by AD 1635. The production of maize intensified throughout the history of the Monongahela, but by the beginning of the Little Ice Age (AD 1400) maize agriculture was already under stress before the climate began deteriorating. Richardson et al. (2002:85) believed that the decrease of temperature of 1° to 2° C with the Little Ice Age forced the Monongahela population southward into "the lower Monongahela and Youghiogheny valleys in southwestern Pennsylvania," because the severe cold caused a problem in maize production, which needs at least a 140-day frost-free growing season. Based on dendrochrological studies of trees in West Virginia, Richardson et al. (2002) concluded that major droughts first identified by research in Virginia and North Carolina (Stahle et al., 1988, 1998) had extended inland as far as the land of the Monongahela. The Lost Colony drought of AD 1587 to AD 1589 was believed to have caused further migration of the Monongahela in southwestern Pennsylvania and with the Jamestown drought of AD 1607 to AD 1612 and increasing warfare with Iroquois, the Monongahela were driven into exile probably in several directions. The coming of the Little Ice Age certainly set in motion a perfect storm for the rice rat populations in the upper Ohio River valley, with falling temperatures and droughts making food scarce and driving their human hosts into a more nomadic lifestyles and finally to depopulate the area. None of the rice rat populations appear to have traveled to areas outside of western Pennsylvania and West Virginia as the Monongahela dispersed away from the area.

Bamforth (1990) summarized the available research on the impact of the Little Ice Age on the Great Plains where there were rice rat populations in Nebraska, Kansas, and western Iowa. He found that tree-ring data supported the conclusion that winter temperatures were colder than today between AD 1602 to AD 1900, but there was no evidence that the summers were cooler. Bamforth (1990) could not find good evidence that the annual precipitation increased on the Great Plains during the Little Ice Age. Documentation was available to conclude that the year-to-year variability in temperature and probably precipitation was greater than at present. Tree-ring data also indicated several major drought periods in Iowa especially AD 1696 to AD 1705 and AD 1735 to AD 1744. On the Great Plains, native people appeared to have placed an increased emphasis on the hunting portion of the diet, particularly the fall hunt. In most instances this required an increase of nomadic behavior following the bison herds aided by the re-introduction of the horse. An example of this shift in diet during the Little Ice Age was documented by Nicholson et al. (2006) for Vickers focus people originally on the northern Great Plains in southwestern Manitoba around AD 1400. These people were involved in hunting and small-scale horticulture that included the raising of maize, but after AD 1450 they abandoned Manitoba and were located later in southeastern Saskatchewan. In this new area, they pursued an increasingly intensive hunting lifestyle emphasizing bison with no evidence of engaging in horticulture. Nicholson et al. (2006:325) attributed this relocation and shift in diet to "a sudden, drastic cold spike during the Little Ice Age."

The scenario that emerged from this review was one of climatic and cultural changes that appeared throughout the Little Ice Age. People were affected at various times and in various ways during this event. From the viewpoint of the rice rat populations throughout the Mississippi River drainage basin, this climatic trend reversed the conditions that came into existence 2000 years earlier when these rodents began expanding their geographic range. The sedentary agricultural societies were becoming more nomadic moving between summer and winter quarters, forming larger villages, palisading villages, and depopulating large areas. It appears that crop failures resulting from droughts, cold temperatures, or shortened growing seasons stressed the dietary reserves of the human populations and thereby the rice rat populations. According to Richardson et al. (2002:88): "droughts are among the most drastic climate catastrophes that impact agriculturally based societies." The gathering of forest resources also may have been less successful because droughts severely affect nut-bearing trees even to the point of killing the trees in prolonged droughts (Richardson et al., 2002; Stahle et al., 2007). Some native groups changed the maize that they were raising to one that had a shorter growing season and other groups placed more emphasis on hunting of large mammals, including bison. All of these changes made the food and shelter availability less predictable for the rice rats, and appears to have had a major impact on their distribution.

The native agriculturalist may have compounded the problems that they were to encounter as the climate became highly variable in the Little Ice Age. They had taken up maize-based agriculture after AD 900 and intensified it over the intervening years, becoming almost wholly dependent on the three sisters—maize, beans, and squash—by AD 1400, with the near abandonment of the crops of the Eastern Agricultural Complex. Maize and beans were tropical plants transferred to upper Midwest, where when conditions deteriorated, they proved to be less adapted to the local environment than the native crops of the Eastern Agricultural Complex. A comparison of the water usage by maize and sunflowers, one of the crops of Eastern Agricultural Complex, demonstrated this issue (Lindstrom et al., 1982). Sunflowers had the reputation of being drought tolerant, but Lindstrom et al. (1982:362) found that sunflowers and maize used similar amounts of water through the growing season. However, sunflowers were found to have "a drought stress escape mechanism" that allowed them to produce a crop under water-stressed conditions, when the maize crop failed. Sunflowers had an extensive branching tap root system that extended two meters into the soil, whereas the roots of corn extend only about a meter into the soil, so that sunflowers were able to access more of the available water even during drought conditions. Sunflowers were drought tolerant except for three weeks from the beginning of flower head creation to completion of flowering and they had the ability to delay flowering under extreme drought conditions and resume development when moisture was available, whereas maize required two periods of available water from the creation of silk in the ears to pollination and then during filling of the kernels in the ears and these processes could not be delayed by the maize (Neild and Newman, 1988). As the climate moved into alternating periods of dry/wet, with extended sessions of drought the native agriculturists would be dealing with repeated crop failures of the entire village's main food source. These immediate problems would have driven people to seek places where their crops would be successful, to start warfare over scarce resources, and succumb to disease and starvation (Richardson et al., 2002). The rice rats would certainly have been impacted by the loss of food resources and shelter and they would not have had ability to move as far or as fast to new areas as their hosts.

Lomolino and Channell (1995, 1998) described the geographic range collapse of endangered nonvolant terrestrial mammals. They found that as species approached extinction the predominate pattern was for populations to persist in more peripheral areas rather than near the center of the population. This pattern is similar to what occurred in rice rat populations in the Mississippi River basin. Populations of rice rats that persisted the longest in this region were located away from the center, which was situated along the Mississippi River in southwestern Illinois. The majority of the rice rat populations had disappeared from the basin by AD 1600, but archeological sites with rice rats that persisted beyond this time were located along the Ohio River in northern Kentucky (Bintz site) and the Kanawaha River in West Virginia (Buffalo Village site). The longest persisting archeological sites along the Illinois River were Norris Farms No. 26 and Emmons Cemetery (AD 1500) located in Fulton Co. In the Missouri River basin the longest persisting archeological site with a rice rat population was also the western-most site—Schmidt site in Nebraska along the North Loup River (AD 1550). Finally, the most recent archeological site (AD 1720 to AD 1772) with a rice rat population was Waterman along the main-stem of the Mississippi River just north of the point of dispersal.

There is little evidence that these extended rice rat populations were continuous between the center of dispersal along the Mississippi River in southern Illinois and the terminal points of dispersal in Fayette and Indiana cos., Pennsylvania, Frontier and Howard cos., Nebraska, and Peoria Co., Illinois. The evidence at hand points to rice rat populations being concentrated around a number of native villages in the upper reaches of these rivers, using the village as a source of refuge and food, but also moving out into the surrounding favorable habitat in riparian situations. Two paleontological sites in southwestern Indiana (Passenger Pigeon Cave and raptor roost) may represent a long persistent population of rice rats (although lacking precise dating) that was not associated directly with a native village site. This population was near the source area in southern Illinois and may have represented a natural dispersal into Indiana. It should be noted that the modern range of rice rats is once again approaching this area. The other two sites that do not conform to the close association of rice rats and native villages were Raven Rocks Rockshelter and Gillie Rockshelter in eastern Ohio. There were no large rivers associated with these seasonal hunting rockshelters and no nearby village sites where rice rat subfossils have been found. The evidence would indicate that these rice rats were occurring in small local natural populations.

I believe that "Early Modern Records from Unusual Locations" become informative in viewing these collapsing populations. These records of Texas rice rats were from unusual locations only in the context of the modern distribution of the species and they were only early modern records from our current vantage point, but they are late persistent records in the context of the Holocene. Emblematic of the collapse of the Mississippi River basin rice rat populations was the last known specimen from Ohio being represented by the posterior half of a rice rat extracted from the stomach of a Red-shouldered Hawk. This partial modern specimen from Madisonville, OH, was recovered in the area of major Fort Ancient archeological sites and was just across the Ohio River from the Bintz site where these rice rats persisted until late in the archeological record. The specimens from Barbourville, KY, were taken just upstream on the Cumberland River from the Mound Bottom and Rutherford-Kizer archeological sites in the vicinity of Nashville, TN. There are recent records of Texas rice rats from near the mouth of the Neosho River on the Arkansas River in northeastern Oklahoma, which is not a long distance along the river from Neosho Falls, KS, where specimens were taken in the late 1850s. Finally the record from near Topeka, KS, was located between the Trowbridge site at the mouth of the Kansas River on the Missouri River near Kansas City and the Witt archeological site near Junction City, KS. All of these records appear to fit the hypothesis that they represent persistent populations of the Texas rice rat remaining from the Holocene expansion of the geographic range of the species. Given the subsequent trapping efforts in these areas, it is almost certain that these populations have joined the other collapsing populations into local extinctions. These populations demonstrated that the collapse did not occur in a uniform pattern, but that they persisted depending upon the availability of favorable local habitats. In addition, these populations demonstrate that rice rats could maintain populations at least for a period of time at some places in the Mississippi basin in the absence of Native Americans.

One issue that remains to be resolved is how these populations were able to disperse to a major portion of the upper Mississippi River drainage basin in less than 2500 years before collapsing. There are not many data that bear directly on this point in the archeological or paleontological records. If this was a natural (the mice walking to the sites) dispersal event, we would expect the sites where rice rats were recorded would radiate outward from the center of distribution with more occupied sites near the center. The sites nearest to the point of dispersal would be expected to be the earliest occupied and those furthest from the point of dispersal would be expected to be the latest occupied. As the rice rats progressed up the river systems, we would expect that they would inhabit most of the villages that they encountered within or adjacent to riverine habitat. Based on the available information rice rats did not occupy even a majority of the riverine associated native villages. For example, there are over 700 [I couldn't fined the most recent number] archeological sites in Hamilton Co., OH, but rice rats have been reported from only eight. The total number of sites can be reduced for many reasons, such as sites not in riverine situations, poor control for recovery of fauna remains, sites not completely excavated, and numerous others, but the fact remains that rice rats were found at only very small percentages of available sites studied. This was true throughout the upper Mississippi River basin because there were thousands of archeological sites associated with rivers throughout the region, but rice rats are known from only 106.

In addition to the pattern of dispersal another issue to consider is whether or not there was sufficient time for this to be a natural dispersal event for rice rats. We can gain some insights from the literature on the hispid cotton rat, which is another small tropical rodent similar in size to rice rats, with a well-documented history of northward movement on the Great Plains. This species was first documented north of Oklahoma in Kansas in 1892 and by 1947 cotton rats had nearly reached the northern boundary of Kansas (Cockrum, 1948). Cockrum (1948) calculated this rate of movement at 7 miles [11. 2 km] per year. In 1958, Jones (1960) captured the first hispid cotton rats in the extreme southeastern part of Nebraska. A second record for Nebraska was based on a specimen taken in Adams Co. in the south-central part of the state in 1965. Based on this specimen, Genoways and Schlitter (1967) estimated a rate of northward movement of the hispid cotton rat between 1948 and 1965 at 5.5 miles [8.9 km] per year. Subsequent studies have shown that in recent years the hispid cotton rat had primarily expanded its geographic range westward in Nebraska and had stalled in northward movement, with a population found north of the Platte River only in 2014 (Wright et al., 2010; Frisch et al., 2015; Roehrs et al., 2021). If rice rats were able to maintain a movement speed similar to the hispid cotton rat over an extended period of time, traveling in a straight-line without encountering obstacles, there would have been just enough time for the rice rats to reach many of the sites occupied in the Mississippi River drainage basin. However, following the river systems would have greatly increased the distance to be traveled and there would not have been sufficient time for the rice rats to have reached the distant points in the Ohio and Missouri river systems.

My hypothesis is that these rice rat populations needed assistance to reach at least some of their points of dispersal and the assistance was provided by humans. This type of dispersal is termed anthropochory. I also believe that natural dispersal was involved in this geographic range expansion. These dispersal methods were certainly intertwined and after AD 1000 it becomes impossible to distinguish them with the data available for these rice rats. However, there are indications in the data that humans aided this dispersal, including the non-linear nature of the dispersal with some distant points being reached before points closer to the center of dispersal (Trakhtenbrot et al., 2005).

Because the dispersal of these rice rats involves, at least in part, anthropochory, the next issue to be considered is whether this was active or passive movement by humans. Bardwell (1981:37; Semken, 1983) suggested that the rice rats were actively moved by humans as a protein source because they were "small, easily transported, easily handled, a rapid reproducer, and easy to feed." This suggestion seems improbable to me because the native people would have been familiar with depredation of these and other rodents on the crops of the Eastern Agricultural Complex or on maize and beans. Even in a protein-starved environment, the trade-off does not seem to be a favorable one. In my mind, one of the major hurdles to overcome would be how to confine the rice rats without metal to make cages. The rats would quickly chew their ways through wood or hide boxes or gourd containers. There are only a few minute clues in the available literature that might inform this discussion. Guilday and Mayer-Oakes (1952:254) commented about rice rat remains from Speidel Farm: "They were complete and unburned." Guilday and Tanner (1965) commented about material from Mt. Carbon: "The exceptional preservation of the rice rat skeletons . . . ," and Guilday and Tanner (1968:44) stated about material from Fairchance Mound: "The perfect condition of these tiny elements left little doubt that rice rats. . . . " These are not the description of animals that have been cooked, eaten, and discarded. Breitburg (1992) found in a study of 117 burned and unburned bones of rice rats recorded from four sites in Kentucky that only 5% of the bones were burned. Again this does not seem to represent a group of bones from animals that have been cooked.

If the anthropochory was passive, how was this possible? Chapple et al. (2012:57) suggested that "proximity to human-occupied environments" would be important in passive human-assisted transport. Because these rice rats were concentrating their activities in lodges, food storage and refuge pits, and gardens, especially in river bottoms, they certainly were available for transport. As food, personal items, and joint cooking and storage equipment was being packed for travel, the rice rats could have easily found hiding places to occupy. Chapple et al. (2012) also believed that occurring in areas near transportation hubs was important for animals being moved to new habitats. In the forested areas of the eastern United States, I believe that most long-distance human travel would have been accomplished by water using canoes. The transportation hubs would have been the storage areas for the village canoes (usually dugouts or of bark construction), which would be expected near the river but above the flood zone. This would be an area of prime habitats for rice rats and they could have made their way upstream as stowaways much as their European cousins (*Rattus norvegicus, R. rattus,* and *Mus musculus*) came to the New World. In areas west of the Missouri River where the rivers and streams were smaller and travel overland would have been easier, it is not clear what the transportation center would have been.

Rice rats share characteristics of other invasive species of mammals, chief among these characters is termed propagule pressure (Lockwood et al., 2005; Jeschke and Strayer, 2006; Olden et al., 2011). This is in reference to the ability of the founding population to reproduce and establish new populations (how many individuals would be needed to found a new population?). As with most rodents, rice rats are capable of a high reproductive rate, with large litter sizes. Goodpaster and Hoffmeister (1952:368; see also Wolfe, 1982) found evidence that at Reelfoot Lake in Tennessee "*Oryzomys* breeds throughout most of the year." These characteristics would produce a high propagule pressure, with only a few individuals needed to establish a new population. Another important characteristic of human-assisted invasive species is their human affiliation, with commensal species being particularly important candidates (Ludsin and Wolfe, 2001; Jeschke and Strayer, 2006; Chapple et al., 2012). Species occupying human-occupied environments and transportation hubs increase their potential to be transported to new habitats. Clearly rice rats easily fit within these models indicating that this species would be a prime candidate for being transported by human activities.

Goslin (1951) was among the first authors to suggest a direct connection between rice rats and Native American villages, but it was Guilday (1955, 1961, 1971, 1972; Guilday et al., 1962; Guilday and Tanner, 1968) who developed the idea and termed the rice rats as being "commensal pests." A commensal relationship is defined as "a relation between two species in which one obtains food or other benefits from the other without the other species being damaged or benefiting" (Merriam-Webster Dictionary). Certainly, the rice rats benefit from this relationship, but it is difficult to believe that the Native Americans would not have felt damaged by the theft and spoilage of food stores. A better term for this relationship may be kleptoparasitism, which is a form of feeding when one species obtains food by stealing it from another species that has collected or otherwise prepared the food (Oxford Dictionary).

Guilday (as cited above) seems to suggest that the relationship of the rice rats with the Native American villages was obligate. He (Guilday, 1961:121) cites as his strongest evidence the rice rats remains at the Varner site: "The dependence of rice rats upon the Indian village *per se* is vividly demonstrated by its presence at the Varner site, on an isolated hilltop in rugged terrain surrounded by unbroken white oak forest and miles from the nearest stream of any consequence." Gilmore (1946:227) reported a similar situation for the subfossil rice rat found on top of Fort Hill described as: "The 'Hill,' an isolated, mesa-like elevation, with precipitous slopes on three sides, rises to a height of 500 feet above the Casselman River, which circles it about a mile from the base." Certainly the nearly simultaneous response of the native villagers and the collapse of the rice rat population in the Mississippi Valley with the onset of the Little Ice Age would support the idea of an obligate relationship. However, as hypothesized before the early modern records of rice rats from Ohio, Kentucky, and Kansas would argue that at least a few restricted populations of rice rats were able to persist 200 to 300 years in the absence of the native villages. Subfossil remains from Passenger Pigeon Cave, IN, Raven Rocks Rockshelter, OH, and Gillie Rockshelter, OH would argue that some populations of rice rats did live away from villages during this dispersal event.

Semken (1983) does warn that most Holocene mammal records come from archeological sites, but this record was biased because most paleontological sites from the Holocene have not been studied because the mammalian faunas are modern in composition. More studies of material from Holocene paleontological sites may change our perception of the close ties between Native American villages and rice rats. Guilday (1972:906) believed: "marsh rice rats were probably directly dependent upon the commensal niche afforded by grain storage of these agricultural peoples—a niche now usurped by the genus *Rattus*." These European commensal rodents stowed away on ships crossing the Atlantic Ocean but in different time periods. The black rat was the first species to arrive coming to Spanish Florida in 1565, to Jamestown, Virginia, with the British in 1607, to New York with the Dutch by the 1650s, and to Boston with the British by 1680 (Armitage, 1993; Alpin et al., 2011; Lack et al., 2013). Black rat populations expanded in the colonies as settlements slowly spread westward, becoming a pest of agriculture and stored foodstuffs. The Norway rat also entered the North American colonies along the eastern seaboard but at a much later date, arriving between 1750s to 1780s with an influx of British immigrants. As the United States became independent and the human population expanded westward, the Norway rat marched with it, replacing in most areas the populations of the black rat. There were early populations of the Norway rat along the Mississippi and Missouri rivers as boats used these aquatic highways for commerce. I have found no archeological reports for sites in the Mississippi River basin where *Oryzomys* and *Rattus* remains were comingled. The only example that I have found in the archeological literature of the Mississippi Valley of *Rattus* replacing *Oryzomys* in chronological sequence was at the Waterman site in Randolph Co., IL (Parmalee and Bogan, 1980). They found rice rat remains associated with a Native American village located in conjunction with Fort du Chartres/Fort Cavendish occupied during the period between AD 1720 to AD 1772, whereas *Rattus* bones (species not given, but probably Norway rat) were found at the same location in features associated with a farmstead occupied from AD 1820 to AD 1840. The archeological evidence and the relatively late arrival dates for the European rats would seem to indicate that *Rattus* did not usurp directly or competitively the ecological niche of *Oryzomys*, but rather the best interpretation of the currently available information is that *Rattus* filled a niche already vacated by *Oryzomys*.

Finally, it would prove informative to monitor in the immediate future the distributional boundary of *Oryzomys texensis* at its northern and central-western boundaries. Rice rats may be reclaiming some of their former geographic range in Oklahoma and Illinois. In Oklahoma early rice rat records were from the southeastern corner of the state (Caire et al., 1989), but beginning in the late 1980s these mice have been found in the northeastern part of the state in association with the Arkansas River and its tributaries (Gettinger, 1991; Braun and Revelez, 2005; McDonald et al., 2006). Specimens to the north along the Neosho River and to the west along the Arkansas River into southern Kansas may be expected. Hoffmeister (2002) reported records of rice rats taken prior to 1990 from seven counties in extreme southern Illinois, with the northern-most record from Franklin Co. Subsequent to this date, rice rats have been obtained from an additional seven counties in southeastern and south-central Illinois, with northern-most records now in Washington and White cos. (Casson, 1984; Hofmann and Gardner, 1987; Hofmann et al., 1990; Eubanks et al., 2011; Cooney et al., 2015). If the geographic range of rice rats in this region is expanding again, new populations should be sought to the north in Illinois in the American Bottom along the Mississippi River east of St. Louis, in the lower Missouri River in eastern Missouri, or to the east in southwestern Indiana in the Ohio River valley. These apparent geographic range changes for *O. texensis* may be in response to the ongoing climatic warming. Monitoring these populations of rice rats may give new insights into the impact of climate change on this species.

## Conclusions

1. The late Holocene geographic range expansion and rapid collapse of the extended geographic range of the Texas rice rat (*Oryzomys texensis*) in the upper Mississippi River basin was unique among North American mammals.

2. Water is the dominant feature of the required habitat for rice rats; therefore, in the upper Mississippi River basin, these rats almost certainly were confined to riverine marshes, sloughs, wetlands, swamps, backwaters, side channels, oxbow lakes, cattail ponds, and they could be expected to venture out on associated mudflats and grasslands.

3. The initial expansion of Texas rice rats in the upper Mississippi River basin in the Archaic period (8000 BC to 1000 BC) to six sites probably was a natural expansion instigated by changing environmental conditions during the Holocene Climatic Optimum—Modoc Rock Shelter, IL; Graham Cave, MO; Anderson Pit Cave, IN; DuPont, Maple Creek, and Bullskin Creek, all from OH.

4. From 500 BC to AD 500 rice rats extended their geographic range from the Archaic period sites to the Scovill site in Fulton Co., IL, along the Illinois River valley, to Fairchance Mound on the upper Ohio River near Moundsville in West Virginia, and far upstream on the Missouri River system to the M.A.D. 1 and M.A.D. 2 sites near Denison, IA. Some of these movements appeared to be long distance dispersal or jump dispersal where there is not a continuous population connecting all sites.

5. A positive impact that climate had for the rice rats was that it allowed native horticulture to begin and develop the Eastern Agricultural Complex, which included pepo squash, sunflower, marshelder or sumpweed, goosefoot, erect knotweed, little barley, and maygrass in semi-permanent gardens. The development of horticulture occurred in the cultural transition from Late Archaic to Early Woodland traditions during the period of 500 BC to AD 250.

6. With the development of native horticulture came other cultural changes that also favored the dispersal of rice rats in the upper Mississippi River basin. These changes included the concentration and storage of food resources in association with more permanent village sites. The food items also included gathered material from forested areas, particularly nuts and acorn crops. The food items were generally stored in pits in the ground, making them readily accessible to the rice rats, including throughout the winter months. As the village sites became more permanent the "house" construction became more elaborate, providing better refuges for the rice rats.

7. The period AD 500 to AD 1000 was one of major changes in the diets of Native Americans and consequently the food items for rice rats. All of the active village sites at the beginning of this period were engaged in Eastern Agricultural Complex gardens, gathering, and hunting, but by AD 900 all sites were engaged in maize-based agriculture, with an increasing emphasis on the raising of maize, squash, and beans—the three sisters—and most of the Eastern Agricultural Complex crops were dropped or limited in the diet. This transition was well documented in the American Bottom of western Illinois. The one climatic change that has been associated with the rise of maize agriculture in the American Bottom was the wettest 50 year-period (AD 1050 to AD 1100) of the second millennium.

8. One feature that all of the archeological sites founded after AD 1000 had in common was maize agriculture. It is hard to dispute the idea that having maize available as a food source and all of the cultural changes that occurred in the human population along with maize agriculture benefitted the rice rats, which reached their zenith

in the upper Mississippi River drainage basin during this period. The 20 archeological sites where remains of 10 or more individual rice rats (MNI) were recovered were all in existence after AD 1000. In the Illinois, Ohio, and Missouri river basins, rice rat distribution reached furthest upstream during this time period.

9. There is little evidence that these extended rice rat populations were continuous between the center of dispersal along the Mississippi River in southern Illinois and the terminal points of dispersal in Fayette and Indiana cos., PA, Frontier and Howard cos., NE, and Peoria Co., IL. The evidence at hand points to rice rat populations being concentrated around a number of native villages in the upper reaches of these rivers, using the village as source of refuge and food, but also moving out into the surrounding favorable habitat in riparian situations.

10. The expansion of the geographic range of Texas rice rats appears to have collapsed between AD 1400 and AD 1600, but it did not occur simultaneously throughout the geographic range. My hypothesis is that this collapse in the rice rat populations was precipitated by the onset of the Little Ice Age with its colder and wetter climate for hundreds of years. It appears that crop failures resulting from droughts, cold temperatures, or shortened growing seasons stressed the dietary reserves of the human populations and thereby the rice rat populations. It is estimated each person in this regional population required nine bushels of maize per year. The sedentary agricultural societies became more nomadic moving between summer and winter quarters, forming larger villages, and depopulating large areas. Some native groups changed the maize they were raising to one that had a shorter growing season and other groups placed more emphasis on hunting of large mammals, including American bison.

11. Although it has not been emphasized in the past, droughts had an important negative climatic impact on Native Americans and the associate rice rat population in the upper Mississippi River Basin, particularly after AD 1000 when maize was the primary dietary item. Maize, a tropical plant, was not as drought resistant as at least some of the Eastern Agricultural Complex crops such as sunflowers, which had been mostly abandoned by the gardeners by this time.

12. "Early Modern Records from Unusual Locations" are hypothesized to represent the last of the collapsing Holocene rice rat populations. These records of Texas rice rats were from unusual locations only in the context of the modern distribution of the species and they were only early modern records from our current vantage point but they were late persistent records in the context of the Holocene.

13. The initial movement of rice rats populations into the upper Mississippi River basin was probably by natural dispersal; however, in order for rice rats to reach the upper reaches of the river systems passive anthropochory is hypothesized to be involved. Because these rice rats were concentrating their activities in the area of lodges, food storage and refuge pits, and gardens, especially in river bottoms, they were available for transport. This proximity to human-occupied environments was important in the passive human-assisted transport. Evidence of passive anthropochory was shown by jump dispersal of rice rat populations, with some sites further upstream being established prior to those closer to the center of dispersal.

14. Previous researchers have termed the relationship between Native Americans and the associated rice rat populations in the upper Mississippi River basin as commensalism; however, a better term would be kleptoparasitism, which is a form of feeding when one species obtains food by stealing it from another species that has collected or otherwise prepared the food.

15. Previous researchers proposed that rice rats were directly dependent upon the niche afforded by grain storage of native agriculturalists—a niche now appropriated by the genus *Rattus*. However, there are no reports of sites in the Mississippi River basin where *Oryzomys* and *Rattus* remains were comingled and only a single example of *Rattus* replacing *Oryzomys* in chronological sequence, which was at the Waterman site in Randolph Co., IL. The archeological evidence and the relatively late arrival dates for the European rats would seem to indicate that *Rattus* did not directly or competitively "appropriate" the ecological niche of kleptoparasite of humans from *Oryzomys*, but rather the best interpretation of the currently available information is that *Rattus* filled a niche already vacated by *Oryzomys*.

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## APPENDIX I

Archeological and paleontological sites (106) in the Mississippi River drainage basin from which the remains of the rice rat *Oryzomys texensis* (former known under the name *O. palustris*) have been reported. The states are arranged, in as far as possible, in order as if one was moving upstream in the major river systems—Mississippi, Illinosis, Ohio, Missouri rivers. Within states the archeological and paleontological sites are arranged in a similar manner working upstream in each drainage basin. The site names, locations, age of the site, and number of rice rat remains were all draw from the original publications. The number of rice rats present is measured either by minimum number of individuals (MNI) based on the most common single skeletal element present or by total remains (TR) based on simple count of all skeletal elements present.

| Site | Locality | Age of site | Number of rice rats | References |
|---|---|---|---|---|
| | | **ARKANSAS (A)** | | |
| **1** Banks Village | 1.5 mi. N Clarksdale, Crittendon Co. | AD 1385-1685 | TR = 25 | Guilday, 1971; Parmalee, 1966; Perino, 1966 |
| **2** Parkin (3CS29;3CS256) | St. Francis River, eastern Cross Co. | AD 1300-1541 | MNI = 23 | Scarry and Reitz, 2005 |
| **3** Upper Nodena (3MS4) | 8 km NE Wilson, Mississippi Co. | AD 1430-1600 | MNI = 55 | Mainfort et al., 2007 |
| **4** McDuffer | Craighead Co. | AD 800-1500 | TR = 14 | Parmalee, 1963a; Guilday, 1971 |
| **5** Lawhorn | 4 mi. N Monette, Craighead Co. | AD 1250-1625 | MNI = 1 | Parmalee, 1962b; Moselage, 1962 |
| **6** Zebree (3MS20) | Little River, 1 mi. N Buckeye Landing, Big Lake National Wildlife Refuge, Mississippi Co. | AD 900-1300 | ? | Guilday and Parmalee, 1971 |
| | | **TENNESSEE (T)** | | |
| **1** Chucalissa | 10 km S Memphis, Shelby Co. | AD 1260-1500 | ? | Cleland, 1966; Mainfort, 1996 |
| **2** Mound Bottom (40CH8) | Harpeth River, Cheatham Co. | AD 700-1400 | TR = 4 | O'Brien and Kutt ruff, 2012 |

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|---|---|---|---|---|
| **3** Gordontown (40DV6) | Brentwood Branch, near Brentwood, Davidson Co. | AD 1275-1475 | MNI = 1 | Moore et al., 2006 |
| **4** Rutherford-Kizer (40SU15) | Drakes Creek, Sumner Co. | AD 1250-1450 | MNI = 7 | Clinton and Peres, 2011 |
| | | **ILLINOIS (I)** | | |
| **1** Modoc Rock Shelter, Levels 4-5 (11RA501) | 2 mi. SE Prairie du Rocher, Randolph Co. | 6500-3100 BC | TP = 3 | Fowler, 1959; Styles, 1981b |
| **2** Modoc Rock Shelter, Level 15 (11RA501) | 2 mi. SE Prairie du Rocher, Randolph Co. | 8000-6500 BC | TP = 1 | Fowler, 1959; Styles, 1981b |
| **3** Waterman | 3.5 mi. W Prairie du Rocher, Randolph Co. | AD 1720-1772 | MNI = 1 | Parmalee and Bogan, 1980 |
| **4** Meyer Cave | 4 mi. SSW Columbia, Monroe Co. | AD 500-1200 | MNI = 15 | Parmalee, 1967a |
| **5** Range (11S47) | 0.5 km E Dupo, St. Clair Co. | AD 600-870 | MNI = 8 | Kelly and Cross,1984; L. Kelly, 1987; Kelly et al., 1987 |
| **6** Merrell Tract (11MS2) | 1 km W Exermont, St. Clair Co. | AD 850-950 | MNI = 4 | Kelly, 1979 |
| **7** Cahokia Mounds | east of East St. Louis, St. Clair Co. | AD 1000-1300 | TR = 54 | Parmalee, 1957 |
| **8** Julien (11S63) | Cahokia, St. Clair Co. | AD 1200-1350 | MNI = 1 | Cross, 1984; Kelly and Cross, 1984 |
| **9** Powell Tract, Cahokia Mounds (11MS2-2) | Cahokia Mounds State Historic Site, Madison Co. | AD 800-1150 | MNI = 1 | Cutler, 1963; Parmalee, 1963b; O'Brien, 1972 |
| **10** Cahokia Mound 31 (premound) | 0.5 km E Monks Mound, St. Clair Co. | AD 1050-1100 | MNI = 1 | Sullivan and Pauketat, 2007 |
| **11** Kane Village (11MS194) | 4 mi. E Mitchell, Madison Co. | AD 900-1100 | TR = 9 | Munson and Anderson, 1973; Parmalee, 1973 |
| **12** Macoupin (11JY70) | 13.5 mi. WNW Jerseyville, Jersey Co. | 100 BC-AD 750 | MNI = 1 | Hill, [ca.1970] |
| **13** Apple Creek (11GE2) | 4 mi. N Eldred, Greene Co. | AD 200-700 | MNI = 1 | Parmalee et al., 1972 |
| **14** Schild Cemetery (11GE15) | 4 mi. Eldred, Greene Co. | AD 1000-1200 | MNI = 1 | Parmalee, 1971b |
| **15** Carlin (11C119) | 6 km N Kampville, Calhoun Co. | AD 400-700 | MNI = 1 | Styles, 1981a |

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|---|---|---|---|---|
| **16** Newbridge | 13 km N Eldred, Greene County | AD 400-700 | MNI = 1 | Styles, 1981a |
| **17** Hill Creek | 12 mi. SE Pittsfield, Pike Co. | AD 1110-1260 | MNI = 3 | Colburn,1985; Conner, 1985 |
| **18** Smiling Dan (11ST123) | 9.7 km S Bluffs, Scott Co. | 70 BC-AD 320 | MNI = 5 | Styles et al., 1985; Purdue and Styles, 1986 |
| **19** Guard | Spring Creek, near Springfield, Sangamon Co. | AD 300-700 | MNI = 2 | Purdue and Styles, 1985 |
| **20** Emmons (11F286) | 1 mi. S Marbletown, Fulton Co. | AD 1200-1500 | MNI = 1 | Guilday, 1971; Parmalee, 1967b |
| **21** Norris Farms No. 26 (11F2107) | Illinois River, 6 mi. SE Lewistown, Fulton Co. | AD 1200-1500 | MNI = 4 | Woodman, n.d. |
| **22** Scovill (11F106) | 3.25 mi. W Lewiston, Fulton Co. | AD 450 | MNI = 1 | Munson et al., 1971 |
| **23** Kingston Lake | Kingston Lake, 15 mi. SW Peoria, Peoria Co. | AD 1100-1400 | TR = 1 | Parmalee, 1962a |
| **24** Kingston Kitchen Midden (11P11) | near Kingston, 15 mi. S Peoria, Peoria Co. | AD 1100-1400 | TR = 3 | Baker, 1936; Parmalee, 1962a |
| | | **INDIANA (D)** | | |
| **1** Anderson Pit Cave | Monroe Co. | 7550 BC | MNI =1 | Richards, 1980; Holman and Richards, 1981 |
| **2** Angel (12VG1) | 8 mi. SE Evansville, Vanderburgh Co. | AD 1000-1500 | MNI = 19 | Adams, 1950; Richards,1980; Monaghan and Peebles, 2010 |
| **3** Passenger Pigeon Cave | Harrison Co. on the Ohio River | ? | MNI = 3 | Richards, 1980 |
| **4** raptor roost | 100 feet east of Passenger Pigeon Cave, Harrison Co. | ? | MNI = 1 | Richards, 1980 |
| **5** Jennison Guard (12D29) | Lawrenceburg Township, Dearborn Co., near junction of Great Miami River and Ohio River | AD 1020-1300 | MNI = 1 | Black, 1934; Cook et al. 2015; Vickery et al., 2016 |

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| **KENTUCKY (Y)** | | | | |
| **1** Salts Cave Vestibule (15ED4) | Mammoth Cave National Park, Edmonson Co. | 720-190 BC | MNI = 1 | Duffield, 1974; Gardner, 1987; Watson, 1974; Watson and Yarnell, 1966 |
| **2** Bintz (15CP1) | Ohio River at mouth of Twelve-mile Creek, Campbell Co. | AD 1500-1650 | ? | McCord, 1953 |
| **3** Snag Creek (15BK2) | near Willow Grove, 0.4 km S of Ohio River on Snag Creek, Bracken Co. | AD 1000-1600 | MNI = 2 | Henderson and Turnbow, 1987; Breitburg, 1992; Tankersley and Lyle, 2019 |
| **4** Augusta (15BK200) | Augusta, Bracken Co. | AD 1400-1740 | MNI = 1 | Henderson and Turnbow, 1987; Breitburg, 1992; Tankersley and Lyle, 2019 |
| **5** Fox Farm (15MS1) | near Mays Lick, Mason Co. | AD 1200-1550 | MNI = 10 | Henderson and Turnbow, 1987; Breitburg, 1992 |
| **6** Bentley [also Lower Shawnee Town] (15GP15) | near South Portsmouth, Greenup/Lewis cos. | AD 1400-1625 | ? | Henderson and Pollack, 1985; Sharp, 1990; Tankersley and Lyle, 2019 |
| **7** Thompson (15GP27) | near South Portsmouth, Greenup Co. | AD 1000-1500 | MNI = 4 | Henderson and Turnbow, 1987; Breitburg, 1992 |
| **OHIO (O)** | | | | |
| **1** DuPont (33HA11) | ≈ 2 mi. S Elizabethtown, Hamilton Co., Great Miami River | 2750-1750 BC | ? | Dalbey, 2007; Tankersley and Lyle, 2019 |
| **2** State Line (33HA58) | ≈ 2 mi. SW Elizabethtown, Hamilton Co., near Great Miami River on the Ohio-Indiana stateline | AD 1100–1300 | MNI = 13 | Essenpreis, 1978; Vickery et al., 2016; Tankersley and Lyle, 2019 |
| **3** Incinerator (33MY57) | Stoney Ridge, Dayton, Montgomery Co., along the Great Miami River | AD 1050–1350 | "remains are abundant" (Shane, 1988:163) | Allman, 1968; Shane, 1988; Wagner, 1988; DeAloia, 2004; Vickery et al., 2016 |

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| **4** Clough Creek (33HA16) | near confluence of Little Miami River and Clough Creek, Cincinnati, Hamilton Co. | AD 1100-1400 | MNI = 3 | Theler and Harris, 1988; Vickery et al., 2016 |
| **5** Turpin (33HA19) (Late Woodland component) | Little Miami River, 3.5 mi. above confluence with Ohio River, Hamilton Co. | AD 500-1000 | MNI = 1 | Theler and Harris, 1988; McCall, 2013 |
| **6** Turpin (33HA19) (Fort Ancient component) | Little Miami River, 3.5 mi. above confluence with Ohio River, Hamilton Co. | AD 1000-1400 | MNI = 2 | Theler and Harris, 1988; McCall, 2013 |
| **7** Madisonville (33HA36) | Madisonville, near Cincinnati, Hamilton Co. | AD 900-1500 | MNI = 2 | Goslin, 1951; Langdon, 1881; Tankersley and Lyle, 2019 |
| **8** Sand Ridge (2) (33HA17) (Fort Ancient component) | near Little Miami River, Cincinnati, Hamilton Co. | AD 1000-1300 | MNI = 8 | Theler and Harris, 1988; Vickery et al., 2016 |
| **9** Sand Ridge (1) (33HA17) | near Little Miami River, Cincinnati, Hamilton Co. | AD 450–800 | MNI = 4 | Vickery et al., 2016 |
| **10** Anderson Village (33WA4) | Little Miami River, near Fort Ancient, Warren Co. | AD 1100-1400 | TR = 3 | Goslin, 1951; Barber, 1978; Essenpreis, 1978 |
| **11** Maple Creek (33CT32) | confluence of Maple Creek and the Ohio River, ≈ 1 mi. N Neville, Clermont Co. | 1750-1000 BC | MNI = 1 | Vickery, 2008; Vickery et al., 2016; Tankersley and Lyle, 2019 |
| 12 Bullskin Creek (33CT29) | Rural, Franklin Township, Clermont Co. | 4000-2500 BC | ? | Vickery, 2008; Tankersley and Lyle, 2019 |
| **13** Feurt Village (33SC6) | 5 mi. N Portsmouth, Clay Twsp., Scioto Co. | AD 1200-1600 | TR = 21 | Goslin, 1950 |
| **14** Baum Village (33RO4) | near Chillicothe, Twin Twsp., Ross Co. | AD 1000-1400 | found in great numbers in refuse pits | Mills, 1906 |

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|---|---|---|---|---|
| **15** Blain Village (33RO49) | Scioto River, 2 mi. SE Chillicothe, Ross Co. [39°18'49"N, 82°56'16"W] | AD 970-1225 | MNI = 11 | Parmalee and Shane, 1970; Prufer and Shane, 1970; Schambach, 1971 |
| **16** Seip Earthworks Complex (Block VII) | near Chillicothe, Ross Co. | 100 BC-AD 500 | MNI = 1 | Lee, 2009 |
| 17 Cramer (33RO33) | north of Chillicothe, west side Scioto River, Ross Co. | AD 1100-1500 | TR = 125 | Goslin, 1951, 1952 |
| **18** McCune | Athens, Athens Co. | AD 1220-1420 | "common scavenger" | Murphy, 1989 |
| **19** Gabriel (33AN6) | near Hocking River, 5 mi. N Athens, Athens Co. | AD 1300-1600 | TR = 2 | Murphy, 1989 |
| **20** Raven Rocks Rockshelter | 1.3 mi. S, 3.3 mi. W Alledonia, Belmont Co. | AD 800-1000 | MNI = 1 | Shane and Parmalee, 1981; Vickery et al., 2016 |
| **21** Gillie Rockshelter (33SU1) | Twinsburg, Summit Co. | AD 750-850 | MNI = 1 | Bernhardt, 1973; Shane, 1973; Vickery et al., 2016 |
| | | **WEST VIRGINIA (V)** | | |
| **1** Buffalo Village (46PU31) | Kanawaha River, Buffalo, Putnam Co. | AD 1650 | MNI = 17 | Guilday, 1971 |
| **2** Mount Carbon (46FA7) | 3.5 mi. SE Montgomery, Fayette Co. | AD 1200-1500 | MNI = 9 | Guilday and Tanner, 1965 |
| **3** Miller (46JA55) | Ravenwood, Jackson Co. | AD 1200–1400 | MNI = 1 | Murphy 1981; Wilkins, 1981 |
| **4** Neale's Landing (46WD39) | Blennerhassett Island, Wood Co. | AD 1550–1650 | MNI = 12 | Hemmings, 1977; Tanner 1977 |
| **5** Fairchance Mound (46MR13) | Moundsville, Marshall Co. | AD 500 | MNI = 7 | Guilday and Tanner, 1968 |
| **6** Speidel Farm (46OH7) | 2 mi. NNE Oglebay Park, Ohio Co. | AD 900-1600 | MNI = 3 | Guilday and Mayer-Oakes, 1952 |

| PENNSYLVANIA (P) | | | | |
|---|---|---|---|---|
| **1** Meadowcroft Rockshelter, Level IV (36WH297) | 2.5 mi. NW Avella, Washington Co. [40°17'12"N, 80°29'00"W] | 1100-250 BC | MNI = 2 | Carlisle and Adovasio, 1984; Adovasio et al., 1990; Guilday et al., 1980 |
| **2** Shippingport (36BV4) | Shippingport, Beaver Co. | AD 1000-1500 | ? | Mrozoski, 1966; Guilday et al., 1980 |
| **3** Ohioview (36BV9) | 0.5 mi. E Industry, Beaver Co. | AD 1000-1500 | MNI = 1 | Alam, 1961; Mrozoski, 1966; Guilday, 1971; Guilday et al., 1980 |
| **4** McKees Rocks (36AL16) | near McKees Rocks, Allegheny Co. [40°28'20"N, 80°02'59"W] | AD 1230-1430 | ? | Crane and Griffin, 1972; Guilday et al., 1980 |
| **5** Boyle (36WH19) | Jct US19/PA519, Canonsburg, Washington Co. | AD 900-1500 | MNI = 1 | Nale, 1963 |
| **6** Bunola (36AL4) | near Bunola, Allegheny Co. [40°14'12"N, 79°57'36"W] | AD 1250-1450 | ? | Crane and Griffin, 1972; Guilday et al., 1980 |
| **7** Campbell Farm (36FA26) | Grindstone, Redstone Township, Fayette Co. [40°00'32"N, 79°51'04"W] | AD 1330-1530 | ? | Crane and Griffin, 1972; Guilday et al., 1980 |
| **8** Hartley (36GR23) | near Carmichaels, Greene Co. | AD 1000-1500 | ? | Guilday et al., 1980; Zimmerman and Randolph, 1986 |
| **9** Varner (36GR1) | 4.5 mi. S Waynesburg, Greene Co. | AD 1200-1400 | TR = 6 | Guilday, 1961 |
| **10** Fort Hill (36SO2) | 4 mi. E Confluence, Somerset Co. | AD 1275-1300 | MNI = 1 | Gilmore, 1946 |
| **11** Martin (36FA87) | 4 mi. S Somerfield, Fayette Co. | AD 1100-1300 | MNI = 1 | Gilmore, 1946 |
| **12** Johnston (36IN2) | Conemaugh River, Blairsville, Indiana Co. | AD 1400-1600 | MNI = 4 | Guilday. 1955; Cleland, 1966 |
| † Guffey (36AL33) | Allegheny Co. | AD 900-1600 | MNI = 1 | Vickery et al., 2016 |
| † Mingo Rock Shelter (36BV81) | Beaver Co. | AD 900-1600 | MNI = 1 | Vickery et al., 2016 |
| **"E"** *Eschelman (36LA12) [located in eastern PA, not included] | Washington Boro, 3 mi. S Columbia, Lancaster Co. | AD 1600-1625 | MNI = 1 | Guilday et al., 1962 |

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|---|---|---|---|---|
| | | **MISSOURI (M)** | | |
| **1** Graham Cave (23MT2) | Loutre River, near Mineola, Montgomery Co. | 5500 BC-AD 500 | TR = 2 | Klippel, 1971; Parmalee, 1971a; Parmalee and Oesch, 1972 |
| **2** Brynjulfson Cave No. 2 | Little Bonne Femme Creek, 6 mi. SSE Columbia, Boone Co. | 510 BC-AD 560 | MNI = 2 | Parmalee and Oesch, 1972 |
| **3** Young (23PL4) | Near mouth of Brush Creek, 4 mi. W Parkvale, Platte Co. | AD 1-500 | MNI = 1 | Adair, 1977 |
| | | **KANSAS (K)** | | |
| **1** Trowbridge (14WY1) | Brenner Heights, northwestern Kansas City, Wyandotte Co. | AD 25-500 | MNI = 1 | Johnson, 1975, Johnson, 1976; Reid, 1976 |
| **2** Witt (14GE600) | 0.75 mi. E Junction City, Geary Co. | AD 1100-1400 | MNI = 6 | Brown, 1982; Souders, 1994; Logan, 1998 |
| | | **IOWA (W)** | | |
| **1** Glenwood (13ML121, 126, 128, 129, 130, 131, 132, 133, 135, 135, 138, 139, 155) | along Pony and Keg creeks as they flow out of loess hills to Missouri River, Mills Co. | AD 900-1250 | MNI = 128 | Johnson, 1972; Hotopp, 1978; Bardwell, 1981; Semken 1983; Pugh, 2009 |
| **2** Wall Ridge Earthlodge (13ML176) | Mills Co. | AD 1000-1300 | MNI = 41 | Croft and Semken, 1994; Lamb, 2011 |
| **3** M.A.D. Valley variant, Area A, Structure 1 (13CF102) | Boyer River, 1 mi. W Denison, Crawford Co. | 50 BC-AD 300 | MNI = 1 | Pyle, 1981; Bozell and Winfrey, 1994 |
| **4** M.A.D. Boyer variant, Area A (13CF102) | Boyer River, 1 mi. W Denison, Crawford Co. | AD 300-900 | MNI = 1 | Pyle, 1981; Bozell, 1995 |

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| | | **NEBRASKA (N)** | | |
| **1** Rulo Southeast (25RH70) | 0.6 km S Rulo, Richardson Co. | AD 1041-1284 | MNI = 2 | Nelson, 2006 |
| **2** Rulo Southeast (25RH69) | 0.4 km S Rulo, Richardson Co. | AD 1037-1396 | MNI = 10 | Nelson, 2006 |
| **3** Parker (25DO2) | on the bluffs north of Ponca Creek and west of the Missouri River, in extreme northeastern Douglas Co. | AD 1000-1350 | *MNI = 2 | Ewing, 2000 |
| **4** Patterson (25SY31) | ≈ 7 mi. S Gretna, Sarpy Co. | AD 1000-1300 | MNI = 2 | Bozell and Ludwickson, 1999 |
| **5** Beaver Creek (25BO23) | 2.4 km N Loretto, Boone Co. | AD 1100-1400 | MNI = 11 | Koch, 2002; Koch and Nelson, 2002 |
| **6** Cunningham (25NC10) | vicinity of Fullerton, Nance Co. | AD 1250-1450 | MNI = 3 | Graham et al., 1987; Ludwickson, n.d. |
| **7** Schmidt (25HW301) | North Loup River, near Elba, Howard Co. | AD 1100-1550 | MNI = 37 | Satorius-Fox, 1982; Graham et al., 1987 |
| **8** Palmer Johnson (25BU37) | east of Ulysses, Butler Co. | AD 1275-1400 | MNI = 3 | Bozell and Koch, n.d.; Souders, 1994 |
| **9** Shipman (25WT7) | south side of Republican River between Red Cloud and Guide Rock, Webster Co. | post AD 1350 | MNI = 1 | Graham et al., 1987 |
| **10** 25FT22 | ≈ 4 km upstream on Medicine Creek from Medicine Creek Dam, Frontier Co. | AD 1100-1400 | MNI = 1? | Turnmire, 1996: 189-191 |

† Locality not precisely found. These do not appear on any maps.

* The Eschelman (36LA12) site is not in the Mississippi River drainage basin. It is included here only for the purpose of discussion of Pennsylvania archeological sites.

# Glossary of Plant Common and Scientific Names

Plants mentioned in the text are listed here in alphabetical order based on their common names.

acorns—*Quercus* sp.
amaranth—*Amaranthus* sp.
bagpod—*Sesbania vesicaria*
beans—*Phaseolus* sp.
bearded beggartick—*Bidens polylepis*
bedstraw—*Galium* sp.
beech—*Fagus grandifolia*
bitternut—*Carya cordiformis*
blackberry—*Rubus* sp.
black cherry—*Prunus serotina*
black nightshade—*Solanum americanum*
black walnut—*Juglans nigra*
black willow—*Salix nigra*
bottle gourd—*Lagenaria siceraria*
broomsedge—*Andropogon virginicus*
bulrushes—*Scirpus cyperinus* or *Scirpus* sp.
bushy beardgrass—*Andropogon glomeratus*
butternut or white walnut—*Juglans cinerea*
cattails—*Typha latifolia*
chenopod— Family Chenopodiaceae [goosefoot family]
chokecherry—*Prunus virginianus*
common buttonbush—*Cephalanthus occidentalis*
common reed—*Phragmites australis*
common rush—*Juncus effuses* or *Juncus* sp.
erect knotweed or smartweed—*Polygonum erectum*
goosefoot—*Chenopodium berlandieri* or *Chenopodium* sp.
gourds—*Cucurbita* sp.
ground nut—*Apios americana*
Gulf cordgrass—*Spartina spartinae*
hazelnut—*Corylus americana* or *Corylus* sp.
hickory nuts—*Carya* sp.
little barley—*Hordeum pusillum*
little bluestem—*Schizachyrium scoparium*
loblolly pine—*Pinus taeda*
maize or corn—*Zea mays*
mallow—*Malvastrum* sp.
maple—*Acer* sp.
marshelder or sumpweed—*Iva annua* or *Iva* sp.
maygrass—*Phalaris caroliniana*
pawpaw—*Asimina triloba*
pecan—*Carya illinoinensis*
pepo squash—*Cucurbita pepo ovifera*
persimmon—*Diospyros virginiana*
pignut hickory—*Carya glabra*
plums—*Prunus americana*
pokeweed—*Phylolacca americana*
purslane—*Portulaca oleracea*
raccoon grape—*Ampelopsis* sp.
reed canary grass—*Phalaris arundinacea*
rice cutgrass—*Leersia oryzoides*
rushes—Family Juncaceae [rush family]
sassafras—*Sassafras albidum*
sedges—*Carex* sp.
shagbark hickory—*Carya ovata*
shellbark hickory—*Carya lacinosa*
small sunflower—*Helianthus* sp.
spike rushes—*Eleocharia* sp.
squash—*Cucurbita pepo*
sumac—*Rhus typhina*
sunflower—*Helianthus annus*
sweet gum—*Liquidambar styraciflua*
thick-shelled hickories—*Carya* sp.
viburnum—*Viburnum* sp.
walnut—*Juglans* sp.
wild bean—*Strophostyles* sp.
wild grapes—*Vitis* sp.
wild rice—*Zizania palustris*

## Glossary of Vertebrate Common and Scientific Names

Vertebrate species mentioned in the text are listed here in alphabetical order based on their common names. Common names of birds by convention are capitalized, whereas they are not for the other four classes of vertebrates.

American bison—*Bison bison*
beaver—*Castor canadensis*
black bear—*Ursus americanus*
black rat—*Rattus ratttus*
Blue-wing Teal—*Anas discors*
bobcat—*Lynx rufus*
buffalo [fish]—*Ictiobus* sp.
Canada Goose— *Branta canadensis*
channel catfish—*Ictalurus punctatus*
common or white sucker—*Catostomus commersoni*
Coues' rice rat—*Oryzomys couesi*
eastern cottontail—*Sylvilagus floridanus*
eastern gray squirrel—*Sciurus canadensis*
elk—*Cervus canadensis*
fox squirrel—*Sciurus niger*
freshwater drum—*Aplodinotus grunniens*
giant armadillo [extinct]—*Dasypus bellus*
gray fox—*Urocyon cinereoargenteus*
hispid cotton rat—*Sigmodon hispidus*
horse—*Equus caballus*
house mouse—*Mus musculus*
marsh rice rat—*Oryzomys palustris*
meadow vole [probably]—*Microtus pennsylvanicus*
mink—*Neovison vison*
mule deer—*Odocoileus hemionus*
muskrat—*Ondatra zibethicus*
Norway rat—*Rattus norvegicus*
Passenger Pigeons [extinct]—*Ectopistes migratorius*
porcupine—*Erethizon dorsatum*
pronghorn—*Antilocapra americana*
raccoon—*Procyon lotor*
red fox—*Vulpes fulva*
red horse [fish]—*Moxostoma carinatum*
suckers—*Catostomus* sp.
Texas rice rat—*Oryzomys texensis*
Red-shouldered Hawk—*Buteo lineatus*
turtles—Order Testudines
Virginia opossum—*Didelphis virginiana*
white-tailed deer—*Odocoileus virginianus*
Wild Turkey— *Meleagris gallopavo*
woodchuck—*Marmota monax*