PALEO-ENVIRONMENTAL
INVESTIGATIONS
OF A
CULTURAL LANDSCAPE
AT
EFFIGY MOUNDS NATIONAL MONUMENT

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Abstract

Effigy Mounds National Monument (EFMO) is a national monument that combines interpretation of Native American landscape features with natural resources management. EFMO was created to protect excellent examples of prehistoric Native American mounds that occur within its boundaries. Since its creation in 1949, EFMO has doubled in land area and the National Park Service (NPS) has become concerned with better interpretation and management of this cultural landscape. NPS desired more detailed information about the paleoenvironmental history of EFMO in order to inform management practices, aimed at reconfiguring the landscape to better imitate its look and feel during the Woodland cultural period. The vegetation was prairie in the early and middle Holocene, and changed to oak savanna with a likely mosaic of prairie, upland forest, and floodplain forest about 2000 cal yr BP. At 2000 cal yr BP, the site begins a transition toward greater tree canopy cover. Charcoal records show regular fires on the landscape that decreased in severity or extent about 1700 cal yr BP.

People of the Early, Middle, and Late Woodland cultural traditions built burial and ceremonial mounds on the landscape from 2500 cal yr BP to 750 cal yr BP. The subsequent Oneota cultural tradition from 950 to 325 cal yr BP included the first extensive maize agriculture in the region. During Woodland times, people used a diverse subsistence base, hunting deer and other animals, fishing, using a wide variety of wetland plant and animal resources, gathering nuts and fruits in uplands, and gathering or cultivating native seed crops. People who produced Oneota cultural materials relied heavily on maize agriculture to supplement gathering, hunting and fishing.

A few cultural changes in the archaeological record correlate temporally with environmental changes in the paleo-record. Prairie declines about 2000 cal yr BP within a century of when the Early Woodland tradition changes to the Middle Woodland tradition. Around this time a substantial dip in the charcoal record occurs, and 300 years later, charcoal accumulation drops substantially, staying low for the remainder of the record. The population increased substantially during Late Woodland (1500 to 750 cal yr BP) when environmental conditions on the landscape were fairly stable. None of these correlations establishes cause or effect, but they present an interesting framework for speculation about the ways in which prehistoric humans manipulated and adapted to the changing environmental conditions at the oak dominated ecotone between western prairies and eastern deciduous forest.

This study provides paleoenvironmental data, review of local archaeology, and analysis of potential prehistoric human-environmental interactions to the National Park Service as it considers a new Resource Management Plan for Effigy Mounds National Monument.
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Introduction

Effigy Mounds National Monument (EFMO) in northeastern Iowa (Figures 1 and 2) was created to protect and preserve the ancient Native American mounds and their natural and scenic setting. Today the mounds and their setting are considered a cultural landscape worthy of restoration. Resource and fire management plans for EFMO make a compelling argument for tying management and restoration practices to prehistoric Native American land use (Rovang 2004, NPS 1991, 1998, 1999). The Monument has a clear mandate to manage the park as a cultural landscape evoking the time of the Woodland Tradition mound-building cultures about 2500 to 750 cal yr BP in order to provide an appropriate interpretive context for the public. The park’s challenge is to manage the vegetation to resemble the structure and composition at the time of the mound-building cultures. To restore and manage for a previous landscape, the Monument should know the fire and vegetation conditions on the local landscape at the time that people were building mounds. Several regional paleoecological studies have been completed that provide a general context (Baker 1996, Umbanhowar 2004), but studies local to the park are lacking, compromising the ability of the Monument to achieve their mandate of ecological and cultural landscape restoration.

Because of the dearth of paleoecological studies, restoration practitioners assume that the vegetation immediately before Euro-American homesteading (hereafter ‘pre-settlement’) is the proper restoration target for most ecosystems (Bollinger et al. 2004). It is easy to
default to this standard because pre-settlement vegetation can be described with some certainty from General Land Office Public Land Survey (PLS) records, and many people have the erroneous perception that pre-settlement vegetation conditions take the ecosystem back to a point with minimal human intervention. Complex cultural transitions, including early interaction of Native Americans with fur-traders and movement of immigrant tribes through the region, influenced the surveyed pre-settlement vegetation. The cultural landscape of EFMO at the time of the PLS surveys was transitional, experiencing a hiatus in Native American management but not yet exposed to intensive Euro-American plow-based agriculture. Therefore, the nineteenth-century PLS data likely do not include useful target vegetation types for restoration at this site, where the goal is to interpret the mounds in the context in which they were built.

My goal was to provide data more relevant than the PLS data to the manager’s needs. This study describes the interplay of vegetation and fires in the context of the oak-prairie ecosystem on the landscape at EFMO in an effort to describe the ecosystem context for mound building and provide guidance for restoration efforts. Fire and vegetation history was reconstructed from a core taken from Founders Pond in Effigy Mounds National Monument. This work described the age and stratigraphic context for the core and placed charcoal and pollen records in time. Analyses included counting of contiguous charcoal samples, radiocarbon dates, pollen analysis, and sedimentology studies.
Holocene Vegetation History for the Effigy Mounds National Monument Region

EFMO lies within the prairie-forest ecotone where the tallgrass prairie biome to the west mixes with the eastern deciduous forest biome. The prairie-forest ecotone encompasses eastern Iowa, southeastern Minnesota, southern Wisconsin, and northern Illinois (Curtis 1959). Here I consider 7 sites within about 200 miles of Founders’ Pond where paleoecological studies have been conducted (Figure 3).

Most of the regional site data show mesic forest in the early Holocene, prairie or savanna in the mid Holocene, and oak-dominated forest in the late Holocene (Figure 4). Those sites that have middle Holocene data show a decrease of mesic forest taxa and an increase of prairie, savanna, and prairie woodland mosaic vegetation between 7300 and 5900 cal yr BP. The Big Woods sites in southeastern Minnesota and Lake Mendota in south-central Wisconsin show the earliest switch to more xeric vegetation at 8000 and 7300 cal yr BP respectively (Umbanhowar 2004, Grimm 1983, Winkler 1985). Devil’s Lake (west of Lake Mendota) shows a later vegetation change at 5900 cal yr BP (Maher 1983) as do the two sites closest to EFMO, Roberts Creek (6300 cal BP) and Coldwater Cave (5900 cal yr BP) (Baker et al. 1996). The later return to oak savanna and oak forest occurred between 4100 and 3600 cal yr BP for two Big Woods sites (Grimm 1983) as well as Roberts Creek (Baker et al. 1996) and Lake Mendota (Winkler 1985). French Lake, another Big Woods site, became more mesic at 2500 cal yr BP (Grimm 1983), and increased precipitation was reconstructed at Coldwater Cave at about 2000 cal yr BP.
(Dorale et al. 1992). The vegetation around Founders Pond was expected to most closely resemble the progression seen in the western sites, especially the closest one, Roberts Creek.

Past studies in northeastern Iowa (Baker et al. 1996) and surrounding regions (Umbanhowar 2004, Grimm 1983, Maher 1983, Winkler 1985) show primarily prairie pollen assemblages before 3900 cal yr BP and a subsequent rise of oak pollen, prairie pollen, and mesic pollen (Figure 4). Pollen records show large percentages of grasses and forbs, as well as oak as the most common arboreal species, since about 3900 cal yr BP (Grimm 1983, Maher 1983, Umbanhowar 2004, Winkler 1985). Despite the fact that mesic trees produce much less pollen than oak, the extreme rarity of mesic tree pollen is interpreted as very little mesic forest on the landscape at these sites in the late Holocene. Instead, pollen assemblages from these records show that oak-prairie ecosystems dominated in the region, suggesting the importance of fire in maintaining an oak-dominated ecosystem.

With Euro-American settlement, ca. 1833, the oak-prairie ecosystem was systematically eradicated from the landscape. When Euro-American settlers used fire to clear land, it was followed by the plow, thus eliminating the usual suite of post-fire savanna herbs and trees. One early account describes widely spaced majestic oaks standing girdled in an agricultural field, casting no shade on the crops, and standing as firewood in reserve (Packard 1997). In places less appropriate for agriculture, savannas were left to grow
into woodlands or were grazed intensively by cattle. Shade and domesticated ungulates quickly decimated the savanna understory. A very few savanna remnants remain along railroad tracks, where serendipitously, sparks from steam locomotives served as surrogate fire sources, frequently burning the native vegetation and preserving small linear remnants of the prairies and savannas. These remnants are only a fragment of the once vast and varied oak-prairie ecosystem, but they indicate that some dimensions of this ecosystem could be propagated and maintained at small spatial scales.

Regional climate history during the last 1000 years
During the last millennium, two well-known climatic fluctuations have been documented. In the northern hemisphere, warmer and drier conditions often occurred during the Mediaeval Climatic Anomaly (MCA) from 1050 to 700 calendar years before present (cal yr BP) (AD 900 to 1250) (Cook et al. 2004). Cooler and wetter conditions prevailed 700 to 100 cal yr BP (AD 1250 to 1850) during the Little Ice Age (LIA) (Cook et al. 2004; Bradbury and Dietrich-Rurup 1993; Matthews and Briffa 2005).

Regional human history over the Holocene
Although there are debates among archaeologists over the timing of the first peopling of the Americas (Dillehay 1997; Meltzer 1997), they do agree that Native Americans were broadly but patchily distributed across much of the continental U. S., including parts of Iowa, by about 11,600 cal yr BP. These first people hunted or scavenged mega-fauna such as the mammoth and mastodon. By the end of the Pleistocene, about 10,000 cal yr
BP, significant changes in climate and biota, including the extinction of the mega-fauna, presented people with new challenges and opportunities. The Archaic people who inhabited the land from 7,000-to 2,500 cal yr BP hunted deer, elk, and other animals, fished, and gathered wild plants, especially from wetland areas. The advent of pottery at about 2,500 cal yr BP marks the beginning of the Woodland Tradition. Early Woodland people (2,500-1,900 cal yr BP) hunted, gathered, and fished for a broad range of species and buried their dead in built mounds. Middle Woodland people (1,900-1,500 cal yr BP) had elaborate burial rituals, and participated in long distance exchange networks. Late Woodland people (1,500-750 cal yr BP) built effigy mounds and lived increasingly sedentary lives. Late Woodland people continued a mixed subsistence practice that included hunting, fishing, gathering of wild resources, and the cultivation of native domesticates in their gardens. In northeastern Iowa, the Woodland Tradition was followed by the Oneota Tradition, which persisted until the time of European contact in the region, ca. AD 1650 (300 cal yr BP). People of the Oneota Tradition settled in larger villages and hunted bison, deer, elk, and a variety of birds and fish. They gathered a variety of wild plants and grew maize and squash, as well as a number of native cultigens. In Iowa, there is evidence indicating that the Oneota were the ancestors of the historical Ioway, Otoc, and Missouri tribes, however, northeastern Iowa was likely very lightly populated from about 350 cal yr BP through French contact, when other native groups appeared in the region.
At the time of the PLS, the upper-Mississippi region would have been inhabited by a changing cast of Native American groups and Euro-American trappers and settlers. In A.D. 1837, 1838, 1849, and 1852, when the Public Land Surveys for Clayton and Alamakee Counties were conducted, Native American groups living in the region had interacted with European fur traders for more than 150 years (Theler and Boszhardt 2003; HRA Gray & Pape, LLC. 2003). Europeans had lived on the Prairie du Chien terrace since about A.D. 1761, and a fort had existed near the present town of Prairie du Chien since A.D. 1685. In A.D. 1750 and 1730 respectively the Sauk and Meskwaki (Fox) tribes, originally from Michigan, were moved into northeastern Iowa and became the dominant regional tribes (Theler and Boszhardt 2003). By A.D. 1836, the Ioway Tribe, which met early French explorers and trappers and traces its ancestry to Late Woodland mound builders and the Oneota, had been moved to a reservation in Kansas. About the same time the Sauk and Fox were moved west to Kansas and Oklahoma, and the Ho-Chunk became the dominant group in northeast Iowa for about 10 years before they were relocated to the north. PLS witness tree data recorded in A.D. 1837, 1838, 1849, 1852, and 1853 show the area with a mix of forests dominated by oak or mesic species as well as prairies and savannas (Moore 1988). Though Euro-American settlement began early in this region with fur trading posts on the Mississippi River, it was after 1833 that homesteaders began to settle the Iowa frontier. After Euro-American settlement, clearing and plowing for agriculture, selective logging and light grazing influenced vegetation structure and composition (Moore 1988).
Methods

Site description
EFMO lies near the western edge of the Driftless Area, a portion of southwest Wisconsin, southeast Minnesota, and northeast Iowa that was not covered by ice during the most recent Wisconsinan glaciation. Although the region was not glaciated, landforms west of the Mississippi River were more greatly influenced by glacial meltwaters and loess, dry sediment uncovered as glaciers receded and deposited by the wind in a blanket over the hills of the driftless area. Effigy Mounds National Monument is situated on the bluffs above the Mississippi River and in a portion of the uplands and lowlands of the Yellow River watershed in Clayton and Allamakee Counties, Iowa. The Monument was designated in 1949 and for many years encompassed about 1000 acres. In 1962, the park added the 140-acre Sny Magill Unit, which contains mounds built on a sand lens near the Mississippi River. The Sny Magill mound group is considered one of the most important mound groups in Iowa, because of the number of mounds preserved there. In 2001, the National Park Service (NPS) purchased 1,045 acres along the Yellow River to the west of the original park boundary. This Heritage Addition land increases the size of the park by 71 percent to 2,521 acres (HRA Gray & Pape, LLC. 2003, O’Bright 1989).

The Yellow River runs through the park, and all park units, except the Sny Magill unit, lie largely within the river’s watershed. The Yellow River originates near Calmar, Iowa,
and terminates just past the park where it flows into the Mississippi River. The watershed encompasses 138,896 acres, of which 47 percent are row crop agricultural lands, 37 percent are grasslands, 14 percent are woodlands, and less than 1 percent is urban and roadway (Iowa DNR 2006). Founders Pond is situated on the south side of the Yellow River about 800 meters from its confluence with the Mississippi. The pond covers about 20 acres and lies at the base of a steep slope to the south. The pond is separated from the Yellow River by a natural berm and a strip of floodplain forest 12 to 100 meters wide. The lock and dam system on the Mississippi River prevents water from flowing out of the Yellow River during flood stages. Without an outlet the Yellow River’s water spreads out over the wetlands and bottomland forest in the lower reaches of the watershed. As a result, Founders Pond becomes connected to the Yellow River during these floods. Due to these flooding events, rapid modern sedimentation occurs in the lower reaches of the Yellow River watershed and particularly at Founders Pond.

**Environmental characteristics**

The climate in northeast Iowa today is continental with normal July high temperatures of 27.8°C and normal January high temperatures of 13.3°C. Normal rainfall is 902.2 mm per year. Modern upland vegetation on the site is a mixture of mesic and xeric forest with a few prairie openings (Stolt 2006). The lowlands have floodplain forest with silver maple (*Acer saccharinum*), ash (*Fraxinus* spp.), and elm (*Ulmus* spp.) and marsh vegetation (Stolt 2006). Mesic stands are composed of sugar maple (*Acer saccharum*), hickory (*Carya* spp.), ash (*Fraxinus* spp.), and red oak (*Quercus rubra*) with a significant
component of elm. Xeric stands are dominated by white oak (*Quercus alba*) with black oak (*Quercus veluntina*), hickory (*Carya spp.*), and black cherry (*Prunus serotina*) (Moore 1988, Stolt 2006). Little disturbance impacted the vegetation for 50 years after the park’s creation, except for a few localized prescribed prairie fires. In 2001, the fire-management plan initiated landscape-scale burning of wooded areas (NPS 2001).

The bedrock of the area around Effigy Mounds National Monument is mainly Ordovician in age with some Cambrian elements. The largest portion of the park is underlain by the Ordovician Prairie du Chien Group and St. Peter Sandstone, which are composed of dolomite, sandstone, and some chert. A few small areas in the park are underlain by Galina Group and Platteville Formation, which are composed of limestone and dolomite, with some chert, shale, and sandstone. The bottomlands of the Yellow River basin are underlain with Cambrian Jordan Sandstone, Saint Lawrence Formation, and Lone Rock Formation, which are composed of sandstone, siltstone, sandy dolomite, and some shale.

*Founders’ Pond*

Founders’ Pond is a 17 ha spring-fed perennial pond on the floodplain of the Yellow River. The pond is located about 800 m west of the Mississippi River. The surface area and depth of the pond vary through the year. When the Mississippi River and Yellow River are at flood stage, the pond is connected to the Yellow River, and the pond is as deep as two meters. In late summer, especially in a dry year, the pond is less than 0.5 meter deep and the inundated area is about 4 ha (personal observation). Modern
vegetation in the pond consists of emergent and floating aquatic plants with a stand of cattails (*Typha* spp.) at the east end. On the southwest side, forest vegetation descends the steep slope to the edge of the pond, while on the gentler slopes of the west side of the pond forest vegetation shifts to wet-tolerant shrubs and trees, which grade into seasonally inundated vegetated wetland (Stolt 2006).

**Period of Study**
Although pollen data span the Holocene, charcoal data collected for this study span about 1800 years from about 2400 cal yr BP to about 600 cal yr BP. This timeframe covers most of the Early Woodland period (2500 to 2000 cal yr BP) and all of the Middle Woodland (2000 to 1500 cal yr BP), Late Woodland (1400 to 1000 cal yr BP), and Oneota (950 to 600 cal yr BP) periods. Since the cultural component is very important to management of the Monument, we sampled intensively during the cultural periods when mound building occurred.

**Treatment of core and initial description**
Two sediment cores were taken from Founders’ Pond, Effigy Mounds National Monument, Iowa to provide a sequence of stratigraphically constrained samples from which pollen and charcoal were extracted for study. The first core was extracted in May, 2004. Radiocarbon analysis indicated that the entire first core was less than 150 years old, so a second core was deemed necessary to complete the project. The second core
was collected on September 27, 2005, within 100 meters of the first coring site on the same pond.

The core segments were extracted from the pond sediments with a Livingstone-Bolivia corer (Myrbo and Wright 2005). The first segment of the first core was collected in a 2.75-inch diameter polycarbonate tube with a tennis ball piston. All subsequent core segments were collected with a modified Livingstone sampler (Cushing and Wright 1965) in one-meter drives. The first core was taken with a plastic core barrel, which was packed with floral foam to secure sediments and absorb excess water, before being capped and taped for core storage. Segments of the second core were extruded in the field and packaged in plastic wrap and aluminum foil with a split PVC shell.

Core processing and initial descriptions were conducted at the Lacustrine Research Center, University of Minnesota, Minneapolis, Minnesota. Cores were split longitudinally and cleaned (Myrbo 2004.) The core halves were digitally imaged (Noren 2004) and scanned for magnetic susceptibility using the GeoTek split-core logger (Geotek accessed 2007). A small amount of sediment from each visibly different section of the core, based on color and texture, was used to make smear slides, which were fixed with Norland Optical Cement and cured under ultraviolet light (Myrbo 2004). Smear slides allow the description of microscopic mineralogy. The texture, color, and general appearance of split surfaces of the core segments were systematically described (Myrbo 2007).
At each half-centimeter interval along the core (153 to 314 cm) two one-cubic centimeter samples were extracted for charcoal analysis and sedimentology studies, and additional one-cubic centimeter samples were spread every 20 cm through the remainder of the core for pollen studies. Also, 6 sites on the core were sampled to extract charcoal and upland macrofossils for AMS radiocarbon dating.

**Chronology**
A series of radiometric dates of macrofossils and charcoal from the sediment core provide an age model for the rate of accumulation of sediment layers in the core. Terrestrial plant macrofossils and charcoal from sediments older than about 150 years were aged using Accelerator Mass Spectrometry (AMS) radiocarbon dates. Linear interpolation between 4 AMS radiocarbon dates provides a chronology for the older sediment layers. Radiocarbon ages were calibrated using the CALIB (Stuiver and Reimer 1993 updated 2005; Reimer et al. 2004) program, and are reported in calendar years BP (cal yr BP), where 0 cal yr BP = A.D. 1950 and the present is approximately -55 cal yr BP. In addition, the sediment depth of the rise of ragweed at A.D. 1850, the time of Euro-American homesteading, was located to aid in creating an age model for the core.

**Sedimentology**
Grain size analysis measures the fraction of particles of different sizes in a particular sample. Water flowing faster can carry larger particles than slower moving water.
Founders’ Pond receives runoff from the surrounding steep slopes and a small stream that drains into the pond. The strong contrast between the current of the Yellow River at flood stage and the slow backwater of Founder’s Pond under normal condition suggests that the pond should have quite fine grains in its sediments when the Yellow River is not overtopping its banks. When the river is connected to the pond during a flood, the higher energy water should deposit larger particles in the pond. A Malvern Instruments Mastersizer 2000 laser diffraction particle size analyzer was employed to construct grain size distributions from core samples. A total of 18 samples were analyzed at approximately 10-centimeter intervals in the top two meters of the core. Samples were treated with 200 ml of bleach for 24 hours to digest organic matter, and rinsed with water. Prepared samples were then mixed with 500 ml of water, sonicated for 30 seconds, and pumped through the Mastersizer 2000. Results were grouped by size fractions of sand, silt, and clay.

Charcoal analysis
Others (reviewed in Whitlock and Larsen 2001) have found that charcoal >125 µm in length is a good indicator of local fires in ponds and lakes without inlet streams. Founder’s Pond, unfortunately, is influenced by the Yellow River, which occasionally is impounded by the Mississippi River. The flooding influence of the Yellow River effectively shifts the watershed of Founder’s Pond from about 500 ha to about 62,524 ha as well as increasing sedimentation rates, making the local watershed origin of macroscopic charcoal pieces questionable and peaks in the charcoal record difficult to
interpret as either local to the watershed of Founder’s Pond, or covering large areas of the Yellow River watershed, or covering small areas of the Yellow River watershed. Therefore I will discuss peaks and background in charcoal accumulation, which should indicate the general charcoal production of the landscape through time, instead of specific local fire events.

Macroscopic charcoal was analyzed by standard methods (Lynch et al. 2006). Sediment subsamples were digested and bleached in 20 ml 6 % hydrogen peroxide solution, then sieved through stacked 250 and 125-µm sieves. Charcoal sized greater than 250 µm was counted in the sieve and charcoal 125 to 250 µm was transferred to a Petri dish and dried before counting.

Charcoal pieces >125 µm in length were classified by type during data collection and converted to charcoal accumulation rates (CHAR). Sutheimer (2006) described charcoal types from laboratory ignition experiments. They found that burned grass cuticle produces charcoal with a cellular pattern, while dark charcoal more often signifies burned woody material. Additionally, branched charcoal corresponds to leaf veins of deciduous species, especially oak and birch, and resin and bordered pits to conifers. Other charcoal types such as fibrous, spongy, porous, and lattice are morphologically distinct, but may come from several sources. Charcoal classified as “other” did not fit into any particular type category.
Charster 0.8.3 (Gavin 2006) was employed to separate the background and peak components of the charcoal record. Analyses were conducted on the entire charcoal record and on several types of charcoal particles through the entire record. Charcoal accumulation rates were linearly interpolated to 5- or 7-year intervals, and a 100-200-year window was used for LOWESS smoothing to estimate charcoal influx. Two charcoal peak thresholds were set for each analysis. The high threshold was set to identify charcoal peaks that were large and distinct, and that showed significant fire activity on the landscape. The lower threshold was set to identify periods and patterns of fire activity through time. Comparison of peaks between the two thresholds should help to describe the range of variability in fire regime in the Founder’s Pond and Yellow River watersheds.

**Pollen**
Pollen samples were prepared using standard methods (Faegri and Iverson 1989). 0.6 cc of sediment was sieved through a 60-micron ceramic sieve prior to initial hydrochloric acid treatment to remove large particles. After sieving, two or three tablets, each containing about 16,180 grains of eucalyptus pollen (Stockmarr, batch: 903722), were added as a marker for calculation of pollen concentration. Samples were processed in room temperature hydrofluoric acid for about 60 hours to remove abundant silicate minerals. Acetolysis was conducted for one minute, and samples were archived in glass vials with silicon oil.
Pollen was counted to 200 grains, aquatics (algal spores, *Sagittaria, Lemna, Potamogeton,* and *Selaginella*) were removed from the sum, and all pollen types are analyzed as percentage of that sum. A second pollen sum was calculated without aquatics or Cyperaceae or Poaceae, for comparison with the sum including graminoids.

A total of 28 pollen samples were counted, spaced at about 20-centimeter intervals except during the period 2500-100 cal yr BP when samples were spaced at 5- to 10-centimeter intervals.

Pollen influx was calculated using the equation:

\[
\text{Pollen concentration} / \text{years per sample}
\]

Where Pollen concentration is:

\[
\text{total pollen sum} \times \text{total eucalyptus grains} / \text{eucalyptus grains counted}
\]

**Results**

**Chronology**

Four AMS radiocarbon dates on plant and charred material from the core, and one date interpreted from the *Ambrosia* pollen rise, provide the basis for the core age model (Table 1). The *Ambrosia* rise was abrupt and interpolated to 100 cal yr BP when Euro-American settlers took over the region from Native American control and established plow-based agriculture (Bassett and Terasmae 1962). Two additional radiocarbon dates were not used in the age model because their results suggested contamination.
The age model derived from the dated material predicts a basal age of 9,080 cal yr BP. The highest sedimentation rates (1.045 cm/yr) occur in the 155 years since the *Ambrosia* rise. Sedimentation rates between 0.08 cm/yr and 0.1 cm/yr occur between 2225 cal yr BP and 100 cal yr BP. The sedimentation rates between the base of the core and 2225 cal yr BP are 0.05 cm/yr.

**Sediment description**
Sediment in the core ranged from pink clay to organic peat (Table 2). The bottom 44 cm (to 9070 cal yr BP) of the core is clay. Of this 13 cm are grey in color and the bottom 12 are pink. A few gastropod shells are found in the grey portion of the clay. From 8200 cal yr BP to about 2000 cal yr BP the sediment is light brown to grey, silty loam with varying amounts of gastropod shells and charcoal. From 2000 cal yr BP to about 200 cal yr BP sediments were dark brown with coarse graminoid organic matter and some gastropod shells. The organic component increased over the next 100 cm until about AD 1950. 15 cm of finer-grained grey silt with some fine-grained organics range from AD 1950 to 1975, and the top 38 cm (AD 2005 to AD 1975) were organic muck.

**Grain Size**
Throughout the 2000-year study period 40 to 60 percent of particles are silt and 20 to 40 percent are clay. The proportion of sand particles is fairly stable until 1300 cal yr BP when it decreases sharply and then returns to previous levels. Sand percentage peaks
twice in the core, between 700 and 600 cal yr BP and at about 1600 cal yr BP. Smaller peaks occur at 1100 and 350 cal yr BP (Figure 5).

Charcoal

CHAR analysis
The dramatic changes in background charcoal accumulation rates in this study required the use of two thresholds to identify peaks relative to background charcoal accumulation rates (CHAR) in CHARSTER (Gavin 2006). A high threshold identifies the highest peaks in CHAR, indicating severe local fires or periods of high fire activity. A low threshold notes all reasonable CHAR peaks above the background, and especially includes wider peaks indicating charcoal influx over a longer period of time in the record, local peaks diluted by increased sedimentation during flooding events, or continued deposition of charcoal from the landscape after a fire event (Long et al. 1998). The cellular, dark, fibrous, and other charcoal types made up most of the data collected. Dark, fibrous and other charcoal types generally concur with the trends in the total charcoal record, while cellular charcoal shows relatively larger peaks at the beginning of the record and more consistent background levels throughout.

The background component of the total charcoal record shows two prominent shifts (Figure 7). The first shift occurs at about 2210 cal yr BP, when the charcoal accumulation rate increases dramatically. At this time the actual number of pieces of charcoal per sample does not change much, but the radiocarbon date at 2210 cal yr BP
indexes the accumulation rate to a lower sedimentation rate. 2210 cal yr BP is an artificial boundary in the dating and the change in sedimentation rate may have occurred before or after this date. Without additional radiocarbon dates it is impossible to better place this boundary. At the second and more interesting shift, about 1740 cal yr BP, CHAR drops by about 20-fold. This change shows up in the raw data, and is not an artifact of the spacing of radiocarbon dates but may reflect a change in sediment accumulation rates. The period since 1740 cal yr BP is much less volatile and charcoal peaks are lower.

The period between 2240 cal yr BP and 1740 cal yr BP is marked by volatile highs and lows in charcoal accumulation, and, as a consequence, high background charcoal. The high threshold (5) identifies 11 peaks in CHAR, and the low threshold (1.7) denotes 39 peaks. Low-threshold peaks are the most frequent during this period with an average of about 21 years between peaks (24 peaks in 500 years). Actual intervals between CHAR peaks fluctuate from 10 to 50 years. The trough below background levels from 1830 to 1880 cal yr BP is notable for its magnitude and duration. It is the longest low period of charcoal accumulation while background charcoal is high.

Background CHAR tapers off after 1740 cal yr BP and never climbs above 7 pieces per centimeter per year during the rest of the record. CHAR peaks denoted by the low threshold occur regularly with longer gaps averaging 45 years, but at least one notable peak occurs. The peak lasting approximately 50 years at 1450 cal yr BP is the only peak
to be captured by the high threshold outside of the high-background period. Low-threshold peaks occur fairly regularly through the rest of the record, with gaps between 1230 and 1020 cal yr BP, and between 830 and 680 cal yr BP.

Charcoal Types
Figure 7 and Table 3 show charcoal accumulation rates subdivided by charcoal types through time. Charcoal types can be distinguished morphologically and sometimes related to life form. In the data from the Founders’ Pond core, fibrous and dark charcoal set the gross trends described above. Branched, porous, and other charcoal types generally follow these trends. Lattice, resin, and bordered pit type charcoal yielded such small numbers of particles that they were ignored in this analysis. Notably, the cellular type charcoal did not follow the overall trends of total charcoal accumulation rates, at least during the most recent 1000 years.

The cellular type’s biggest peak was at about 940 cal yr BP, which was a relatively lower period for the total charcoal accumulation rate. Before 1000 cal yr BP, the cellular charcoal tracks the total charcoal. The six cellular charcoal peaks at the high threshold are grouped around 940 cal yr BP and around 2050 cal yr BP. Another large peak at 1260 cal yr BP splits a 1000-year period lacking large peaks. The low threshold of 0.7 identifies 20 peaks. Clusters of peaks still occur grouped around 2100 cal yr BP and 900 cal yr BP, but smaller peaks are clustered between 500-700 cal yr BP, around 1260 cal yr BP, and between 1650 and 1810 cal yr BP. Together the larger and smaller peaks occur
regularly in 20- to 70-year intervals, and four longer peak-free periods occur at 670-890, 1015-1190, 1265-1685, and 1805-1970 cal yr BP.

**Pollen**

**Pollen Zones**
Throughout the Founders’ Pond core, herbaceous pollen dominates pollen percentages, making up at least 80 percent of every sample counted (Figure 8). The most important pollen types are Chenopodiaceae/Amaranthaceae, Poaceae, and Cyperaceae at different times. A total of six zones defined by CONISS stratigraphically constrained cluster analysis (Grimm 1987) were used to divide changes in pollen assemblages. The first cluster division separates the most recent 600 years from all earlier data. Two second level divisions occur: the first separates post-settlement pollen from the latest pre-settlement pollen assemblage (zones 1 and 2), and the second divides pollen assemblages prior to about 7700 cal yr BP (zone 1) from the middle part of the record. The third level division separates zone 3 from zone 2 at about 2200 cal yr BP. The fourth level division divides zones 2 and 2a (Figure 8). These particular third and fourth level divisions were interpreted as pollen zones because each contained several pollen samples and traversed a large time span. Additionally, zones 2a and 3 fall after 2400 cal yr BP, the period of interest for management and restoration planning at EFMO.

Zone 1 (9080 to 7700 cal yr BP) is dominated by Chenopodiaceae and Amaranthaceae pollen. Cyperaceae is relatively prominent (9%) at the beginning of the zone and declines
through the zone. *Ambrosia* pollen is also present. *Quercus* is the most common arboreal pollen type at 5%, and *Picea, Corylus, Salix, Pinus*, and *Fraxinus* occur at very low numbers. The sediment in this zone was mainly clay.

Zone 2 (7700 to 5500 cal yr BP) continues to be dominated by Chenopodiaceae and Amaranthaceae, but Poaceae also begins to rise. Cyperaceae declines during the first half of the zone and other NAP peaks a bit at the end of the zone. *Quercus* and *Pinus* are the most important trees, with *Acer, Picea, Salix, Corylus*, and *Tilia* represented at low levels.

Zone 2a (5500 to 2000 cal yr BP) is the long Poaceae peak, with grass pollen rising at the beginning of the period and leveling off at nearly 80 percent of pollen around 4000 cal yr BP. As grass increases, Chenopodiaceae/Amaranthaceae-type declines in the record. Cyperaceae, *Ambrosia*, and other NAP are low during this zone. *Quercus* increases slightly as the zone progresses. Pine and mesic trees are very uncommon during this zone.

Zone 3 (2000 to 700 cal yr BP) includes the decline of grass and the rise of Cyperaceae pollen. The sedge pollen peaks about halfway through the period then grass again overtakes the sedge. Oak pollen increases to a moderate level (7-13 percent) through this period, and pine is present at a low but increasing level (1-6 percent). *Fraxinus, Ostrya-Carpinus, Sambucus, Tilia, Ulmus, Juglans*, and *Acer* are all present at higher levels than
previously. Wetland herbs are at their most prominent during this period, and other NAP peaks in the middle of the period.

Zone 4 (700 to 150 cal yr BP) sees oak, pine, and mesic trees peak at the beginning of the period, then fall off to almost non-existent levels. Grass falls off sharply at the beginning of this period and does not recover, while sedge peaks early in the period and Chenopodiaceae/Amaranthaceae peaks late in the period.

Zone 5 (150 cal yr BP to present) represents the Euro-American settlement period and is characterized by a sharp spike in Ambrosia pollen along with relatively high NAP, Chenopodiaceae/Amaranthaceae, and sedge. Quercus is relatively high (10-22%) and Pinus and several mesic trees are present.

Pollen Influx
Pollen influx data generally agree with percentage data (Figure 10). Total influx is low from 8000 cal yr BP until about 5500 cal yr BP when it increases at the same time that Poaceae increases. Just before 2500 cal yr BP, total influx becomes more volatile with sharp peaks at 2700 cal yr BP, 1800 cal yr BP, and 1200 cal yr BP. A last peak occurs with the Ambrosia rise at 150 cal yr BP. From the beginning of the record to about 3000 cal yr BP both the influx and percentage records are dominated by the large shift from Chenopodiaceae/Amaranthaceae to Poaceae. From 3000 to about 750 cal yr BP a variety of pollen types influence the record including Poaceae, Cyperaceae, Quercus, and mesic
trees. After 750 cal yr BP the influx record shows the influence of Euro-American settlement with a spike in the influx of *Ambrosia* pollen. A rise in Chenopodiaceae/Amaranthaceae early in the core shows up in both influx and percentage data (Figures 8-10), as does the large amount of grass pollen between 6000 and 1500. The gentle rise in the oak percentage from 3000 to 750 cal yr BP is notable though longer in the influx data as is a similar pattern in mesic trees.

### Pollen in the past 2500 years

Figure 11 focuses on the past 2500 years in order to highlight the relationship between the environmental data and cultural periods. Cluster analysis first divides this period of interest at about 600 cal yr BP with the earlier vegetation dominated by Poaceae and the later vegetation dominated sequentially by Cyperaceae, Chenopodiaceae/Amaranthaceae, and *Ambrosia*. Additionally, oak and mesic trees decline after 600 cal BP, then spike up again with *Ambrosia* after Euro-American settlement. A further division, beyond that considered above, could be added at about 1500 cal yr BP, which would divide a period of increased Cyperaceae from the earlier largely Poaceae-dominated vegetation.

### Discussion

**Environment**

The pollen record is dominated by five changes that delineate the six pollen zones: 1) about 7700 cal yr BP Poaceae increases abruptly in percentage, although not in influx rate (Figures 8-10); 2) then between 5500 and 5000 cal yr BP Chenopodiaceae/Amaranthaceae drops and Poaceae rises even more sharply in both
percentage and influx rate; 3) Poaceae declines and Cyperaceae, and percentages of mesic trees increase, from 2000 to 1000 cal yr BP; 4) Poaceae abruptly declines and percentages of Cyperaceae and Chenopodiaceae/Amaranthaceae increase at 600 cal yr BP; and 5) *Ambrosia* rises at Euro-American settlement about 100 cal yr BP (Figure 8).

A major decrease in charcoal background at 1710 cal yr BP is the most prominent component of the charcoal record (Figure 7). Charcoal peak frequency is similar until ca. 600 cal yr BP when fires become very infrequent. The type of charcoal identified also shifts – with dark, fiber, and other char being more prominent before 1710 cal yr BP (Figure 7). The grain size record suggests periods of flooding at 1600, 1000, 600, and 300 cal yr BP (Figures 5 and 12).

9080 to 8400 cal yr BP: The earliest pollen zone from the bottom of the core to 8400 cal yr BP contained an assemblage of mainly Chenopodiaceae/Amaranthaceae with some oak, sedge, *Ambrosia*, and mesic trees, but, notably, little grass (Figures 8-10). The pollen assemblages at Founders’ Pond are dominated by very high percentages of Chenopodiaceae/Amaranthaceae pollen, which likely occurred on disturbed mudflats around the pond at this time. Regionally, paleoecological studies reconstruct mesic forest with northern species (*Picea, Abies*, and *Larix*) or oak forests through this period (Baker et al. 1996, Umbanhowar 2004, and Winkler 1985) (Figure 3). The Coldwater Cave speleothem reconstructs a warm moist climate that would support mesic vegetation, and the Roberts’ Creek study found evidence of northern mesic forest vegetation such as spruce and fir (Baker et al. 1996). If the immediate watershed of Founders’ Pond
followed regional trends, forest vegetation may have occurred in the uplands above Founders’ Pond, but pollen evidence is sparse.

8400 to 5500 cal yr BP: Chenopodiaceae/Amaranthaceae pollen remains dominant after the pollen zone boundary at 8400 cal yr BP, but grass and pine increase as sedge and Chenopodiaceae/Amaranthaceae decline (Figures 8-10). Pine, mesic trees, and non-arboreal pollen (especially Apiaceae) have a small peak about 6000 cal yr BP. Additionally, mesic trees appear in this vegetation type. The vegetation in this zone appears to be still somewhat ruderal, but the upswing in grass pollen suggests that prairie vegetation was likely beginning to take hold in uplands.

5500 to 2000 cal yr BP: The rise of Poaceae starting about 6000 cal yr BP suggests a change toward prairie vegetation, which culminates about 4500 cal yr BP and remains dominated by grass for another 2500 years (Figures 8-10). Quercus increases slightly, and remains in the record during the prairie period as do mesic trees, Cyperaceae, and Ambrosia. During this 3000-year period the record largely lacks Pinus, Chenopodiaceae/Amaranthaceae, and most non-arboreal pollen. Although the distribution of vegetation on the landscape is impossible to infer from this single site, the less-dominant pollen types suggest that pockets of mesic forest and oak savanna remained on the landscape. The charcoal record begins at 2400 cal yr BP with a high background CHAR level (Figure 7). The average return interval of 21 years for low peaks and 54 years for high peaks suggests frequent and sometimes large or intense fires,
both of which would be expected in a tallgrass prairie ecosystem. An interval as short as 3 years between low intensity fires would be expected in a Midwestern prairie ecosystem, but samples in this portion of the core represent about 5 years, so peaks represent at least 5 years when fire was active on the landscape (Figures 7 and 12).

The Founders’ Pond data showing a strong grass signal at 5000 to 2000 cal yr BP lag Baker et al.’s (1996) finding of a change from mesic forest to prairie at about 6200 cal yr BP at Roberts Creek, but match the timing of a 1.5 °C increase in annual temperature inferred from Coldwater Cave (Baker et al. 1996). Founders’ Pond data generally agree with Baker and others’ conclusion that northeastern Iowa lacked dominant prairie vegetation 3000 years longer that sites not far to the west and north due to climatic patterns. Sites in western Iowa and southern Minnesota record the change to prairie as much as 3000 years earlier (Wright et al. 1963, Van Zant, 1973, and Kim, 1986).

2000 to 100 cal yr BP: At 2000 cal yr BP vegetation at Founders’ Pond begins a transition toward greater tree canopy cover (Figures 8-12). Poaceae declines prior to 2000 cal yr BP as oak increases. Then grass declines sharply again between 1700 and 1100 cal yr BP. At the same time, oak, pine, sedge, wetland herbs, non-arboreal pollen, and Chenopodiaceae/Amaranthaceae increase in the record. This assemblage likely represents a mosaic of oak savanna vegetation with pockets of oak forest, mesic forest, and prairie. Baker et al. (1996) interpreted increasing oak and declining but still significant percentages of ragweed, grass, and Asteraceae with a few mesic trees as an
oak savanna. The present study provides less certainty to the interpreted oak savanna community because its few samples provide only a snapshot of the local vegetation. The charcoal record settles to a lower background level with less volatile peaks suggesting fires of lower intensity or smaller extent after 1700 cal yr BP, which would support vegetation with more trees, especially fire-intolerant mesic trees (Figures 7 and 12). A large charcoal peak occurs at about 1450 cal yr BP, which is concurrent with a sudden vegetation change from oak to pine at Ferry Lake in NW Wisconsin (Lynch et al. 2006) and an episode of drier conditions at a bog in the Upper Peninsula of Michigan (Booth 2005). Vegetation in the Founders’ Pond core does not change significantly at 1450 cal yr BP (Figures 8-12), though a small peak in the percent of sand suggests a flood (Figures 5 and 12). Two additional and more significant floods occur during this period. The earlier and larger flood occurs about 1600 cal yr BP, soon after charcoal background drops. The flood and wet local climatic conditions may explain the 110-year gap in charcoal peaks during this time. The second and smaller peak in sand occurs at 1100 cal yr BP, around the time of another 100-year gap in the record of fire peaks. Knox (1993) records a flood on the Mississippi River about the same time. These floods, resulting from a wetter climate, likely contributed to the decline of grass pollen through this period.

Another flood, observed 600 years ago in the Founders’ Pond grain size record and also in Knox’s (1993) record, coupled with the cool and wet conditions of the Little Ice Age starting about the same time may have helped to precipitate and maintain radical
vegetation shifts (Figures 5 and 12). This largest flood in the record likely drowns or washes away much of the grass on the terrace around Founders’ Pond, and as grass plummets sedge rockets up in the record (Figures 8-12). A large spike in Chenopodiaceae/Amaranthaceae follows. Wetter Little Ice Age conditions probably kept more water in Founders’ Pond and on the floodplain helping to maintain the high levels of sedge. In the uplands around the terrace, pine, which was at its greatest percentage in the record just prior to 600 cal yr BP, falls off, while oak and mesic trees peak at the transition point before falling off.

Sites in southwestern Wisconsin and northwestern Illinois (Knox 2006) show peaks in sand at corresponding dates, suggesting that sand peaks in Founders’ Pond correspond to regional flood events. Knox’s sites also show a dramatic increase in percent sand at about 1500 cal yr BP. Near the time of European settlement the proportion of sand and silt-sized particles decreases as clay particles increase.

100 cal yr BP to present: At 100 cal yr BP, Euro-Americans arrived *en masse* with their mouldboard plows. The ensuing field clearing and cultivation along with timber removal precipitate a spike in *Ambrosia* and short-spined Asteraceae Tubuliflorae pollen, which include lovers of disturbed places (Figures 8-12). Oaks, pines, and mesic trees also increase slightly during this period.
Native Americans and Environmental Variation
Woodland people were building mounds on this landscape from about 2500 to 750 cal yr BP (Figure 12). During that period, three cultural groups, the Early, Middle, and Late Woodland, used environmental resources in subtly different ways. The beginning of the decline of the prairie coincided with the first signs of Early Woodland culture at 2500 cal yr BP (Stevenson 1996). However, a change in charcoal accumulation lagged the vegetation change by 200 years. Although a dip in charcoal accumulation occurs during the cultural transition at 2500 cal yr BP, if a patchier mosaic of vegetation arose with cooler temperatures and less grass, then it would likely have included abundant edge habitat, which is excellent for deer, an important resource for all Woodland people (Theler and Boszhardt 2003). Easier hunting could have allowed the Early Woodland people to inhabit smaller regions and move around the landscape less, and may have led to exchange with other groups and the adoption of pottery and mound building (Stevenson 1996). Middle Woodland people (1900 to 1500 cal yr BP) contended with increasingly changeable environmental conditions as charcoal accumulation dropped off at 1710 cal yr BP and grain size data indicate a large flood at about 1600 cal yr BP (Figure 12). Despite the changing environment, Middle Woodland people moved around the landscape less than their predecessors, settling into villages for long portions of the year (Stevenson 1996).

Late Woodland people arrived on the landscape about 1500 cal yr BP, just before the last high charcoal peak in the record (Figure 12). The likely mixture of vegetation composed of prairie, savanna, and forest seems to persist after this charcoal peak and throughout the
Late Woodland, Effigy Mound building period. Late Woodland people became increasingly concentrated on the landscape as they began using the bow and arrow about 1200 cal yr BP (Stevenson et al. 1997), but no impact on vegetation or fire regimes is observed in Founders’ Pond. About 1000 cal yr BP, a flood deposited sand in Founders’ Pond but no clear cultural changes occur until about 950 cal yr BP when the Oneota culture arose (Stevenson et al. 1997). The Oneota (900 to 400 cal yr BP) rode the wave of warm temperatures during the Medieval Climate Anomaly (ca. 1200 to 950 cal yr BP) bringing corn agriculture as well as some Mississippian material culture to the Upper Mississippi River Valley. The cause of the decline of the Oneota after about 500-400 cal yr BP is unknown, but archaeologists alternately blame environmental factors such as difficulty with maize crops due to the cooler Little Ice Age climate period and cultural factors such as the introduction of European diseases and warfare (Theler and Boszhardt 2003). Whatever the reason for the Oneota decline, there was a period of low habitation in the driftless area including northeast Iowa for about 100 years before the Ioway Tribe became the dominant tribe to meet European explorers and fur traders in A.D. 1673 (ref).

**Implications for management**
The mounds at EFMO were built by three traditions of Woodland people spanning almost 2000 years. Since the pollen data show some agreement with other regional sites (Baker et al. 1996, Grimm 1983, Umbanhowar 2004, Maher 1983, Winkler 1985, Baker 1990) reconstructing prairie and oak savanna vegetation, the earliest Woodland people at EFMO likely lived in a prairie-dominated region with significant landscape fires, and
later mound builders likely inhabited a mixture of vegetation types that are blended at the spatial scale of this pollen record, but likely contained elements of mesic forest, oak woodland, savanna, and prairie with localized fires.

EFMO must choose a mound building period as a model for their management goals. Considering that the vegetation on the ground today at EFMO is largely mesic with some xeric and wetland areas, aiming for a mosaic of mesic woodland, flood plain forest, savanna, and prairie, while focusing on oak regeneration in upland sites would be reasonable. The mosaic of vegetation types is also consistent with pollen assemblages from the time that the effigy mounds were built (Figure 12). Fire will certainly be required in the restoration and management process. Though charcoal accumulation decreased before the prairie-savanna-woodland vegetation mosaic occurred on the landscape, fire remained a force on the landscape during the time that the effigy mounds were being built (Figure 12).

**Conclusions**

The pollen and charcoal records coupled with the grain size data from this core suggest that the portions of the landscape around Founders’ Pond have varied from prairie to mesic forest during the past 8500 years. The inferred mosaic was composed of open grasslands with arboreal vegetation dominated by oaks, probably mixed with mesic and wet areas on slopes and floodplains respectively. The vegetation burned at different intervals during different periods, but signs of fires always ceased during periods of
flooding. The transition from mesic forest to prairie starting at 5500 cal yr BP and the transition back to savanna and forest at 2000 cal yr BP are supported by Baker’s (1996) extensive data from Roberts Creek and Coldwater Cave.

People on this landscape, at least in terms of broad cultural traditions, have been able to persist through environmental changes, with shifts in culture only occasionally co-occurring with the environmental changes described in this study. This human resilience holds when environmental change is gradual as with changes in vegetation and also when change is abrupt like a flood. Various cultural characteristics, such as seasonal mobility and a diverse subsistence base probably made prehistoric cultures adaptable to environmental change.

Although this study documents the prevalence of fire on the EFMO landscape, the vegetation at EFMO has been subjected to logging, agricultural disturbance, and succession in the 750 years since the last mounds were built. Today’s mesic vegetation provides a stable state for the landscape, and merely applying fire cannot be expected to recreate the mix of native vegetation types reconstructed during the Woodland people’s tenure on the land. Restoration may use fire as a tool, but must be combined with careful planning of revegetation, exotic species control, and monitoring, if a return to a mosaic landscape is to be achieved.
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Umbanhowar, C.E.,Jr (2004). Interaction of fire, climate and vegetation change at a large landscape scale in the big woods of Minnesota, USA. The Holocene, 14, 661-676.


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Table 1. Radiocarbon dates and *Ambrosia* rise from Founders’ Pond.
Table 2. Sediment description, depth in core, and age.

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<td>123 - 296 cm</td>
<td>296 - 802 cm</td>
<td>Brown (10 yr 3/1), medium bedded, fine-grained organic grain sand, with significant charcoal and calcareous minerals</td>
</tr>
<tr>
<td>C1D7 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 803 cm</td>
<td>Brown (10 yr 4/1), medium bedded, fine-grained organic grain sand, with significant charcoal and calcareous minerals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth in Core</th>
<th>Total Depth (cm)</th>
<th>Age (cal yr BP)</th>
<th>Sediment Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1D1 10-40 cm</td>
<td>3.5 - 33.5 cm</td>
<td>0 - 20 BP</td>
<td>Dark brown muck</td>
</tr>
<tr>
<td>C1D1 40 cm</td>
<td>123 - 296 cm</td>
<td>296 - 766 cm</td>
<td>Grey clayey silt</td>
</tr>
<tr>
<td>C1D2 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 776 cm</td>
<td>Very dark brown (2/2 10 yr), medium bedded, fine-grained organic grain sand, contacts indistinct</td>
</tr>
<tr>
<td>C1D3 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 787 cm</td>
<td>Dark brown (2.5/7 7.5 yr), thick-bedded, fine-grained organic grain sand, contacts indistinct.</td>
</tr>
<tr>
<td>C1D4 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 797 cm</td>
<td>Dark brown (2/1 10 yr, lighter than above), thick-bedded, fine-grained organic grain sand, contacts, large charcoal piece (5mm)</td>
</tr>
<tr>
<td>C1D5 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 801 cm</td>
<td>Brown (10 yr 2/1), medium bedded, fine-grained organic grain sand, with significant charcoal and calcareous minerals</td>
</tr>
<tr>
<td>C1D6 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 802 cm</td>
<td>Brown (10 yr 3/1), medium bedded, fine-grained organic grain sand, with significant charcoal and calcareous minerals</td>
</tr>
<tr>
<td>C1D7 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 803 cm</td>
<td>Brown (10 yr 4/1), medium bedded, fine-grained organic grain sand, with significant charcoal and calcareous minerals</td>
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<tr>
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<th>Total Depth (cm)</th>
<th>Age (cal yr BP)</th>
<th>Sediment Description</th>
</tr>
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</tr>
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<td>123 - 296 cm</td>
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</tr>
<tr>
<td>C1D2 296 cm</td>
<td>123 - 296 cm</td>
<td>296 - 776 cm</td>
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<td>C1D3 296 cm</td>
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</tr>
<tr>
<td>Charcoal type</td>
<td>Total pieces counted</td>
<td>Associated life form</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>5356</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellular</td>
<td>1979</td>
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<tr>
<td>Fibrous</td>
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<tr>
<td>Spongy</td>
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<tr>
<td>Porous</td>
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</tr>
<tr>
<td>Branched</td>
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<td>Hardwoods</td>
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<tr>
<td>Resin</td>
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</tr>
<tr>
<td>Bordered Pits</td>
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<td>Conifers</td>
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</tr>
<tr>
<td>Lattice</td>
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<td></td>
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<tr>
<td>Other</td>
<td>2242</td>
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<tr>
<td>Total</td>
<td>15670</td>
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Table 3. Charcoal types tracked in the study.
Table 4. Pollen types encountered in this study.

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<thead>
<tr>
<th>Pollen type</th>
<th>Pollen group in Figure x</th>
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<tbody>
<tr>
<td><em>Quercus</em></td>
<td><em>Quercus</em></td>
</tr>
<tr>
<td><em>Carya</em></td>
<td><em>Carya + Juglans</em></td>
</tr>
<tr>
<td><em>Juglans</em></td>
<td><em>Carya + Juglans</em></td>
</tr>
<tr>
<td><em>Pinus</em> diplox (red pine type)</td>
<td><em>Pinus</em>, total</td>
</tr>
<tr>
<td><em>Pinus</em> haplox (white pine type)</td>
<td><em>Pinus</em>, total</td>
</tr>
<tr>
<td><em>Pinus</em> undifferentiated</td>
<td><em>Pinus</em>, total</td>
</tr>
<tr>
<td><em>Picea</em></td>
<td><em>Picea</em></td>
</tr>
<tr>
<td><em>Tsuga</em></td>
<td>Not grouped</td>
</tr>
<tr>
<td><em>Fraxinus</em></td>
<td>Mesic Hardwoods</td>
</tr>
<tr>
<td><em>Ulmus</em></td>
<td>Mesic Hardwoods</td>
</tr>
<tr>
<td><em>Tilia</em></td>
<td>Mesic Hardwoods</td>
</tr>
<tr>
<td><em>Acer</em></td>
<td>Mesic hardwoods</td>
</tr>
<tr>
<td><em>Betula</em></td>
<td>Mesic Hardwoods</td>
</tr>
<tr>
<td><em>Ostrya-Carpinus</em></td>
<td>Mesic Hardwoods</td>
</tr>
<tr>
<td><em>Sambucus</em></td>
<td>Shrubs</td>
</tr>
<tr>
<td><em>Corylus</em></td>
<td>Shrubs</td>
</tr>
<tr>
<td><em>Alnus</em></td>
<td>Shrubs</td>
</tr>
<tr>
<td><em>Salix</em></td>
<td>Shrubs</td>
</tr>
<tr>
<td><em>Chenopodiaceae/Amaranthaceae</em></td>
<td><em>Chenopodiaceae/Amaranthaceae</em></td>
</tr>
<tr>
<td><em>Ambrosia</em></td>
<td><em>Ambrosia</em></td>
</tr>
<tr>
<td><em>Asteraceae</em> Tubuliflorae, long-spined</td>
<td>Asteraceae, total</td>
</tr>
<tr>
<td><em>Asteraceae</em> Tubuliflorae, short-spined</td>
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</tr>
<tr>
<td><em>Asteraceae</em> Liguliflorae</td>
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</tr>
<tr>
<td><em>Apiaceae</em></td>
<td>Herbs</td>
</tr>
<tr>
<td><em>Rumex</em></td>
<td>Herbs</td>
</tr>
<tr>
<td><em>Plantago</em></td>
<td>Herbs</td>
</tr>
<tr>
<td><em>Gallium</em></td>
<td>Herbs</td>
</tr>
<tr>
<td><em>Solidago</em></td>
<td>Herbs</td>
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<tr>
<td><em>Artemisia</em></td>
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<tr>
<td><em>Caryophyllaceae</em></td>
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</tr>
<tr>
<td><em>Trilete spores</em></td>
<td>Ferns and allies</td>
</tr>
<tr>
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<td>Ferns and allies</td>
</tr>
<tr>
<td><em>Lycopodium</em></td>
<td>Ferns and allies</td>
</tr>
<tr>
<td><em>Cyperaceae</em></td>
<td>Cyperaceae</td>
</tr>
<tr>
<td><em>Poaceae</em></td>
<td>Poaceae</td>
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<tr>
<td><em>Lemma</em></td>
<td>Aquatics</td>
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<td><em>Sagittaria</em></td>
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<td><em>Potamogeton</em></td>
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<tr>
<td><em>Selaginella</em></td>
<td>Aquatics</td>
</tr>
<tr>
<td><em>Algae</em></td>
<td>Aquatics</td>
</tr>
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Figure 1. Location of Effigy Mounds National Monument, Iowa.
Figure 2. Effigy Mounds National Monument boundaries.
Figure 3. Regional paleodata sites.
Figure 4. Interpretations of pollen data from studies in the region. All data are from authors’ interpretations of pollen reconstructions except Coldwater Cave, IA, which is author’s reconstruction from an oxygen isotope record of speleothem carbonates.
Figure 5. Grain size data presented as percent of total number of grains analyzed.
Figure 6. Age model for Founders Pond Core constructed using linear interpolation between dates.
Figure 7. Accumulation rate of charcoal types through time. Blue dots represent high-threshold peaks in charcoal accumulation, and pink triangles represent low-threshold peaks in charcoal accumulation. The green line represents a LOWESS smoothing of charcoal accumulation rates, below which charcoal accumulation is considered background.
Figure 8. Pollen percentages for all pollen types observed in the core. Aquatics are not included in the pollen sum. Tree diagram from CONISS stratigraphically constrained cluster analysis included.
Figure 9. Pollen percentages calculated without Poaceae and Cyperaceae in the pollen sum.
Figure 10. Pollen influx calculated without aquatics in the pollen sum.
Figure 11. Summary diagram of pollen types and interpreted vegetation zones during the past 2500 calendar years.
Figure 12. Summary diagram of pollen types, percent sand, charcoal accumulation rate, charcoal accumulation background, charcoal peaks, cultural periods, and interpreted vegetation zones.
References Cited


Green, W., Chumbley, C.A. & others Iowa Office of State Archaeologist (1988). *Archaeological and paleoenvironmental studies in the Turkey River Valley, northeastern Iowa.* Office of the State Archaeologist, Eastlawn, the University of Iowa, Iowa City, Iowa.

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