POLLEN-BASED LANDSCAPE RECONSTRUCTION OF AN UPPER MISSISSIPPIAN AGRICULTURAL SITE AT HOVEY LAKE, INDIANA, USA

By

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ABSTRACT

POLLEN-BASED LANDSCAPE RECONSTRUCTION OF AN UPPER MISSISSIPPIAN AGRICULTURAL SITE AT HOVEY LAKE, INDIANA

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The study of fossil pollen grains preserved in lake sediments tracks vegetation changes of the past. Typically, changes are interpreted as responses of former plant communities to paleoclimatic changes, thus ignoring possible impacts from prehistoric Native American land use. In Midwestern USA, there are few pollen records conducted at fine temporal resolution (multidecadal) near archaeological sites that detect anthropogenic signals, and none so far for small Native American agricultural sites. This thesis describes and interprets the pollen analysis of Hovey Lake, Indiana, which is adjacent to the Hovey Lake Village Site (12PO10), a small Caborn-Welborn (Upper Mississippian) settlement. The pollen record of this lake indicates a primarily stable forest dominated by *Quercus*, *Carya*, *Acer*, and other hardwoods in the area's uplands, and *Taxodium*, *Fraxinus*, *Populus*, and *Salix* in the lowlands over the past 1,300 years. However, small but significant changes in key taxa indicate possible impacts of Native American land use and prevailing climate. From 1,260 to 860 cal yrs BP, there was a slight increase of *Ambrosia* and other herbaceous plants, indicating possible, limited forest disturbance by people in addition to the effects of the warmer/drier climate of the Medieval Warm Anomaly. Between 860 and 650 cal yrs BP, there may have been limited farming in the region, as evidenced by the presence of *Zea mays* in the pollen record. There is a strong signal in the pollen record for the growing of *Z. mays* in the area from 650 to 340 cal yrs BP. The village was abandoned at 300 cal yrs BP and this is clearly seen in the pollen record. From 340 to 250 cal yrs BP, reforestation occurred in the uplands and *Salix* expanded in the lowlands, which were probably facilitated by the cool/moist climate of the Little Ice Age. Finally, the forests again were cleared and *Ambrosia* colonized open, disturbed areas starting at ~250 cal yrs BP, but this time by early Euro-Americans.

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CHAPTER 1: INTRODUCTION

The Lower Ohio River Valley of southern Indiana and Illinois, and northern Kentucky, USA (Figure 1.1), has long been a highly productive environment for plants, animals and humans. The Lower Ohio River Valley has a humid and warm continental climate with a long growing season and fertile soils. The soil is frequently enriched by sediments and organic matter deposited by overbank flooding, which support a diverse array of plant and animal species (Braun, 1950; Crisman and Whitehead, 1975; McWilliams, 1979). Besides a hospitable climate and considerable soil fertility, the great species richness in this area is due to an overlap of three ecozones. Ranges of plants and animals of Midwest, western prairie and southern affiliations intersect and appears in the modern vegetation. The mesic temperate, deciduous forests of the Midwest include such taxa as *Quercus* (oak), *Acer* (maple), *Fagus* (beech), *Populus deltoides* (eastern cottonwood), and *Ulmus* (elm) (Dickmann, 2009; Hupy and Yansa, 2008). Southern affiliation species are hydric and sub-tropical in their ecology, and include *Taxodium* (cypress), *Nyssa*

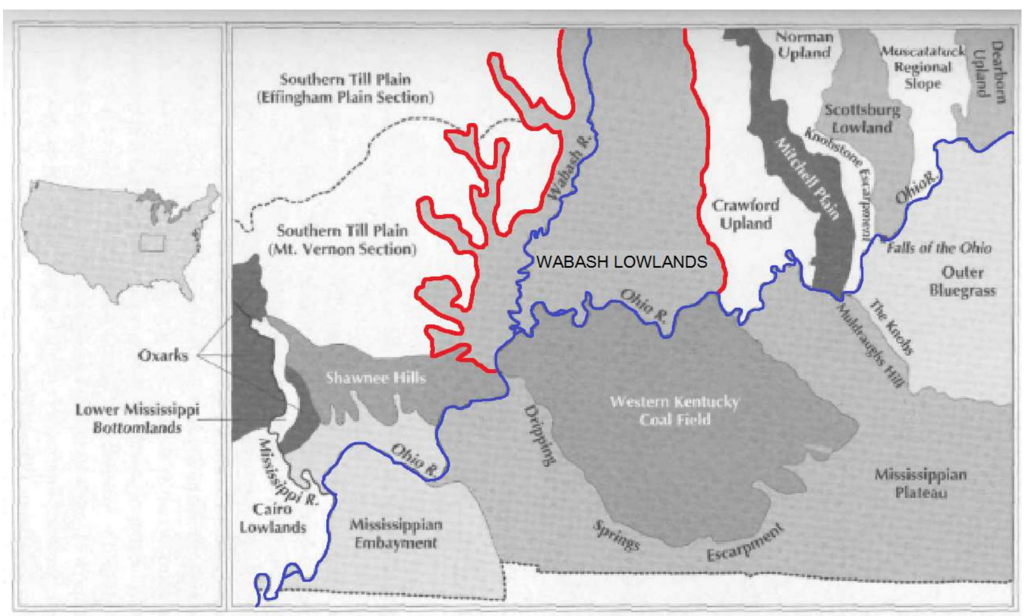

Figure 1.1 *The Lower Ohio River Valley is located in southern Indiana and Illinois, and northern Kentucky. The Wabash Lowlands (outlined in red) is in the southwestern Lower Ohio River Valley. Figure adapted from Figure 2.1, Jefferies, 2008.*

(gum), *Liquidambar* (sweet gum), and *Magnolia* (magnolia). Xeric prairie taxa typically consist of grasses and sedges with a few tree species adapted to drier soils, particularly *Quercus* species and *Populus tremuloides* (trembling aspen) and *P. deltoides*.

Today the primary land use of the Lower Ohio River Valley is agriculture, mainly corn and soybean cultivation as well as large-scale corporate livestock production (McWilliams, 1979; Bigham, 1998). While Euro-Americans have changed the landscape of this and other areas profoundly since AD 18th Century, they were not the first to clear land for farming. Native American populations, particularly during the Late Woodland (~3,000 to 1,000 cal yrs BP; ~1050 BC to AD 950) and Mississippian periods (~1,000 to 400 cal yrs BP; ~AD 950 to 1550), cleared forests for construction materials, fuel, and planted domesticated crops. Albeit at a smaller scale than done later by Euro-Americans (i.e. Delcourt, 1987; Fritz, 1993; Smith, 2007; Muller, 2009).

Archaeological research has documented that prehistoric Native Americans utilized the resource-rich Lower Ohio River Valley for thousands of years before the arrival of Euro-Americans. There is little evidence of the earliest Paleoindian (18,500 to 11,600 cal yrs BP) and Archaic (10,000 to 3,000 cal yrs BP) populations. The majority of sites dated to Paleoindian and Archaic periods times are based on lithic concentrations and hearths (Muller, 2009). More data exist for later cultural traditions during the Woodlands (3,000 to 1,000 cal yrs BP; 1050 BC to AD 950) and Mississippian (1,200 to 350 cal yrs BP; AD 750 to 1600) periods in the form of lithics, hearths, ceramics, skeletal remains, remains of permanent settlements or structures suggestive of increased population densities, as well as evidence of farming (Smith, 2007; Jefferies, 2008). Evidence of planting, or at least use of domesticated crops acquired presumably by trade, includes phytoliths and starch granules of maize and other cultivars extracted from ceramic residues, charred macrobotanicals, maize storage pits and agricultural implements (Pollack, 2004; Muller, 2008; Scott Cummings and Yost, 2008). These data provide valuable details on prehistoric aboriginal lifeways, subsistence strategies and diet, however they are unable to assess changes to the landscape surrounding settlements. Questions that cannot be answered by archaeology include: how extensive was deforestation in the area surrounding villages as a result of agriculture by Native Americans? What were the vegetation communities before, during and after village occupation, and the timing of when agriculture was practiced in that area? Can vegetation changes induced by prehistoric landuse be isolated from those caused by past climate change?

The analysis of pollen grains (palynology) deposited in the sediments of lakes and wetlands adjacent to archaeological sites, which when examined can reconstruct local vegetation change over time (with chronologies provided by ^{14}C radiocarbon dating of plant macrofossils). There are only a handful of such pollen studies in eastern and Midwest North America (e.g. McAndrews and Turton, 2010; McLaughlin, 2003; Munoz et al., 2014), that document local land use by prehistoric Native Americans. The majority of palynological investigations in this area of the continent, as elsewhere, focus on paleoclimate reconstructions. For instance, paleovegetation studies conducted in the Lower Ohio River Valley (i.e. Lindsey et al., 1965; Delcourt, 1979; Webb et al., 1983; Delcourt et al., 1986; Shane, 1987; Jackson et al., 1997), discussed in detail below, focus on climate interpretations of plant community changes over a long time frame. Typically, pollen studies span the entire Holocene and limit their interpretations of anthropogenic-induced vegetation change to the topmost part of pollen records, most often associated with Euro-Americans. These pollen studies are often located far from archaeological sites, creating a gap between paleovegetation and archaeological datasets preventing any interpretations of human impacts on vegetation. An additional limitation is many of these prior pollen studies in the Midwest USA were conducted at a coarse temporal resolution and hence are often limited in their ^{14}C correlations to specific occupations documented in archaeological records.

The broader purpose of this M.S. thesis research was to provide a landscape context for the archaeological data previously published (Munson, 1984, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004) on a small Middle Mississippian, Caborn-Welborn Phase village (12PO10) that occupied a river terrace overlooking Hovey Lake from ~700 to 300 cal yrs BP (~AD 1250—1650). Hovey Lake is an oxbow lake situated within the Lower Wabash Lowland and is part of the Lower Ohio River floodplain. Archaeological data, including charred macrobotanicals from hearths reveal that Hovey Lake villagers were sedentary agriculturalists who cleared away stands of trees, shrubs, and cane thickets along the shores of this lake to plant native domesticates of the Eastern Agricultural Complex (EAC) in addition to the tropical cultivar *Zea mays* (maize, corn) (e.g. Fritz, 1990; Delcourt et al., 1998; Smith, 2007). The archaeological data provides details on food consumption and indirectly infers human impacts on local forests to some degree. However, an independent study of fossil pollen from a lake or wetland adjacent to the Hovey Lake Village is required obtain data on landscape-scales changes of the local vegetation. Hence, my pollen analysis of the sediments of Hovey Lake documents changes to the forest species composition, and infers times of land clearance and the planting of crop domesticates and reforestation after village abandonment. Radiocarbon dates from macrobotanical obtained from sediments were used identifies the timing of vegetation changes at Hovey Lake before, during, and after the Hovey Lake Village occupation, providing a longer environmental record than that of the archaeological record itself.

1.1 Pollen Analysis as a Proxy to Detect Anthropogenic and Climate Changes

The analysis of pollen grains of plants is a commonly used proxy to determine past vegetation changes over time. All trees, shrubs, and herbs produce pollen which when released by an individual plant becomes airborne and is deposited across the landscape as pollen rain (Behre, 1981). Pollen grains that fall into wetlands and lakes become buried, preserved in saturated, i.e. anaerobic conditions, which inhibits oxidation and decay. The deposited sediments are then cored providing a stratigraphic profile of pollen accumulation over time, which serves as a proxy of vegetation changes (Davis, 1967; Behre, 1981). Pollen analysts must consider pollen production rates vary by species and are correlated to the mode of pollen transportation. Plants that have windborne pollen, such as *Pinus* (pine) and *Quercus*, produce more pollen than plants pollinated by insects or animals. Arboreal pollen (AP) is over represented in the local vegetation, conversely nonarboreal pollen (NAP) is underrepresented, and so when interpreting the pollen record of a site, the pollen analyst needs to take pollen production into account (Davis, 1967; Faegri and Iverson, 1975).

Most pollen analysts evoke climate change as the causal mechanism for major shifts in the dominance of different plant species over time as interpreted by abundance changes of key taxa in pollen records up-core (i.e. from older to more recent times). Plant species have a particular temperature and precipitation range, so the presence and the amount of pollen grain values (percentages) of key plant taxa are interpreted in the context of modern growing limits of these species in that region (Seppa and Bennett, 2003). For instance, boreal forest species, such as *Picea* (spruce) and *Abies* (fir), are common in Subarctic Canada today where summer temperatures are cool (<18°C average July temperature) and the growing season is short (Ritchie, 1987). Therefore, when boreal species are identified in pollen samples from sites in the Midwest USA, this would indicate a climate significantly cooler than modern, such as during the Last Glacial Maximum (Grimley et al., 2009). Conversely, the pollen of deciduous tree and shrub species correlate with warmer temperatures (i.e. temperate climate). Pollen of Poaceae (grass family) and other herbaceous (forbs) taxa in the Midwest are correlated to a reduction in precipitation and possibly a warmer climate, and are classified as “xeric” taxa along with *Quercus* and *Carya* (hickory species) (Hupy and Yansa, 2008). Therefore, pollen records can provide interpretation of broad changes in temperature and precipitation over time (Davis, 1967; Behre, 1981; Jackson and Overpeck, 2000).

Pollen records that are not situated nearer archaeological sites they provide a paleoclimate record, given that climate change was the only or main driver of shifts in species dominance within plant communities over time. Palynological records that are derived from the analysis of lake/wetland sediments adjacent to archaeological sites, as in the case of the Hovey Lake record, then distinguishing between climate and anthropogenic impacts on paleovegetation is more challenging. For instance: a decrease in tree and shrub pollen (AP) regardless of species, and a corresponding increase of herbaceous plants (NAP) can be attributed to a decrease in precipitation and/or forest clearance by humans (Behre, 1981; Munoz et al. 2014). For conclusive proof of prehistoric farming, more evidence is required such as the presence of pollen grains of cultivars, plants domesticated by people such as *Zea mays* (maize) (Lane et al., 2010; Munoz et al. 2014). Less conclusive evidence for human disturbance is the presence pollen grains of native domesticate crops from the EAC. The EAC includes the species: *Iva annua* (marshelder), *Helianthus annuus* (sunflower), *Chenopodium berlandireri* (goosefoot), and *Cucurbita pepo* (squash), *Polygonum erectum* (knotweed), *Phalaris caroliniana* (maygrass), and *Hordeum pusillum* (little barley) (Smith, 2007). If EAC taxa are found in very high percentages that are above any background levels prior to human occupation, they may represent local agriculture (Smith, 2007). Similarly, a spike in the pollen abundance of other weedy plants, such as *Ambrosia* (ragweed), can also indicate of land clearance if there are supporting proxy data from pollen (cultivar pollen) or other proxy data sources that discredit a drought or interval of reduced precipitation (e.g., oxygen isotopes from lake sediments or cave speleothems) (Dorale et al., 1998). Therefore, care was exercised in the interpretation of prehistoric human landscape impacts in the Hovey Lake pollen record.

1.2 Problem Statement

Several prior pollen studies have been conducted in the southern Midwest, adjacent American Bottom (lowlands of the Mississippi River Valley), and Appalachians by some of the discipline's most renowned palynologists, including Hazel and Paul Delcourt, Daniel Royall, and Thomas Webb III. Of note, there has only been one previous pollen study in the Lower Ohio River Valley, and it is of Hovey Lake (Crisman and Whitehead, 1975). However, this earlier study lacks ^{14}C radiocarbon dates and therefore the interpretation of their pollen diagram is highly subjective. Additionally, the Crisman and Whitehead (1975) study was done at coarse temporal resolution, with 100 or more years between samples analyzed, and focused on covering the entire Holocene with divisions into pollen zones spanning ~1,000 or more years. Actually, the resolution of this study is comparable to the vast majority of the pollen records of the

Midwest, but such a coarse temporal reconstruction in these cases can fail to detect shorter (multi-centennial), yet significant, climatic episodes. For instance, the Medieval Warm Anomaly ~1150—700 cal yrs BP (AD 950—1250) and the Little Ice Age ~550—200 cal yrs BP (AD 1400–1750) were notable multi-centennial climate events that most likely impacted the food, fuel, and building resources of local human populations. Also, prehistoric archaeological record of Native American occupations could be of shorter duration than the scale of the vegetation reconstructions from these coarse-resolution pollen stratigraphies. Hence the need for a fine temporal resolution of pollen analysis of a lake adjacent to a known archaeological site which documents Native American agriculture. Such a pollen record should be able to detect the landscape impacts of these prehistoric aboriginal farmers, vegetation changes that probably were more subtle than what occurred later by Euro-Americans, who commenced widespread logging and agriculture in southern Indiana as early as ~200 cal yrs BP (AD 1750).

1.3 Research Objective

The objective of this M.S. thesis research was to conduct a fine-scale pollen analysis of lake core sediments collected from Hovey Lake in the southern Wabash Lowlands, for the intervals before, during and after the Hovey Lake Village occupation. The pollen record reconstructed here spans 1,260 to 200 cal yrs BP (AD 690 to 1750). The archaeological reports document that the adjacent village was inhabited for about 400 years within this interval (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). Sediments were analyzed at ~30-year intervals to capture the significant shifts in species dominance over time. The 30-year temporal scale is equivalent to the 30-year climate normals used in climatology for the historic period (World Meteorological Organization, 1989). Sediment cores were collected from the deepest part of Hovey Lake by Dr. Broxton Bird, Indiana University-Purdue University Indianapolis, Indianapolis in the summer of 2014 for his geochemistry analysis, and was made available for this pollen study, which followed standard laboratory protocols. This research specifically aimed to identify the relative impacts of deforestation and farming by Native Americans during the Mississippian period on the vegetation surrounding Hovey Lake, and to isolate signals indicative of land use from those of climate change, by answering these research questions:

1. *What was the species composition of the vegetation surrounding Hovey Lake prior to the establishment of the Hovey Lake Village (~1255—700 cal yrs BP; AD 695—1250)?*

The pollen record for this time provides a baseline reference to compare the subsequent effects (if any) the Hovey Lake Village inhabitants and/or climatic changes had on the landscape surrounding Hovey Lake. As mentioned above, it is important to identify the species composition of the forest prior to significant human settlement in the area, which was at ~700 cal yrs BP (AD 1300), based on archaeological data (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). Although human populations certainly occupied portions of the landscape, I hypothesized that at this time tree and shrub species are at their greatest abundance in the southern Wabash Lowlands as it was prior to the onset of Mississippian agriculture. Based on the location of Hovey Lake at the overlap of three diverse ecozones (Midwest, southern, and prairie taxa affiliates), the upland forest make-up was probably a *Quercus-Carya-Juglans* forest and the lowland forest make up dominated by *Acer-Populus-Fraxinus* (see Table A.1 in the Appendices for common names).

2. *What vegetation changes, if any, occurred when the Hovey Lake Village was occupied (~700—300 cal yrs BP; AD 1250—1650)?*

When the Hovey Lake Village was established, local forests were likely cleared for cultivation, but the wood was also used for fuel and building materials, hence the portion of the pollen record coeval with the duration of village occupation was closely examined. I hypothesized before conducting the analysis that this pollen zone would be characterized by a (1) positive association between a decline in arboreal pollen (AP) and a concurrent increase in herbaceous nonarboreal pollen (NAP), including that of weedy taxa such as *Ambrosia*; and (2) greater abundance of early successional shrub and tree species for this pollen zone. Included in the NAP should be those domesticate species of the EAC, which include *Iva annua*, *Helianthus annuus*, *Chenopodium berlandireri*, and *Cucurbita pepo* (Fritz, 1990, 1993; Smith, 2006, 2007, 2009). Unfortunately, most of these EAC crops can only be identified to genus or family based on their pollen, but their appearance in the pollen record at Hovey Lake would be significant. EAC species are domesticated from native plants that would still be locally common, so the pollen of domesticates are indistinguishable from the native plants. Therefore, the percentage of EAC taxa during the time of the Hovey Lake occupation will be compared to before and after this occupation when the pollen from these plants most likely came from non-domesticated plants, i.e. the "background level."

Conclusive evidence for Native American agriculture would be the presence of *Zea mays* pollen even if in low numbers; given it is a tropical exotic. *Z. mays* was an important food resource for the Native Americans living in the region during the time the Hovey Lake T-1 terrace was inhabited (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). Therefore, I hypothesis that the number of *Z. mays* pollen grains should be in the pollen record and increase when the village was occupied, and disappear when the village was later abandoned. There is a possibility that *Z. mays* could be present in the area prior to the Hovey Lake Village settlement. However, it is more likely that any *Z. mays* pollen recovered is directly associated with local human agriculture practices given that maize produces the largest of all pollen grains and hence is poorly dispersed (Lane et al., 2010).

3. *Did the vegetation around Hovey Lake change in response to the Medieval Warm Anomaly (MWA; ~1150—700 cal yrs BP; AD 950—1250)?*

Hovey Lake's location at the intersection of three diverse ecosystems, Midwest, southern and prairie should result in vegetation changes, even if climate changes are subtle, such as during the MWA. Indicators of a drying trend would be a decline in mesic tree species, such as *Fagus* and *Ulmus*, and an increase of *Quercus* and other drought-tolerant (xeric) taxa. There would also likely be a greater pollen abundance of prairie species, particularly Poaceae, weeds such as *Ambrosia*, and some Cyperaceae (sedge family). These more xeric species today are found in the drier uplands surrounding Hovey Lake (Braun, 1950) and would be expected to increase in pollen grain values when the climate became dry and warm.

4. *Did the vegetation around Hovey Lake change in response to the Little Ice Age (LIA; ~550—200 cal yrs BP; AD 1400–1750)?*

Again, the overlap of the three ecozones in the Hovey Lake area should result in vegetation shifts in times of climate changes, including that of the LIA. It is expected that with the cooler and moister LIA climate there would be an increase in more lowland (hydric) taxa, including *Salix* (willow), *Populus*, and Cyperaceae, in addition to a decrease in taxa adapted to disturbance and warmer/drier conditions that were more abundant earlier, during the MWA.

5. *Which vegetation changes can be attributed to anthropogenic forces, and which to climatic forces of the MWA or the LIA?*

Human disturbance was probably a major, if not the main cause of vegetation change around Hovey Lake during the time of Native American occupation, and certainly later during the Euro-American period. However climate change probably also played a role during both intervals. As described above, distinguishing between climate and anthropogenic impacts on vegetation is challenging, both may effect vegetation at the same time and discerning their relative impacts on vegetation based on pollen analysis is tricky. The presence of *Zea mays* pollen can conclusively documents land use, and to a lesser extent, great abundance of EAC taxa may prove an anthropogenic signal. Although the latter occurs naturally in this region and may become more numerous during drier climate intervals or natural disturbances (i.e. fire). Aiding the task of distinguishing the landscape impacts of Native American forest clearance and farming from that of climate change are comparisons of the patterns and timing of the pollen record to that of other data sources—particularly, the archaeological record of the Hovey Lake Village (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004) and other paleoclimate records from the region (e.g., Delcourt, 1979; Watts, 1980; Royall, 1988; Ollendorf, 1993; Jackson et al., 2000; Wanner et al., 2008; Mann et al., 2009). Comparisons of these records hinge upon the correlation of ^{14}C radiocarbon dates, between those obtained for pollen stratigraphies and those from archaeological deposits.

1.4 Outline of Thesis

This thesis is composed of seven chapters. The topic and research questions are presented here in Chapter 1. The following two chapters focus of the history of Hovey Lake and its surrounding area. Specifically, Chapter 2 provides a literature review, which summarizes previously conducted archaeological research in the Midwest region, as well as the paleoecology and paleoclimate of the Wabash Lowlands, Lower Ohio River Valley, and surrounding areas. The paleoecology and paleoclimate are reconstructed by proxy data from a variety of sources (pollen and plant macrofossil records from other lake sites, oxygen isotopes of cave speleothems, Mg/Ca ratios from lacustrine ostracods and Greenland ice cores) which are used to reconstruct the regional vegetation and climate changes over time. The main topics are presented chronologically, beginning briefly with the geomorphology, which shaped the landscape and the archaeological record from Paleoindian to historic times. Chapter 3 includes a description of the study site, including relevant details pertaining to the physical geography and cultural history of the region. Chapter 4 presents the materials and methods used to prepare sediment samples to extract pollen grains and details how these grains were identified, tallied and analyzed for this thesis's research. Chapter 5 presents the results, as illustrated by a pollen diagram for Hovey Lake, as well as some interpretation of the major findings based on interpreting this diagram. Chapter 6 contains compares interpretations of the Hovey Lake pollen record to (1) prior archaeological reconstructions of the Hovey Lake Village occupation, as well as (2) to other pollen and paleoclimate studies in the region, with the purpose of distinguishing between regional climate change and local Native American land use over the last 1,300 cal yrs BP. Finally, Chapter 7 outlines the broader significance of this study and proposes future implications of this research.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

This chapter provides a review of the environment and the people of the Wabash Lowlands in southwestern Indiana and the surrounding regions during the Holocene (~11,600 cal yrs BP to present). During the Holocene, vegetation varied geographically and temporally across the Midwest USA. Proxy data from the analyses of lake sediments, such as fossil pollen, plant macrofossils, charcoal, stable oxygen isotopes, and ostracods, as well as tree-ring records (where available), are used to reconstruct the ecology and climate of an area. Similarly, archaeological artifacts and stratigraphy are employed to infer the cultural, social, political, and economic characteristics of prehistoric Native American populations and to assess their changing interactions with the surrounding environment before the arrival of Euro-Americans. ^{14}C radiocarbon dating of organic materials (plant, bone, shell) from stratigraphically distinct cores or excavations also provides chronologies that facilitate correlation and comparison of the information derived from all these different datasets and their respective settings. To note, all ^{14}C radiocarbon ages, regardless of context and material dated, zero to AD 1950, because of ^{14}C enrichment resulting from nuclear explosions just before and after this date (Stuiver et al., 1998).

One issue regarding the archaeological evidence is that academic terms for cultures, phases, and periods vary geographically depending on the amount of research conducted, and when classification schemes were devised by archaeologists. There are also spatial and temporal differences in the types and styles of cultural artifacts recovered and their classification, and the dating results can vary between different archaeological occupation levels and sites. For the purpose of this thesis's research, a broader archaeological categorization of cultural period transformations, phases, and complexes in the Midwest is followed (Table 2.1), since most archaeologists have abandoned the formal McKern (1939) system (Yerkes, 1988).

*Table 2.1: Archaeological, Climatic, and Geologic Time Periods Used in this Thesis. *Present in cal years BP is equivalent to AD 1950.*

Archaeological Time Periods of Southwestern Indiana	Time Range ~cal year BP (~years AD)	Climatic Time Periods of North America	Time Range ~ cal years BP (~years AD)	Geological Time Period
HISTORICAL TO PRESENT	150 to 0 (1800 to *1950)			**HOLOCENE** ~11,600 years BP to present
VACANT QUARTER	350 to 150 (1600 to 1800)	**LITTLE ICE AGE**	550 to 200 (1400 to 1750)	
UPPER MISSISSIPPIAN	700 to 350 (1250 to 1600)			
MIDDLE MISSISSIPPIAN	1,050 to 700 (900 to 1300)	**MEDIEVAL WARM ANOMOLY**	1,000 to 750 (950 to 1250)	
TERMINAL WOODLAND / EMERGENT MISSISSIPPIAN	1,200 to 1,000 (800 to 1000)			
LATE WOODLAND	1,500 to 1,000 (500 to 1000)			
MIDDLE WOODLAND	2,000 to 1,500			
EARLY WOODLAND	3,000 to 2,000			
LATE ARCHAIC	5,000 to 3,000	**HYPSITHERMAL**	7,800 to 4,500	
MIDDLE ARCHAIC	8,000 to 5,000			
EARLY ARCHAIC	10,000 to 8,000			
PALEOINDIAN	18,500 to 11,600	**YOUNGER DRYAS**	12,900 to 11,600	**PLEISTOCENE** ~2,500,000 to 11,600 years BP
		BØLLING-ALLERØD	14,500 to 12,900	
		TERMINATION I **WISCONSIN GLACIATION** ***LAST GLACIAL MAXIMUM***	19,500 to 11,600 110,000 to 19,500 *25,000 to 19,500*	
		ILLINOIAN GLACIATION	190,000 to 130,000	
		PRE-ILLINOIAN GLACIATION	All Pleistocene glaciations prior to 500,000	

(McKern, 1939; Price, 1985; Smith, 1992; Wymer, 1993; Grove and Switsur, 1994; Larson and Schaetzl, 2001; Clark et al., 2002; Cobb et al., 2002; Dyke et al., 2002; Cronin et al., 2003; Anderson et al., 2004; Pauketat, 2004; Applegate, 2005; Jefferies, 2008; Panyushkina et al., 2008; Abrams, 2009; Mann et al., 2009; Muller, 2009; Cronin et al., 2010; Jones and Johnson, 2012).

2.1 The **Environment** Before People

Much of the Midwest was covered by, or affected by, multiple Pleistocene glaciations (~2.5 to 0.01 million cal yrs BP) (Clark et al., 1999). The furthest extent of penultimate glacial ice is not exactly known, but Pre-Illinoian glaciation till (~245,000 cal yrs BP) exists as far as present day southern Illinois, Indiana, and Ohio (Figure 2.1) (Counts et al., 2014). The Laurentide Ice Sheet (LIS) of the Last Glacial Maximum (LGM; ~20-19,500 cal yrs BP) originated in northern Canada, but this ice mass did not advance as far south as Hovey Lake in the Wabash Lowlands (Figure 2.1). The glacial ice still had a profound effect on the geomorphology of the landscape south of the LGM margin, including massive glacial meltwater discharge and loess deposition (Pielou, 1991; Royall et al., 1991). Based on pollen analysis and $\delta O^{16}/O^{18}$ratios from Greenland ice cores, the LGM climate of the Midwest was much colder and drier than that of today (Clark et al., 1999). Temperatures averaged ~-24.0 °C in January and ~16 °C in July, with annual precipitation at ~60.0 cm (Overpeck et al., 1992; Jackson et al., 2000). The extreme cold and dry climate is due to orbital parameters that defined the intensity of insolation at northern latitudes, causing glaciers to form at high latitudes increasing the earth's overall albedo and hence cooling (Clark et al.,

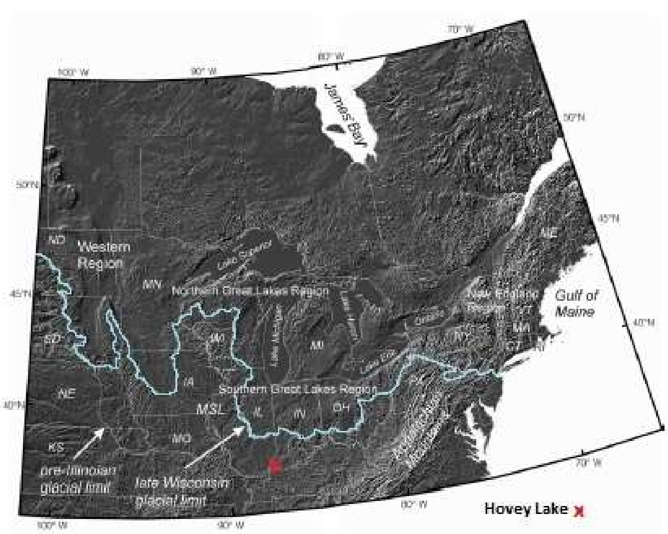

Figure 2.1 Extent of the Laurentide Ice Sheet during the Last Glacial Maximum. Figure adapted from Figure 1 of Mickelson and Colgan, 2003.

1999). Anticyclonic circulation over the massive Laurentide Ice Sheet, which covered north-central and northeastern North America, produced cold katabatic winds that chilled areas close to the ice front (Pielou, 1991; Clark and Mix, 2002). This high-pressure system also deflected the polar jet stream south, resulting in heavy precipitation in the Midwestern and southern USA during the LGM (Kutzbach et al., 1998).

The colder climate and high winds along the retreating ice margin (beginning ~ 19,500 cal yrs BP) was a hostile environment to most plants, as reconstructed from pollen and plant macrofossil analyses. The first vegetation to colonize the recently deglaciated landscape was tundra-like, with species such as Cyperaceae (sedge), *Salix* (willow) initially, and over time followed by boreal species, particularly *Picea* (spruce). These pioneering plants followed the northward recession of the ice margin (Jacobson et al., 1987). Further south of the ice, the vegetation occupying the ancient Ohio River Valley was a boreal forest dominated by *Picea glauca* (white spruce), with some diploxylon *Pinus* (likely *P. banksiana*, jack-pine), and a few *Abies* (fir). This vegetation may have included small numbers of mesic hardwoods such as *Ostrya/Carpinus* (hophornbeam/hornbeam), *Quercus* (oak), and *Fraxinus nigra* (black ash), although some of this pollen was likely of long-distant origin, rather than from local trees (Jacobson et al., 1987). The understory consisted of primarily *Artemisia* (wormwood) in upland locales and Cyperaceae in the lowlands (Royal et al., 1991; Wilkins et al., 1991; Williams, 2002; Muller, 2009). The conifer-dominated forests of the Ohio River Valleys were more open than the closed canopy forests of today, because of the cooler air and water temperatures (Watts, 1980; Royall et al., 1991). To the west, in the Central Mississippi River Valley, there were broad expanses of Poaceae (grass family) prairie dotted by cold-temperate *Picea* trees (Jackson et al., 2000).

There is currently little to no evidence of humans inhabiting the North American continent until well after the LGM, during the latter part of the Termination I (deglaciation) (Pielou, 1991; Jefferies, 2008). The earliest evidence of humans south of the LIS is at ~16,200 cal yrs BP from dated skeletal remains, but the exact dates are contentious among archaeologists (Meltzer, 1989; Anderson and Gillam, 2000; Pitblado, 2004; Goebal et al., 2008). There is solid evidence humans occupied the shoreline of glacial Lake Chicago in what is now Wisconsin at ~14,500 cal yrs BP, and consumed mammoth (Joyce, 2006). We can infer the earliest human populations in the Lower Ohio River Valley encountered an environment still heavily influenced by the Laurentide Ice Sheet to the north, although direct evidence is lacking. Paleoenvironmental data indicate meltwater streams had high discharges and were responsible for considerable alluvial sedimentation, and a cool climate existed, evidenced by patches of boreal spruce in the wetlands with cool-temperate-adapted deciduous hardwoods on the uplands (Grimley et al., 2009).

2.2 Paleoindian Paleoenvironment and Archaeology (14,500–11,600 cal yrs BP)

The environment of early Paleoindians at the end of the Pleistocene between ~14,500 and 11,600 cal yrs BP, during the latter part of Termination I (which started ~19,500 cal yrs BP), was a time of great change in climate and vegetation. The warming trend accelerated with significant glacial retreat during the Bølling-Allerød (~14,500-12,900 cal yrs BP), followed by the Younger Dryas cool stadial (~12,900 to 11,600 cal yrs BP) (Yu et al., 1997; Panyushkina et al., 2008). During the Bølling-Allerød, the ancestral Ohio River and tributaries were braided streams that transported and deposited large amounts of sediments. When the ice margin moved farther north, the ancient Ohio River began to incise into the previously deposited glacial outwash and became ephemeral sluiceways for a tremendous amount of glacial melt-water (Delcourt et al., 1999; Muller, 2009). The braided stream channels, once abandoned, first were colonized by herbaceous and riparian shrub species followed by a *Quercus-Carya* (oak-hickory) forest (Royall et al., 1991; Delcourt et al., 1999). The arrival of temperate and warm-adapted taxa in the study area during the Bølling-Allerød is in part due to the northward retreat of the Polar Frontal Zone near the shrinking glacial ice as well as greater precipitation than before, starting at ~14,000 cal yrs BP, which supported these trees (Delcourt et al., 1999; Jackson et al., 1997). The vegetation of the Midwest at this time consisted of conifers, such as *Picea*, *Abies*, *Larix* (larch), and diploxylon *Pinus* (again, probably *P.*

banksiana) and hardwoods that included *Quercus*, *Alnus* (alder), *Betula* (birch), *Fraxinus* (ash), and *Ostrya/Carpnius* (King, 1981; Smith, 1984; Jacobson et al., 1987; Shane, 1987; Wilkins et al., 1991; Liu et al., 2013).

Pollen data from over 100 lakes in the Midwest indicate that during the Younger Dryas moisture declined significantly, and there was a distinct north-south latitudinal temperature gradient more pronounced than that of today (Jackson et al., 1997). In the Great Lakes region, the species composition of the boreal forest was enriched, from having only a few cold-adapted species dominated by *Picea*, to now including newly arrived temperate *Pinus* and *Fraxinus nigra*-type. Meanwhile, *Pinus* density decreased in the central Midwest due to the influx of more hardwoods (Watts, 1980; Holloway and Bryant, 1985). *Quercus-Carya* and *Quercus-Ostrya/Carpinus* forests expanded their range northward from the southern Midwest and southeastern coastal plain into the study area, while the distribution of the boreal forest in the Great Lakes region rapidly shifted northward into Canada over time (Watts, 1980; Royall et al., 1991). There was also a strong declining west-east precipitation gradient south of the Great Lake region, in central Illinois, Indiana, and Ohio, as evident in the pollen record specifically between ~14,000 to 7,000 cal yrs BP (Jackson and Overpeck, 1997; Jackson et al., 2000). The prairie grasses and shrubs of the Central and Great Plains at this time were dotted with *Ulmus-Fraxinus* (elm-ash) stands (Jacobson et al., 1987; Williams, 2002), which graded into the newly formed Midwest deciduous forests, which recently migrated northward from the southeastern coastal plain, and the Lower Mississippi Valley (Watts, 1980; Delcourt et al., 1999).

The vegetation underwent significant changes about the time of the Younger Dryas at the end of the Pleistocene at ~11,600 cal yrs BP. Warmer temperatures that approximate modern levels resulted in a longer growing season that favored deciduous trees over conifers (Delcourt, 1979; Anderson and Sassaman, 2004). *Ulmus*, among other warmer-adapted tree taxa, migrated northward from the southern Midwest, creating species-diverse hardwood forests in upland and lowland habits that continued, with minor range fluctuations, to the present day (Jacobson et al., 1987; Williams, 2002). In the Lower Ohio River Valley and adjacent Cumberland Plateau, specifically, the upland vegetation consisted of boreal taxa remnants, including *Pinus banksiana* and *Picea*, which were being rapidly replaced by mixed mesophytic hardwoods (Delcourt, 1979; Delcourt, 1987; Muller, 2009). Based on pollen records from numerous lakes across the Midwest, the first hardwood trees to arrive in the Lower Ohio River Valley and adjacent Cumberland Plateau were *Fraxinus, Ostrya/Carpinus, Carya, Fagus* (beech), and Ulmus trees and *Salix* shrubs. The species arrived into the area during the Bølling-Allerød, and later followed by greater numbers of *Acer* (maple) and *Betula* (Delcourt, 1979; King, 1981; Smith, 1984; Jacobson et al., 1987; Shane, 1987; Wilkins et al., 1991; Liu et al., 2013). Farther south at the same time in the Lower Mississippi Valley and lowlands of the Ozark Plateau, *Fraxinus-Salix* vegetation dominated the sluiceways, while farther north in the Central Mississippi Valley the lowlands were occupied by a *Picea-Salix* forest (Delcourt et al., 1999).

The first people to colonize North American experienced these dramatic changes in climate and vegetation during the Bølling-Allerød and Younger Dryas. See Anderson and Gillam (2000), Meltzer (2003 and 2009), Waters and Stafford (2007), Goebel et al. (2008), Meltzer and Holliday (2010), Pitblado (2011) for more detail on the colonization and distribution of the first people in North and South Americas. Within the Lower Ohio River Valley the earliest evidence for hunter-gatherer Paleoindian (~18,500 to 14,500 cal yrs BP) populations is a lithic complex of a range of fluted projectile types: from basic large-biface points to Dalton-esque projection points, dated to ~13,500 cal yrs BP in western Kentucky, (Straus et al., 1996; Anderson and Sassaman, 2004; Jefferies, 2008). Paleoindian archaeological sites are rare. Little physical material is left behind and preserved along the Ohio River, because of site destruction by the drastic changing course of the river and material becoming buried beneath meters of overbank deposits (Jefferies, 2008; Counts et al., 2014). Paleoindian archaeological sites are typically located on T-1 or T-2 river terraces along the Ohio River, where both upland and lowland food and lithic resources were readily available. Unfortunately, cultural remains are thus susceptible to burial by alluvial deposits and fluvial destruction (Jones and Johnson, 2012).

Around Paleoindian campsites, debitage and other artifacts are limited, suggesting that Paleoindians traveled in bands of 500 to 1,500 individuals and occupied a single site for only a short period of time (McMillan and Klippel, 1981; Anderson and Sassaman, 2004). The social organization of Paleoindian populations is not well known or understood given the paucity of data. What is known, however, is that the Paleoindians were generalists who hunted both small and big game, including mastodons and other megafauna that later went extinct, at ~13,500 cal yrs BP in the region (Morse et al., 1996; Anderson and Sassaman, 2004; Jefferies, 2008; Saunders et al., 2010). Paleoindians also gathered nuts of local mast trees, probably those of *Carya* and *Juglans* (walnut), various berries and tubers (Morse et al., 1996; Anderson and Sassaman, 2004; Jefferies, 2008). During the snowy winter months, mobility likely decreased. Groups dispersed across the region to better forage for game and other resources (Anderson and Sassaman, 2004). Diverse "tool kits" of lithic projectiles, butchering implements, hide working tools, and adzes (used to make wooden tools) have been found in western Kentucky, northern Missouri, and elsewhere, indicate the presence and the distribution of Paleoindians in this region. The tool kits also imply that Paleoindians inhabited a wide variety of environments and utilized various tools to obtain local resources (McMillan and Klippel, 1981; Jefferies, 2008). Paleoindian populations took advantage of the north-south vegetation (habitat) gradient, traveling between the tundra and boreal northern forests in the Great Lakes region, the mixed coniferous-deciduous forests in the southern and central Midwest (Jefferies, 2008).

2.3 Archaic Paleoenvironment and Archaeology (11,000—3,000 cal yrs BP)

The transition from the Late Pleistocene to the Holocene in the Midwest is marked by a significant change in vegetation influenced by climatic changes. At the start of the Holocene, at ~11,600 cal yrs BP, average annual temperatures were as much as 2.5 °C cooler than they are today (Yerkes, 1988). Upland vegetation of the Lower Ohio River Valley and Cumberland Plateau was comprised of mixed mesophytic closed forests of *Quercus-Carya* in areas of sandier soils and *Fagus, Tsuga* (hemlock), and *Tilia* (basswood) in mesic, fertile (fine-grained) soils. Bottomland forests included *Fraxinus, Ostrya/Carpinus, Betula*, *Juglans*, *Ulmus*, *Populus* (cottonwood) and *Acer* (Delcourt, 1979; Delcourt et al., 1986). Southern subtropical taxa, such as *Taxodium* (cypress), *Nyssa* (gum or tupelo gum), and *Quercus* (probably *Q. virginiana*, southern oak), first appear in the pollen grain and macrofossil records, and are interpreted as having occupied moist lowlands, including swales (Yerkes, 1988; Muller, 2009). At this time, there is little evidence of migrating southern taxa of *Pinus* (Delcourt, 1979; Delcourt et al., 1986). In addition herbaceous, non-arboreal pollen (NAP), plants were minor components of these forests (Delcourt, 1979; Delcourt et al., 1986). Within the Central Mississippi River Valley to the west, the uplands were covered by *Quercus-Fraxinus* forests with an initial minor abundance increase of *Corylus* (hazel) (Royall et al., 1991). In central Illinois, further north, vegetation was similar but dominated by *Quercus-Carya* forests that contained patches of *Quercus*-dominated barrens that included *Ambrosia* (ragweed) and other prairie Poaceae species (King, 1981). In the southern Great Lakes region, *Quercus*, *Acer*, *Ulmus*, *Fraxinus*, and *Ostrya/Carpinus* had already begun to encroach on the predominantly boreal forests dominated by *Picea*, *Abies*, *Larix*, *Betula papyrifera* (paper birch), and the temperate *Quercus* (Webb et al., 1983; Jackson et al., 1997).

Starting ~9,400 cal yrs BP, the climate became significantly warmer and drier, and is known as the Hypsithermal or the Holocene Climatic Optimum (King, 1981). The Hypsithermal is a time-transgressive paleoclimatic event reconstructed from pollen data and other proxies, including plant and animal micro- and macrofossils from lakes as well as oxygen isotopes from lacustrine and cave sites. Compared to the Younger Dryas, mean annual temperatures increased by 1.0 to 4.5°C (Yerkes, 1988), where average July temperatures rose by 0.5 to 2.0 °C (Bettis and Hajic, 1995), indicating that about half of the warming occurred during winters. Milankovitch orbital forces explain the early Holocene warming peak insolation from ~9,000—6,000 cal yrs BP during the earliest part of the interglaciation (Kutzbach et al., 1998).

Frequent and severe droughts on the Great Plains and mountainous West and greater dryness in the Midwest are well documented during the Hypsithermal. In the Midwest, the prevailing zonal (west-to-east) flow of dry Pacific westerlies were responsible for expanding the "prairie peninsula," an eastward range extension of grassland from the Central Plains into the now forested (and converted to agriculture) Midwest as far east as western Ohio (Shane and Anderson, 1993; Shuman et al., 2002). The prairie peninsula would have continued to expand eastward if it were not for the influence of the (weakened compared to today) Gulf of Mexico air mass, (Webb et al., 1983). The combination of the drier Pacific air mass, decreased solar output, and decreased albedo of the LIS contributed to the lessening of subtropical moisture intrusion into the midcontinent from the Gulf of Mexico air mass at this time (Perry and Hsu, 2000; Shuman et al., 2002). Consequently, annual precipitation dropped by 10—25% during the Hypsithermal, given the responses recorded in multi-proxy data (Bettis and Hajic, 1995). Maximum aridity of the Hypsithermal occurred in the Midwest at ~7,800 to 5,800 cal yrs BP due to development of a dominant east-west precipitation gradient. This was largely driven by the dominance of the dry Pacific air mass, as opposed to a north-south precipitation gradient controlled primary by the interactions of the cool-cold/dry continental Polar air mass centered over the LIS with the warm-moist southern Gulf of Mexico air mass (Baker et al., 1992; Bettis and Hajic, 1995).

Between ~8,900 to 7,800 cal yrs BP, the prairie peninsula stemming from the Central Plains fully extended, reaching into the southern Great Lakes region of Lower Michigan and into parts of western Ohio (Webb et al., 1983; Baker et al., 1992). The uplands of these regions experienced significant drying, which led to the spread of *Quercus-Carya* forests and a small numbers of mesic taxa *Acer* and *Fagus* (Wilkins et al., 1991; Delcourt et al., 1986). Populations of mesic hardwoods, such as *Ostrya/Carpinus*, and relict *Picea* declined significantly in the Lower Ohio River Valley and the Cumberland Plateau at this time and soon after *Picea* disappears from the pollen record (Wilkins et al., 1991).

The continued warming and drying effect of the Hypsithermal climate led to the abandonment of many minor stream systems (Delcourt et al., 1999). Generally, with the reduced precipitation, the distribution of riparian vegetation in marshes and midlevel abandoned stream terraces in the southern Midwest was restricted (Delcourt et. al., 1999). However, in the Ohio and Mississippi River Valleys, the Hypsithermal had a slightly different impact on vegetation; swampy lowlands did not completely dry up. Rather, *Salix* and other thicket shrub taxa, along with *Arundinaria* (cane), increased greatly in abundance when river and lake levels dropped (King and Allen, 1977; King, 1981; Delcourt et al., 1986; Wilkins et al., 1991). During the early Holocene, higher moisture availability in the southeastern coastal plain and the Cumberland Plateau, compared to the southern Great Lakes region to the north is attributed to greater precipitation from the onshore, northward movement of the subtropical Gulf air mass, which elevated stream and lake levels (Baker et al., 1992; Shuman et al., 2002).

In central Illinois, there were several important changes to the local flora by ~8,500 cal yrs BP (e.g. Holloway and Bryant, 1985). *Tsuga* and *Ulmus* forests became denser in lowlands and uplands were covered by prairie and other drought tolerant species, including *Ambrosia*, *Artemisia*, *Amorphia canescens* (leadplant), *Petalostemum* (prairie clover), and members of the Chenopodiaceae/Amaranthaceae (abbreviated to Cheno-Am family), Asteraceae (daisy family), and Poaceae families (Holloway and Bryant, 1985; King and Allen, 1977; Baker et al., 1992). Within ~500 years (from 8,500 to 8,000 cal yrs BP), the deciduous forests on uplands were almost completely replaced by prairie species, Poaceae and other herbs (Holloway and Bryant, 1985). The once mesic temperate forests of *Fagus*, *Tilia*, *Acer saccharum* (silver maple), *Ostrya/Carpinus*, and *Juglans* along the southern border of the Prairie Peninsula were now thinning *Quercus-Carya* forests that had a grass-dominated understory (King, 1981; Delcourt et al., 1999). *Nyssa-Ulmus-Platanus* (gum-elm-sycamore) forests and mixed forest of *Planera* (water elm), *Celtis* (hackberry), *Acer negundo* (box elder), and *Betula* continued to occupy the low terraces, floodplains, abandoned valley trains and ephemeral sluiceways (Delcourt, 1987; Delcourt et al., 1999).

Early Archaic (~10,000 to 8,000 cal yrs BP) and Middle Archaic (~8,000 to 5,000 cal yrs BP) people had to adapt to this changing environment. These archaeology sites are not often discovered in closed upland and lowland wooded regions (Delcourt et al., 1986). The majority of sites from the Archaic are found in caves and rock shelters, located in central Kentucky and Illinois and have multiple occupation levels (Anderson and Sassaman, 2004; Jefferies, 2008). The amount and location of Archaic cultural deposits discovered may be a result of unintentional bias of cave exploration and survey compared to finding sites in other geomorphic settings like heavily wooded areas. Archaic lithic technology is considered more "advanced" than Paleoindian lithics assigned. Regional styles began to develop throughout the Midcontinent during the Early Archaic, based primarily on the appearance of Kirk style (corner notched) or Big Sandy (side-notched) points, a type of post-Dalton stylized lithics (Morse et al., 1996; Anderson and Sassaman, 2004; Muller, 2009). During this period the atlatl was also developed, which significantly altered big game hunting practices (Morse et al., 1992). Chert sources for projectiles were initially a mix of local and more distant proveniences, indicating that Early Archaic populations were still highly mobile. Over time more local sources were used, which suggest decreased territorial ranges, an idea supported by a variety of archaeological data indicating sedentism with increased human population density (Morse et al., 1992; Anderson and Sassaman, 2004; Jefferies, 2008). The archaeological data also indicate that populations strategically moved to other habitats to utilize a diverse range of resources throughout the year, whereas within-season movement was less frequent and limited to travel to nearby locations (Stafford, 1994).

Several researchers have suggested that significant dietary diversification took place in the Early Archaic, when human populations adapted to decreased resources, associated with shifting plant diversity caused by the Hypsithermal warming and drying (King and Graham, 1981; Delcourt et al., 1986; Jefferies, 2008). Macrobotanical analyses of charcoal and seeds from Early Archaic hearths indicate that the Natives were using primarily the wood of *Quercus*, *Gleditsia* (locust), and *Carya* as fuel (Delcourt et al., 1986; Stafford, 1994). Charred seeds, fruit, and cultigen remains from Cumberland Plateau sites document the introduction and adoption of exotic cultigens, such as *Cucurbita pepo* sp. *ovifera* (gourd), as well as utilization of wild plant resources, including *Lagenaria siceraria* (bottle gourd) and wild *Iva annua* (marsh elder/sumpweed) by 8,000—7,000 cal yrs BP (Delcourt et al., 1986; Fritz, 1990). A variety of native wild plants were first collected by Native American populations from presumably floodplain habitats. Later, these species were cultivated throughout the Southeast, Midwest and parts of the Northeast regions of North America (Delcourt et al., 1986; Smith, 1992). The first members of the Eastern Agricultural Complex (EAC) cultivated identified were *Iva annua*, *Chenopodium berlandieri* (goosefoot/lambsquarters), *C. pepo* sp. *ovifera*, and *Helianthus annuus* (sunflower) (Delcourt et al., 1986; Smith, 1992; 2006; 2007). Later additional native taxa were added to the EAC collective to include the cultivated *Polygonum erectum* (knotweed), *Phalaris caroliniana* (maygrass), and *Hordeum pusillum* (little barley). Prior to ~4,500 cal yrs BP there is little evidence EAC plants were domesticated versions, but rather predecessors to later indigenous domesticated species (Smith and Yarnell, 2009).

By the Middle Archaic (~8,000 to 5,000 cal yrs BP), the Hypsithermal-induced climate certainly affected Midwest human populations (Jones and Johnson, 2012). Summers were warmer and drier, and winters cooler across the continent, as compared to today (Anderson and Sassaman, 2004). Middle Archaic cultural deposits are found deeply buried along abandoned meanders and on first-order terraces of the Ohio River, which suggest high overbank sediment deposition during this time (Bettis and Hajic, 1995). Mobility of Middle Archaic populations changed from residential mobile groups to more foraging subsistence strategies, as indicated by smaller amounts of non-local chert and continued development of task-specific lithic, bone, and (probably) wooden tools (Jefferies, 2008). Storage pits dated to this time are rare compared to those of the Late Archaic (Stafford, 1994). Large grooved axes and spear throwing weights began to appear in the archaeology record for this period (Anderson and Sassaman, 2004; Jones and Johnson, 2012). The increase in artifacts from Middle to Late Archaic sites suggest that settlements along medium-sized river drainages were becoming occupied for generally longer periods of time (Jones and Johnson, 2012). Residential mobility was on a declining trend; however, this trend was not ubiquitous among all Middle Archaic populations (Stafford, 1994). Some populations settled in larger groups and focused primarily on foraging and potentially some farming in lowlands where water resources provided diverse resources, whereas other, smaller Middle Archaic populations remained highly mobile, hunting and gathering across wide territories that included both lowland and upland areas (Jefferies, 2008).

With increased human populations came a restriction in their mobility and territory, which is attributed to a decrease in resources, forcing the populations to constrict their territorial ranging in more centralized locations (Anderson and Sassaman, 2004; Muller, 2009). A reduction in the number of lower Middle Archaic sites, compared to earlier, suggests that there was depopulation of the uplands in the Cumberland Plateau, and it is thought that many of these groups disbanded temporarily into smaller wandering bands within a limited area (Stafford, 1994; Delcourt et al., 1998). The reduction in AP taxa recovered from lakes and swales dating to the Hypsithermal has been largely attributed to the dry climate, but another possibility is that Middle Archaic populations cleared the forests (by girdling and possibly fire) for fuel and to promote the growth of light-demanding, nut-producing trees (*Quercus*, *Carya* and *Juglans*) (Wilkins et al., 1991). Charred wood analysis of hearths indicates that in addition to *Quercus*, *Gleditsia triacanthos* (honey locust), and *Carya*, there was an increase in *Fraxinus* and *Juglans* charcoal towards the end of the Middle Archaic, possibly indicating greater tree diversity as the effect of Hypsithermal was waning (Delcourt et al., 1986). Macrobotanicals provide evidence for incipient agriculture during the Middle Archaic, in that wild *Cucurbita* were beginning to be manipulated for larger seeds and thicker rinds (Anderson and Sassaman, 2004), and wild (i.e. smaller) *Iva annua* seeds are present (Fritz, 1990).

Hypsithermal warming and drying diminished in some areas as early as ~5,700 cal yrs BP, which was when the prairie peninsula in the southern Midwest began to retreat westward, back to the Central Plains, where *Quercus*-prairie barren uplands and lowlands persist to this day (King, 1981; Holloway and Bryant, 1985). In the Lower Ohio River Valley and Cumberland Plateau there was a 1,200-year lag in the shift to more forest cover than compared to the southern Midwest, which heralds the end of the Hypsithermal. The peak of prairie species abundance in the Lower Ohio River Valley and Cumberland Plateau occurred at ~4,500 cal yrs BP, at which time there were minor amounts of deciduous forest taxa, most commonly in the form of grassy barrens with scattered xeric-adapted trees, particularly *Quercus* and *Carya* (Wilkins et al., 1991). There was also greater fire occurrence (indicated from charcoal) and a decline in the abundance of *Tsuga*, a conifer native to the northern Great Lakes region today, suggestive of drier conditions until ~4,500 cal yrs BP (Delcourt et al., 1998). Alternatively, *Tsuga* decline could be due, in part or solely, to the hemlock looper—an insect infestation at ~4,800 cal yrs BP. However, charcoal and NAP prairie taxa suggests a drier climate was the main driver of vegetation change at this time (Delcourt et al., 1998). This interpretation is supported by independent paleoclimate reconstructions of severe and persistent drought having occurred in the Upper Midwest from 4,400—4,000 cal yrs BP (Booth et al., 2005).

The onset of greater humidity and precipitation did vary spatially during the transition from the middle and late Holocene. Between ~4,500 and 2,600 cal yrs BP entrenchment and lateral channel migration of the Ohio River occurred in the small valleys of older Holocene alluvium suggestive of greater precipitation (Bettis and Hajic, 1995). In the Ohio River lowlands, after the *Quercus*-*Carya* savanna peak at ~4,500 cal yrs BP, populations of *Quercus* began to decrease and were replaced by more mesic taxa, including *Juglans* and *Fraxinus* (Delcourt et al., 1986). In contrast, *Quercus* became significantly more numerous in the uplands (Delcourt et al., 1998). Earlier (by ~5,000 cal yrs BP) a Cyperaceae-*Salix* community occupied lakes and swales, which over time included greater numbers of swamp trees, such as *Ulmus*, *Nyssa*, *Taxodium*, *Planera*, and *Acer rubrum* (red maple/swamp maple), in the Central Mississippi River Valley (Royall et al., 1991). The greater availability of swamp habitat and colonization of lowlands by hydric and mesic deciduous trees indicates a precipitation increase attributed to the end of the Hypsithermal (Delcourt et al., 1979).

During this middle to late Holocene transition, the vegetation of the Ozark Plateau uplands remained primarily xeric, specifically a *Quercus-Carya* forest, which began to encroach on the lowland forests dominated by *Liquidambar-Ulmus* (sweetgum-elm) (Stafford, 1994; Delcourt et al., 1999). Plant communities dominated by *Salix-Arundinaria* and in other places *Taxodium* and *Nyssa* (black gum or tupelo gum) were intermittently distributed in the sluiceways, drainages and shifting meanders of the river valleys as expected for swamp tree and shrub taxa (Delcourt et al., 1999).

The Late Holocene, the last 4,000 cal yrs BP (although some scientists recognize the last 200 years as a separate geologic epoch, the Anthropocene), is characterized by cooler and moister climatic conditions in eastern North America as compared to before and hence greater tree density, particularly of mesic species (Williams, 2002). By ~3,200 cal yrs BP, the eastward edge of the prairie peninsula had retreated out of the southern Great Lakes and southern Midwest regions to occupy its current range in the Central Great Plains (Webb et al., 1983; Baker et al., 1992). Soon into the Late Holocene, the plant communities we see today became established. For instance, the species composition of deciduous forests of the Lower Ohio River Valley remained the same throughout the Late Holocene, more-or-less, until the arrival of European settlers (Delcourt et al., 1998; Jefferies, 2008; Muller, 2009). However, there were minor fluctuations in the abundances of key taxa in response to less pronounced climate changes over the last 4,000 years, as compared to the early and middle Holocene and clear signals for human occupation become apparent (Baker et al., 1992; Delcourt et al., 1998; McLauchlan, 2003; Munoz et al., 2014).

The transition from Middle to Late Archaic reflects, in part, human adaptations to these vegetation and climate changes, and the timing for this archaeological transition varied across the Midwest. In Kentucky, the shift from Middle to Late Archaic occurred as early as ~6,000 cal yrs BP, whereas in Indiana and Illinois this transition began later, at ~5,500 cal yrs BP and ~5,000 cal yrs BP, respectively (Delcourt et al., 1998; Muller, 2009). Temporal variations in the onset of the Middle-Late Archaic transition lies primarily with artifact differences (identified lithic complexes) and inferred social pattern changes (Muller, 2009). Subregional variations of the timing of the prairie peninsula retreat out of the Cumberland Plateau and associated increase in more diverse forest habitats likely played a role in some of these cultural shifts (Muller, 2009).

Several significant cultural changes occurred at the transition from the Middle to Late Archaic at ~5,000 cal yrs BP and during the Late Archaic (~5,000 to 3,000 cal yrs BP) itself. Specifically, Native populations switched from generalized to more specialized hunter-gatherer economies and also became more sedentary (King and Graham, 1981; Price, 1985; Bettis and Hajic, 1995; Muller, 2009). The settlement system was characterized by multi-seasonal, long-term major base camps in ecotones between the uplands and lowlands (King and Graham, 1981; Price, 1985; Bettis and Hajic, 1995; Muller, 2009). Because of increasing population sizes, Late Archaic people focused on creating larger, long-term base camps in highly productive, well-drained patches of the landscape. Poorly drained valleys, backwater lakes, and sloughs were more often used as temporary resource-gathering camps (Bettis and Hajic, 1995; Smith and Yarnell, 2009). The Late Archaic begins as the effects of the Hypsithermal climate weaken, so human populations would have had to adapt to the expansion of the mesic forests into the uplands once again (Muller, 2009). Late Archaic sites (between ~5,000 to 3,000 cal yrs BP) were more abundant in the uplands, possibly indicating their use as autumn base camps for nut gathering and processing (Delcourt et al., 1998). This interpretation is supported by the large amounts of *Carya*, *Celtis*, and *Juglans* carbonized nutshells extracted from hearths, which confirm the importance of mast trees from both upland and lowland habitats for Late Archaic subsistence (Crawford, 1982; Price, 1985; Delcourt et al., 1998). As Late Archaic populations grew and felled trees for fuel, the uplands opened up which likely increased the natural productivity of shade-intolerant, nut-bearing trees (Yarnell, 1993).

Over the duration of the Late Archaic, the number of carbonized seeds recovered surpass those of nutshells, indicative of plant domestication and incipient horticulture (Price, 1985; Crawford, 1982). The wild seed- and fruit-bearing plants included native *Iva annua*, *Rubus* (blackberry), *Vitis* (grape), *Gleditsia triacanthos, Diospyrous* (persimmon), *Polygonum*, *Phaseolus* (bean), and *Portulaca oleracea* (purslane) (Crawford, 1982). *Zizania palustris* (wild rice) is also present at some sites in the Midwest and Atlantic Northeast, but not in the Lower Ohio River Valley given its native northern range (Crawford, 1982; Hart and Lovis, 2013). By ~4,500 cal yrs BP the seed size of the *I. annua* recovered from hearths surpassed the size of the wild-type, though they do not represent the fully domesticated variety at this time (Fritz, 1990). As a result of seed selection, *Lanenaria siceraria* seeds became larger and *Chenopodium* spp. seed coats became thinner, which is part of the domestication process that was now in full force (Fritz, 1990). Earlier, during the Middle Archaic, *C. pepo* sp. *ovifera* was selected for thinner seed coats and thicker rinds throughout the midcontinent. It was during the Late Archaic that EAC cultivars began to have more prominence in the archaeological record (Crawford, 1982; Fritz, 1993). For instance, chemical analysis of strontium/calcium ratios taken from Late Archaic human skeletal remains indicate that ~20% of the diet of Late Archaic peoples came from plants (Price, 1985).

Between ~4,500 and 3,200 cal yrs BP, more plants were domesticated and utilized by Late Archaic people. These plants include *Helianthus annuus* var. *macrocapus* (domesticated sunflower), *Phalaris carolinia*, and possibly cultivation of *Horedum pusillum*, in addition to previously cultivated taxa: *C. pepo* var. *ovifera*; *L. siceraria*; *I. annua*; and *Chenopodium* (Fritz, 1990; Yarnell, 1993; Delcourt et al., 1998; Smith and Yarnell, 2009; Lovis and Hart, 2013). Abundant pollen grains of these EAC crops as well as those of *Ambrosia*, a native weed known to colonize disturbed areas, from lake/wetland sediments near archaeological sites confirm local forest disturbance and crop cultivation (Delcourt et al., 1998). In addition, garden plots identified near Late Archaic base camps and between rock shelters, supporting interpretations for the process of domestication (or, at a minimum, cultivation) (Delcourt et al., 1998). Importantly, all of these domesticates, or plants *en route* to domestication, provide a good mixture of food nutrients (Lovis and Hart, 2013).

Another main identifier of Late Archaic people's cultural change is the gradual adoption of crude pottery and the intensification of ritualized mortuary practices (Price, 1985; Delcourt, 1998; Jones and Johnson, 2012). The first appearance of pottery in the archaeological record has long been the signifier for the beginning of the Woodland period, although recent evidence suggests that pottery developed earlier, during the Late Archaic (Yerkes, 1988; Jefferies, 2008). Likewise, earthen burial mounds were historically attributed to Woodland populations, but it is now recognized that they began to appear in the Midwest landscape, primarily in Ohio, Indiana, and Illinois, during the Late Archaic (Price, 1985). However, a significant increase in the types of grave goods and the amount of artifacts recovered from burials suggest that hierarchical social organization began to intensify during the Late Archaic (Yerkes, 1988; Jefferies, 2008). Few locally resourced items are found in graves, but a number of the elaborate grave goods appear to have been created specifically for burials (Yerkes, 1988). Long stems on barbed points, turkey tails projectiles, and an overall increase in local lithic material were recovered from several Late Archaic sites (Jones and Johnson, 2012). There is no exact time for the transition between the Late Archaic and the Early Woodland. The transition is more of a subjective identification based on the timing for the adoption of certain cultural and technological advancements. Some of these benchmark indicators of the Early Woodland include refined chipped stone tools, the invention of the atlatl, and ceramic diversification and macrobotanical evidence for intensified cultivation and domestication of wild (and imported) plant species (Jefferies, 2008).

2.4 Early and Middle Woodland Paleoenvironment and Archaeology (3,000—1,500 cal yrs BP)

The environment of the Late Holocene (~3,000 to present), coeval with the time span of the Early and Middle Woodland (~3,000 to 1,500 cal yrs BP), was not markedly different from that of the Late Archaic. A cooler and moister climate broadly characterizes the Late Holocene, as compared to the preceding Hypsithermal, and overall the shifts in temperature and moisture over the last ~3,000 cal yrs BP were more subtle (Yerkes, 1988). As a result of more precipitation throughout the Midwest, ground water levels rose and there was a greater occurrence of overbank flooding, particularly in the lowlands, as compared to the Middle Holocene (Delcourt et al., 1999; Perry and Hsu, 2000). Precipitation increased significantly with the onset of the Late Holocene, which changed the spatial arrangement of the upland and lowland forests within a broader vegetation mosaic, but the greater moisture did not significantly alter plant species diversity (Delcourt, 1979; King, 1981; Delcourt et al., 1999). Populations of *Salix* increased dramatically due to fluvial disturbance that created newly flooded areas and a high water table (Royall et al., 1991). The increase in moisture availability also allowed for the re-establishment of hydric tree species, including *Taxodium, Fraxinus*, *Ulmus*, *Planera*, *Tilia*, *Gleditsia, Liquidambar*, and *Nyssa*, in lowlands throughout the Lower Ohio River Valley and the western Interior Plateau (Royall et al., 1991; Delcourt et al., 1999). This increase in moisture also effectively pushed out mesic forests dominated by *Quercus*, *Ulmus*, and *Carya,* from the lowlands, which reestablished themselves on more well-drained levees and relic braided stream channel terraces (Royall et al., 1991). To the south, in the Ozark Plateau, *Quercus-Carya* forests re-occupied on the uplands whereas forests of *Liquidambar-Ulmus* and *Salix-Arundinaria* became established the abandoned meandering belts in the lowlands (Delcourt et al., 1999).

In Illinois and northern Missouri, prairie was restricted to uplands and graded eastward into the mosaic deciduous forests at the border of the Central Plains (Webb et al., 1983). Westerly winds aided the fires that frequently swept through the patches of open, species-diverse prairie and *Quercus*-grassland barrens; however, these fires usually did not penetrate into the lowlands or into areas with deciduous forests (McMillan and Klippel, 1981; Webb et al., 1983). *Quercus macrocarpa* (bur oak) and *Populus tremuloides* (quaking aspen) were the most common trees in these fire-prone areas, given that the former has very resistant bark that is able to survive fire, and the latter is an early successional small tree that regenerates from its roots (Wilkins, 1991; Webb et al., 1993). This vegetation also contained numerous disturbance herbs species, most notably the early successional *Ambrosia* and many grass taxa (Wilkins, 1991; Webb et al., 1993). Although lightning ignition was probably the main cause of fires during the Late Holocene, some fires may have been lit by Native Americans (Delcourt et al., 1985). Anthropogenic fire was used to clear prairie gaps in the upland forests and prepare garden plots for planting crops in the upper slopes and ridge tops surrounding Early and Middle Woodland habitation sites (Delcourt et al., 1985; 1998). At this time, settlement patterns shifted from generally mobile or seasonally mobile to more long-term sedentary hamlets along forest edges where availability to both upland (nut, fauna, fuel) and lowland wetland resources was plentiful (King and Graham, 1981; McMillan and Klippel, 1981). Early Woodland domestic structures are rare in the archaeological record, though it is suggested that these groups resided at base camps for most of the year, only breaking into smaller groups to forage for upland resources in the summer months (Yerkes, 1988). When gardens were abandoned *Ambrosia*, *P. tremuloides*, *Liriodendron tulipifera* (tulip tree), and other early successional species were the first to colonize (old-field succession), similar to the aftermath of wild fires, (Burns and Honkala, 1990b; Fritz, 1993; Delcourt et al., 1998).

From ~3,200 to 1,500 cal yrs BP, Early and Middle Woodland populations consumed a wide variety of animal and plant foods. In particular, they relied heavily on white-tailed deer, which would have thrived due to the ecotones created by the patches of forest cleared for agriculture (King and Graham, 1981; Abrams, 2009). These people also consumed fully domesticated EAC plants, which entailed *Cucurbita pepo* sp. *ovifera*; *Langenaria siceraria*; *Chenopodium* spp.; *Iva annua*; *Helianthus annuus* var. *macrocapus*; *Phalaris carolinia*; and *Hordeum pusillum* (Fritz, 1990; Smith, 1992; Delcourt et al., 1998; Smith and

Yarnell, 2009; Lovis and Hart, 2013). Wild fruits (*Vitis* and *Rubus*) and nuts from upland and lowland trees (*Quercus*, *Carya*, and *Ulmus*) were additional plant foods (Muller, 2009). The amount of any particular plant species consumed by any human population varied greatly between settlements and with the seasons (see Chapter 6 for the inter-site discussion) (Smith, 1992; McLauchlan, 2003). By the Middle Woodland, human populations increased their intake of starchy seeds (*Phalaris caroliniana*, *Polygonum erectum*, and *Chenopodium berlandieri*), as indicated from carbonized macrobotanicals and coprolites (Fritz, 1993). Starchy seeds require longer cooking time and hotter fires, and so a greater reliance upon these seeds may have encouraged the development of thinner, durable ceramics as these would heat faster (Muller, 2009). *Zea mays* (maize) first appeared in North America at ~2,000 cal yrs BP though it was not ubiquitous throughout the continent (Smith, 1992; Hart and Lovis, 2013).

Early Woodland (~3,000 to 2,000 cal yrs BP) mounds were constructed containing elaborate graves goods throughout the Midwest (Jones and Johnson, 2012). Artifacts recovered from within burial mounds include large bladed, thin projectile points and ornately decorated, fabric-impressed ceramics (Jones and Johnson, 2012). These ceramic grave goods are much thinner and designed with either pressed or paddled features, as compared to utilitarian pottery, the latter being crude, heavy, and thick ceramics recovered from trash middens or broken from within hearths from this period (Applegate, 2005; Muller, 2009). The mound culture of central and northern Indiana likely coevolved with the Adena culture of Ohio and these exemplify a series of Native American societies with similar ceremonial systems within the Upper Midwest (Yerkes, 1988). Of these, the Adena populations of south-central Ohio produced elaborate ceramics and have larger plaza regions to perform ceremonial rituals, and gradually shifted from foraging based subsistence economies to maize-centered agriculture (Yerkes, 1988; Clay, 1998; Muller, 2009). The mound culture was less developed in central and northern Indiana, in comparison (Yerkes, 1988).

Figure 2.2 *The range of the Hopewell culture during the Woodland period in the Midwest. Figure adapted from Figure 1, Abrams, 2009 (modified from Charles et al., 2004).*

The Middle Woodland period (~2,000 to 1,500 cal yrs BP) is primarily manifested as the hierarchical Hopewell complex (Figure 2.2), a complex of inter-related cultural groups building earthen mounds as ceremonial and ritualized mortuary sites (Jones and Johnson, 2012). Similar to the earlier Adena complex, Hopewell refers to the mortuary practices, and not necessarily the group of people who built these mounds (Muller, 2009). Hopewell settlements are small, sedentary localized communities dispersed radially around mound structures and complexes and have been termed "dispersed agricultural hamlets" (Abrams, 2009). Generally, domestic sites are not within the earthwork complex proper (Abrams, 2009). Hopewell mounds typically appear in small complexes dotted throughout Illinois, Indiana, and Ohio and can be conical, platform, or effigy shaped (Yerkes, 1988; Muller, 2009). Common grave goods found within the burial mounds are ceramics, clay figurines, copper celts, panpipes, and platform pipes, which are all diagnostic Hopewell (Middle Woodland) artifacts (Muller, 2009; Jones and Johnson, 2012). Exotic goods, both from mortuary mounds and from domestic sites, increase during the Hopewell Period (Yerkes, 1988). Artistic expression was becoming more frequent as well, but it is hard to determine if there was craft specialization (Yerkes, 1988). Utilitarian ceramics recovered from Hopewell sites are typically cord marked or cord impressed with great temper variability depending on the available resources. Shell was commonly used as a temper at sites along the Lower Mississippi River Valley and in the Southeast, while crushed clay and grass is more common in the Cumberland Plateau and east of the Central Plains (Abrams, 2009; Muller, 2009). Middle Woodland ceramics are typically thinner than the Early Woodland, which is attributed in the higher starchy seed consumption during this later period (Fritz, 1993). The Fort Ancient Phase is a term associated with the Woodland peoples who inhabited south-central Ohio, and characterized primarily by pottery style (Schroeder, 2004). Fort Ancient populations at this time lived in small, scattered settlements throughout Ohio where they built earthen mounds and practiced a form of EAC cultivation, gathered wild plant foods, and hunted game (Cobb and Butler, 2002; Pollack et al., 2002; Jefferies, 2008).

In the Wabash Lowlands of southern Indiana, there is definitive evidence of Hopewellian complexes, but are poorly understood. At the Mann Site in southwestern Indiana, more than 55,000 m^3 of earth was piled into a series of mounds on a terrace high above a swampy floodplain (Yerkes, 1988; Muller, 2009). Exotic artifacts, such as intricately stamped ceramics, clay figurines, and rare high quality chert were recovered from these mounds (Yerkes, 1988). This site clearly documents the comingling of habitation structures and the mounds themselves, but it is unclear if the mounds encouraged people to congregate or if the mounds were merely built nearby a pre-existing settlement (Muller, 2009). Thus archaeologists have debated on how typical the Mann Site is, in terms of its location and cultural features, in relation to the Middle Woodland Hopewell of the Lower Ohio River Valley (Muller, 2009). In summary, the Early and Middle Woodland periods are characterized by significant advancement in mound construction, ceramics and the cultivation of native weedy taxa, even though the climate during these periods were very similar, and did not change thereafter.

2.5 Late Woodland Paleoenvironment and Archaeology (1,050—1,000 cal yrs BP)

The environment of Late Woodland populations (~1,500 to 1,000 cal yrs BP; ~AD 500 to 1000) was essentially the same as during earlier Woodland periods, except for one significant climatic episode, described later in this section of the chapter. Temperatures at the beginning of the Late Woodland (~1,500 cal yrs BP; AD 500) were 3 to 4 °C cooler than present, as they had been during the Early and Late Woodland (Cronin et al., 2010; Booth et al., 2012). The upland and lowland forests reclaimed land that was prairie during the Hypsithermal and deciduous trees also encroached on western prairie to form patchy mosaic forests in western Illinois (King, 1981; Delcourt et al., 1999). Modern-like precipitation, hydrology, and temperatures prevailed, which supported productive upland forests comprised of *Quercus* and *Carya* in certain areas and *Ulmus*, and *Acer* in others; while warm-adapted vegetation of southern affiliations, particularly *Quercus-Pinus echinata* (oak-shortleaf pine) forest, occupied the central Mississippi River Valley (Delcourt et al., 1999). Four different lowland forest communities were still present at the beginning of the Late Woodland: *Salix-Arundinaria*, *Liquidambar-Ulmus*, *Populus*, and *Taxodium-Nyssa* (Royall et al., 1991; Delcourt et al., 1999; Muller, 2009). Greater precipitation at ~1,500 cal yrs BP caused rising groundwater levels and overbank flooding of tributary rivers into the central Mississippi River and Lower Ohio River (Delcourt et al., 1999).

At ~1,400 cal yrs BP (~AD 550) ^{14}C radiocarbon records of well dated upland tree rings tacked fluctuations of solar intensity (Perry and Hsu, 2000), which may have contributed to continued wild fires throughout the Midwest, in particular in uplands and in prairie gaps (Webb et al., 1983). There is good pollen evidence for an increase in fire occurrence at this time, given that *Quercus* values are high and fluctuate, and more notably, the values for *Pinus virginiana* (scrub pine), another fire-tolerant tree, increased significantly to nearly 70% of the pollen grain record of sites within the Cumberland Plateau

(Delcourt et al., 1986). Anthropogenic disturbance of the uplands was likely minimal until the time of Euro-American settlement. Prehistoric Native Americans did greatly alter portions of bottomland forests throughout the Midwest, where trees were removed, possibly by girdling, and intentionally burned to clear land to plant crops (Delcourt et al., 1986; Delcourt et al., 1999). This lowland disturbance is interpreted by the identification of *Arundinaria* charcoal at sites and high percentages of *Ambrosia* pollen grains in the pollen record (King, 1981; Delcourt et al., 1986). Evidence of lowland disturbance identified by decreased *Taxodium dictichum* (bald cypress) pollen grains, as these trees were likely selected for their building durability (Delcourt, 1987). The environment can be thought of as a domesticated landscape in that Late Woodland populations had great knowledge of how to exploit plant species for fuel, food, building material, and other resources necessary for survival (Hart and Lovis, 2013). Pollen analysis indicates that abandoned fields had high rates of plant succession, which created a mosaic with primarily Poaceae, *Quercus*, and *Ambrosia* in the uplands and *Populus* and *Arundinaria* in the lowlands (Delcourt et al., 1999). Plant succession rates vary by taxa. Most often, weedy herbaceous plants like *Ambrosia* or Poaceae will reclaim an area first followed by fast growing trees and shrubs like *Populus tremuloides*.

The human populations at Late Woodland sites were generally smaller than earlier Woodland periods, although overall population throughout the region continued to increase (Muller, 2009). Groups were semi-sedentary and dispersed over a wide variety of environments to utilize a diverse array of resources (Muller, 2009; Jones and Johnson, 2012). In contrast, the opposite demographic trend occurred at the Fort Ancient site in south-central Ohio. Previously scattered populations (Early and Middle Woodlands) collectivized in a nucleated mound city during the Late Woodland (McLauchlan, 2003). Archaeological excavations of the Fort Ancient city revealed that the centralized plaza likely served as a general trade center for the dispersed permanent Fort Ancient Phase settlements (Essenpries, 1979; Yerkes, 1988).

In the Lower Ohio River Valley, EAC crops were likely cultivated in the lowlands by semi-sedentary populations that developed out of the mound-building Early and Middle Woodland populations (Muller, 2009). Northern Late Woodland populations likely were practicing some *Zea mays* cultivation, but direct evidence was notably absent from the Lower Ohio River Valley until ~1,100 cal yrs BP (~AD 850) (Muller, 2009). When *Z. mays* was added to the diet in the Lower Ohio Valley there is little evidence that early consumption of maize led to a decrease in EAC dependence (Smith, 1992). Maize agriculture is time and energy expensive to maintain, and the areas along the Ohio River were resource rich, and so that the adoption of maize was likely much slower than in the more resource-limited northeastern USA (Hart and Lovis, 2013).

The archaeological record indicates that by ~1,100 cal yrs BP (~AD 850) *Z. mays* agriculture takes off, clearly becoming the main food staple for these "mobile farmers," along with *Phaseolus* and *Cucurbita pepo*. EAC taxa were present in the diet but at a significantly reduced importance (Hart and Lovis, 2013). Even when Terminal Late Woodland populations adopted maize as the primary food source, they did not become a sedentary society, as there is no link between the establishment of maize and settled life (Hart and Lovis, 2013). There was still a great diversity of edible plants in the Lower Ohio River Valley at this time. Nuts from *Carya* and *Quercus* as well as the seeds of EAC crops, wild weeds: *Plantago* (plantain), *Lycopus americanus* (horehound), *Galium* (bedstraw), and *Portulaca*, as well as native grasses: *Pancium* (panic grass), *Phalaris canariensis* (canary grass), *Echinochloa* (barnyard grass), and *Hordeum pusillum* were potentially utilized (Delcourt et al., 1986; Hart and Lovis, 2013).

The Late Woodland period is known more for the absence and/or decline of certain cultural features and artifacts rather than for any new innovations (Yerkes, 1988). By ~1,500 cal yrs BP (~AD 450), mound building was not as common, and sites did not often appear in large complexes (Muller, 2009; Jones and Johnson, 2012), with the exception of Fort Ancient in Ohio. Fort Ancient populations differed greatly genetically and culturally from Lower Ohio Valley residents during the Late Woodland and later

Mississippian periods (Pollack et al., 2002; Muller, 2009). Fort Ancient Phase communities consisted primarily of farms and large self-sufficient villages that were often associated with stockades (Muller, 2009). Satellite communities, affiliated with the Fort Ancient city, typically had platform mounds located in a distinctly public place with ceremonial architecture situated in plazas within a wattle and daub palisade. These structures are associated with cemeteries, intensive maize-based agriculture and nearby villages and hamlets were heavily influenced by the social organization (i.e. hierarchical chiefdoms) of the Fort Ancient city (Jones and Johnson, 2012).

In the Lower Ohio River Valley, grave goods were still present alongside skeletal remains buried at other Terminal/Late Woodland sites, but the goods were much less ornate that before (Yerkes, 1988; Smith, 1992). These populations were generally scattered and small, which does not leave a huge detectable archaeological impact; the majority of sites from this period are identified by lithic scatterings associated with hearths and middens containing ceramics, debitage, and faunal remains. Bows and arrows were developed during the Late Woodland and used to hunt local fauna. Arrowheads and debitage collected from Late Woodlands sites are small and primarily made of local stone, suggesting human populations were limited to smaller territories, hence only local resources were used (Yerkes, 1988; Jones and Johnson, 2012).

2.5.1 Terminal Late Woodland Paleoenvironment and Archaeology (1,200—1,000 cal yrs BP)

At the end of the Terminal Late Woodland, at ~1000 cal yrs BP (AD 950), the Medieval Warm Anomaly (MWA) began and lasted until ~700 cal yrs BP (AD 1250) (Mann et al., 2009). Average annual temperatures during the MWA were ~ 0.5 to 1.5 °C warmer than in the preceding centuries (Cronin et al., 2010; Booth et al., 2012). This climate episode was initially defined by a warming trend observed in Medieval Europe. In North America, the Medieval Warm Anomaly is apparent by the unusually high hydroclimatic variability compared to the time periods just before and after (Cook et al., 2004; Booth et al., 2012). Archaeological evidence does not currently suggest that the MWA had a significant impact on the majority of Terminal/Late Woodland societies, but it probably did impact later Mississippian populations (see next section, 2.4) (Benson et al., 2007). Terminal/Late Woodland populations likely dealt with a slow increase in temperatures and in some regions, less precipitation. These MWA climatic trends are extratropical signatures of El Niño-Southern Oscillation (ENSO) (particularly El Niño events), and changes in multidecadal North Atlantic Oscillations (NAO). North Atlantic thermohaline circulation and the closely related Arctic Oscillations (AO) sea levels that have been extensively modeled to track the MWA (Cronin et al., 2003; Mann et al., 2009; Cronin et al., 2010). Various models use the combined effects of ENSO and Pacific decadal variability to recreate the teleconnections that occurred during the MWA (Cook et al., 2004). Solar irradiance changes and stratographic aerosols from explosive volcanoes near the equator may have also contributed to the intensity of the MWA (Mann et al., 2009). Droughts became more common during the MWA climatic episode, as evidenced by tree-ring analysis (Cook et al., 2004). Dendroclimatological data were correlated to the Palmer Drought Severity Index (PDSI) in order to reconstruct annual changes in moisture for the past, including identifying intervals of intense drought and wetness over large regions of the Midwest (Cook et al., 2004; Benson et al., 2007; Munoz et al., 2014). The first multidecadal drought of the MWA is at ~1060 cal yrs BP (Cook et al, 2004; Munoz et al., 2014).

Sedimentation increased significantly in lakes located near Terminal Late Woodland sites (1,200 to 1,000 cal yrs BP; AD 800 to 1000), which is attributed primarily to soil erosion resulted from more intensive agriculture rather than climate change (Delcourt, 1987). Skeletal remains from Terminal/Late Woodland sites indicate that the caloric contribution of maize increased from ~10% to nearly 50% during this time, with an observable decreased in EAC crops (Smith, 1992). Ceramic techniques were more refined, exampled by grog and limestone-tempered ceramics, cord-marking, and collared or thickened rimed vessels. (Yerkes, 1988; Muller, 2009; Jones and Johnson, 2012). For instance, the Yankeetown complex becomes its own complex based on its unique ceramic style; although evidence for increased social hierarchy and central authority is weak (Yerkes, 1988; Muller, 2009). Effigy and platform mounds again were built at Yankeetown, and there is an increase of ornate grave goods. One well known site from this time is the Lewis Phase at Kincaid Mounds in southern Illinois. This phase occurred from ~1,400 to 1,100 cal yrs BP (~AD 550 to 850) (before the Mississippian mounds were built), and is characterized by numerous small, permanent houses of a rectangular shape which are located on low ridges and bluffs (Muller, 2009; Pollack, 2009). Archaeological data suggest that in summer months, Terminal Late Woodland people dispersed into smaller groups to forage in the resource-rich lowlands with use of uplands to harvest nuts and hunt game primarily during the other seasons (Muller, 2009). As maize consumption intensified, agricultural tools became more abundant at almost all Terminal Late Woodland sites. Yerkes (1988) proposed *Z. mays* went from being a "garden crop" planted alongside EAC taxa, and harvested along with several wild plant foods, to become the main staple, being that it is a storable crop and a versatile food.

The boundaries between the Terminal Late Woodland, Emergent Mississippian, and later Middle Mississippian cultures are blurry and the timing of these cultural transitions vary between regions. Some cultures and phases (such as Fort Ancient) span multiple centuries and contain certain cultural distinctions, but ultimately, are classified as a single phase or culture due to continued occupation of the same geographic area. Other large Middle Mississippian settlements, such as populations at or near Cahokia in western Illinois, began during the Terminal Late Woodland, but did not reach their pinnacles until the Mississippian period proper.

2.6 The Middle Mississippian Paleoenvironment and Archaeology (1,050—700 cal yrs BP)

The Medieval Warm Anomaly (MWA; ~1000 to ~700 cal yrs BP; AD 950 to 1250; Mann et al., 2009) prevailed during the Mississippian period (~1,000 to 600 cal yrs BP). Global ice core records of glaciers in coastal British Columbia mountains, the Andes, Alps, Himalayas, and in New Zealand all report a rapid ice advance at ~1100—1000 cal yrs BP (~AD 850—900) and an equally rapid glacier retreat at ~1050—950 cal yrs BP (~AD 900-1000) (Grove and Switsur, 1994). The latter date more closely aligned with the age for the onset of the MWA (Mann et al., 2009). The severity and timing of the MWA varied depending of geographic location. For instance, the eastern coast of North America in Chesapeake Bay, Maryland experienced an early temperature increase at ~1,400 cal yrs BP (AD 550), followed by a temporary cool episode at ~900 cal yrs BP (AD 1050), and then a return of warmer conditions that peaked at ~800 cal yrs BP (AD 1150). Ostracods, formifera, and stable oxygen isotopes (Cronin et al., 2003; Cronin et al., 2010) indicate these oscillations. The climatic oscillations reconstructed for the Chesapeake Bay region differed only slightly in age from that inferred for the Lower Ohio Valley and much of the southern Midwest, ranging from the Central Mississippi River Valley north to the southern Great Lakes (Booth et al., 2012). For those regions other proxy data including tree-ring reconstruction, pollen, plant macrofossils, and testate amoeba subfossils from lakes, swales, and peatlands, also provide a similar reconstruction of the MWA climate (Benson et al., 2007; Booth et al., 2012). Humid regions, such that of the Midwest, can be vulnerable to droughts if these dry spells are persistent, such as what occurred during the MWA, particularly in the dry uplands (Booth et al., 2012). In contrast, meandering streams are able to recharge the landscape by occasional overbank flooding thereby alleviating drought conditions (Booth et al., 2012). In the Midwest there was a decline in upland tree density and the species dominance changed in favor of those better tolerant of drought, with lesser impacts on the lowland forests (Delcourt et al., 1986). Paleoclimate data indicate that multidecadal droughts occurred in the Midwestern USA at ~970, 850, and 750 cal yrs BP (AD 980, 1100, and 1200, respectively) (Cook et al., 2004; Benson et al., 2007; Booth et al., 2012). It can be assumed that the vegetation was significantly impacted at these times. By ~800 to 700 cal yrs BP (AD 1150 to 1250), arid conditions lessen considerably, and this is when the MWA is thought to have ended (King, 1993; Cook et al., 2004).

Pollen data dating to the MWA indicate that there was a drastic decline in upland trees, given that *Quercus* percentages dropped considerably from 35 to 15%, and those of *Pinus* decreased from 70 to 50% (Delcourt et al., 1986; 1999). In contrast, pollen values indicate that in the lowlands the numbers of *Salix* and *Fraxinus* increased slightly along with other southern taxa exemplified by *Liquidambar-Ulmus*, *Populus*, and *Taxodium-Nyssa* forests (Delcourt et al., 1986; 1999). Another key pollen indicator of a warm-dry MWA climate is the *Ambrosia* spike. *Ambrosia* rises in Kentucky pollen records from less than 1% to over 60% of the non-arboreal pollen grains (NAP), which reaches a peak at ~700 cal yrs BP (AD 1250) (Delcourt et al., 1986; Royall et al., 1991; Delcourt et al., 1999). The trends in the pollen data along with the low ratio of AP (tree and shrub) to NAP (grasses and other herbaceous plants) for this time documents a shift from a contiguous forest with a mosaic of tree types to a considerably more open landscape. Patchwork forests and open areas, including agricultural fields characterized the landscape (Delcourt et al., 1999). Macrobotanical remains of herbaceous seeds are abundant and species diverse, including *Galium*, *Portulaca*, *Rubus*, *Ambrosia*, *Potentilla* (cinquefoils), *Hypericum* (St. John's wort), *Verbascum* (mullein), *Mollugo verticullata* (carpetweed), *Verbena* (verbena), and *Viola* (violet) (Delcourt et al., 1986).

After ~650 cal yrs BP (~AD 1300), weedy seed-bearing species such as those listed above, as well pollen of *Pteridium aquilinum* (eagle fern) and indigenous EAC species increases, which all indicate greater local forest clearance and crop cultivation (Delcourt et al., 1999). High amounts of charcoal in lacustrine and wetland sediments suggest that the Midwest burned frequently during the MWA and after (Booth et al., 2012). The abundance of maize and beans become more dominate in the archaeological record at ~650 cal yrs BP (~AD 1300) (Delcourt et al., 1986; Hart and Lovis, 2013), discussed further below.

The Middle Mississippian period is characterized by a more complex and hierarchical social organization (Muller, 2009). During the Middle Mississippian population density increased and there was higher total population, two settlement patterns, nucleated and dispersed homesteads (Muller, 2009). Nucleated settlements were tightly settlements packed into a very small area and surrounded by some type of fortification comprised of hundreds of wattle and daub, rectangular structures that served residential, political, and public purposes (Muller, 2009). Dispersed settlements typically contained two to five structures with adjacent garden plots located between lowland ecotones on the outskirts of nucleated settlements (Muller, 2009; Jones and Johnson, 2012). Mounds were not always associated with large nucleated cities or towns. Between larger mound complexes, farmsteads orbited a single mound (Yarnell, 1988). Gravesites from both nucleated and dispersed Mississippian settlements vary. Some graves were located within structures, others directly outside structures, and others outside the garden periphery at the boundaries of sites (Muller, 2009). Non-utilitarian ceramics made up a small percentage of the total ceramic assemblage, ceremonial ceramics were likely traded over great distances (Muller, 2009). It has been suggested the chiefdom hierarchies of Mississippian society were the catalyst for the redistribution of specialist products and increased in trade between settlements, which drove the intensification of maize cultivation in the larger settlements (Pauketat, 2003; Muller, 2009). An increase in the number of agricultural households would only have strengthened Mississippian political and social hierarchies (Pauketat, 2003), as was seen in the largest settlement in the Midwest–Cahokia.

Cahokia is situated on the eastern side of the Mississippi River in what is now East St. Louis, Illinois. The site was a permanent nucleated settlement comprised of ~120 earthen mounds in a compact area of ~16.0 km^2 (Yarnell, 1988; Pauketat, 2003). The people originally settled the Cahokia region during the Terminal/Late Woodland Lewis phase (Emergent Mississippian). The population boomed at this time, as indicated by an increase in large residential buildings, a greater number of residential storage pits, and other evidence for intensive maize-bean-squash agriculture (Yarnell, 1988). Smaller hamlets and villages in the uplands were abandoned at ~950 cal yrs BP (AD 1000), and it is suggested that the displaced populations migrated to Cahokia for political support which further contributed to the population boom of this city (Pauketat, 2003). During Cahokia's most populous time, from ~1050 to 700 cal yrs BP (AD 900 to 1250), anywhere between 5,000 to 43,000 people lived within the city's palisade (Yarnell, 1988). Farming aided by stone axes and hoes occurred outside the city proper in the forested alluvial valleys as well as in the uplands (Yarnell, 1988).

Cahokia society was a complex theocratic hierarchy with a distinct elite class, as well as priests and craft specialists (Yarnell, 1988). Buildings were clearly arranged in an organized manner with centralized public space and public buildings that were surrounded by specialized buildings and temples. Residential buildings expanded outwards from the center (Yarnell, 1988; Pauketat, 2003). Trade and exchange of exotic goods increases greatly during Cahokia's heyday, and were likely considered "status goods" for elite members of society (Yarnell, 1988). Many villages and hamlets orbited the large Cahokia capital. However, these settlements were not uniform in their engagement in agriculture vis-à-vis the gathering of native foods (Pauketat, 2203). There was considerable mobility and fluidity of human populations who settled within Cahokia and later left on presumably a regular basis (Pauketat, 2003). Some of the northern outposts and villages farther away from Cahokia may have been ancestors of later Oneota populations (Yarnell, 1988). The distribution of Oneota (~1000 to 300 cal yrs BP; ~AD 950 to 1650) sites extends from central Illinois near Cahokia northward to the Great Lakes region (King, 1993). In many cases, the cultural term Oneota refers to populations that postdate the Mississippians (King, 1993). However, there is evidence that early Oneota settlements were either founded by, or at least heavily influenced by, contemporary Cahokia settlements between ~950 to 750 cal yrs BP (AD 1000 to 1200) (King, 1993). After ~700 cal yrs BP (~AD 1250), Cahokia population rapidly declined, which is attributed to a combination of climatic changes, reduced local resources, and warfare (Yarnell, 1988; Cobb and Butler, 2002).

Angel Mounds, in southwestern Indiana, is a smaller Middle Mississippian settlement contemporaneous to Cahokia. The Angel Site, situated at the confluence of the Green and Ohio Rivers, has 13 mounds that were built and utilized from ~900 to 510 cal yrs BP (AD 1050 to 1440), with a peak population density at ~750 cal yrs BP (AD 1200) (Butler and Cobb, 2002; Counts et al., 2014). This site is a fortified nucleated town and temple complex that had social and trade connections to nearby villages and hamlets situated within the Wabash Lowlands (Muller, 2009; Jones and Johnson, 2012). An estimated

1,000 to 7,000 people lived at Angel at any one time and they subsisted on farming, gathering, fishing and hunting (Muller, 2009). Domesticates planted in the fields of the area included *Zea mays*, *Cucurbita* spp., *Helianthus annuus*, *Phalaris caroliniana*, *Echinochloa*, Cheno-Ams, *Nicotiana* (tobacco), and *Ilex vomitoria* (yaupon holly) (Muller, 2009).

Downstream from the Angel Site there was a series of small village to hamlet-sized Middle Mississippian settlements (typically lacking palisades) scattered along the Lower Ohio River Valley (Muller, 2009). Some of these site's descendants later founded the Murphy Site, Bone Bank, and Hovey Lake Upper Mississippian sites, which are located on both the northern and southern side of the same river valley (Monaghan et al., 2004; Muller, 2009). Few shell goods or other ornate artifacts have been recovered from the Wabash Lowlands during the Middle Mississippian period (Muller, 2009). Archaeological data suggest cultural and economic activities occurred throughout dispersed sites. No single limited-activity zones were identified except for garden plots, those garden plots excavated revealed stone hoe chips and reused (reworked) Late Woodland stone tools, which indicate the long history of some of these Lower Ohio River Valley settlements (Muller, 2009).

2.6.1 People-Plant Interactions During the Middle Mississippian

Whether a Mississippian settlement was a single residential farmstead, or a large earthen mound city like Cahokia, resource availability was heavily influenced by the population density. Wild food resources became increasingly restricted to the lowland floodplains, because of warming temperatures and minimal precipitation in the uplands. Settlements were closely aligned with supporting environmental conditions during the MWA. For instance, people settled and farmed the ridges of ridge-swale topography within the lowlands, these ridges were elevated enough to escape the brunt of the annual flooding yet were still moist (Muller, 2009). Moreover, almost all Mississippian sites are associated with "high yield" soils, which supported production of maize and other cultivars. By this time, the archaeological record show domesticated indigenous crops were utilized as a critical food source for several thousand years, but now there was a driving force that pushed the large-scale adoption and investment in maize (Delcourt et al., 1986). Beans and squashes (e.g. pumpkins, acorn squash) were also grown (Muller, 2009). Despite the *Zea mays*-focused economy of the Middle Mississippians, wild upland plant resources were still harvested, particularly the nuts of *Carya* and *Quercus*, which were still a very important for their diet (Muller, 2009). At one Black Bottom site in southwestern Illinois, *Carya* made up one-third of the charred botanical mass, with very small amounts of *Juglans* and *Quercus* nutshells (Muller, 2009). Because mast trees are cyclical in their nut production, any individual settlements that relied heavily on these resources either managed the production or were able to move around the uplands to harvest from various stands (Muller, 2009). Faunal remains from sites throughout the Mississippian Midwest indicate an increased consumption of raccoon and deer. Deer, raccoons, and various birds all are “predators” of maize and were probably drawn out of the ever thinning forest into cropland to forage on corn and other cultivars thus making hunting easier (Muller, 2009).

The increasing population density during the Middle Mississippian greatly impacted the local vegetation (Pauketat, 2003). Trees were heavily harvested for fuel, building materials, and tools. Their nuts, fruits, and bark used for food and medicine. An average (25—50 cm diameter) sized hardwood tree could provide enough wood for multiple beams used in the construction of one dwelling, however, people were limited in how far they could transport logs (Lopinot and Woods, 1993; Newsom, 1993). One study by Lopinot and Woods (1993) estimated that each residential structure (of five individuals) required ~80 beams, so for an estimated population of 25,000 people, at least 800,000 average diameter full-grown trees were required. Given this great demand for wood and transportation limitations, over time there was a decrease in the size of available trees as well as a decline in the number of tree species favored for building material (Lopinot and Woods, 1993). This pattern is evident particularly at Cahokia where there two levels of deforestation occurred. Immediate deforestation was by cutting down trees surrounding the city, and secondary deforestation where non-local wood (perhaps less desirable) was brought in from areas farther away (Newsom, 1993). The depletion of local resources by sedentary Mississippians may have contributed (in some unknown degree) to warfare or interregional conflict during this time, as evidenced by trauma on skeletal remains and iconography depicted raids (Cobb and Butler, 2002).

The combination of intense local deforestation along with greater reliance on intensified production of domesticated crops resulted in high rates of soil erosion, culminating in high sedimentation rates in lakes (Delcourt, 1987; Lopinot and Woods, 1993; Munoz et al., 2014, 2015). On one hand, flooding is beneficial to an agricultural landscape as it deposits sediments, but it can destroy crops if it comes when and where plants are growing; it is likely that lowland agriculture increased during the Middle Mississippian, but potentially was less productive (Lopinot and Woods, 1993; Munoz et al., 2014, 2015). Agriculture in the uplands was abandoned entirely by ~700 cal yrs BP (AD 1250), however, cultivation continued in the lowlands (Lopinot and Woods, 1993; Munoz et al., 2014, 2015). This reduction in areal crop production may have been due, in part, to the cumulative effects of a warm-dry MWA climate.

2.7 Upper Mississippian and Vacant Quarter Paleoenvironment and Archaeology (700—150 cal yrs BP)

Climatic changes and/or warfare have been invoked as causal mechanisms for a notable decline in human population and mound building in the southern Midwest towards the end of the Middle Mississippian period (Kimball Brown, 1979; Milner et al., 1991; Cobb and Butler, 2002). Depopulation in previously prominent Mississippian settlements, including Cahokia and Angel Mounds and their satellite communities, resulted in this area became sparsely inhabited known as the Vacant Quarter (VQ) (Kimball Brown, 1979; Miller et al., 1991; Cobb and Butler, 2002). The VQ lasted from ~500 cal yrs BP (AD 1450) until the arrival of Euro-Americans in the central Midwest in the early 19th Century AD, although the depopulation may have begun earlier (Clay, 1997; Cobb and Butler, 2002).

The lingering effects of the MWA were long gone by ~650 cal yrs BP (~AD 1300) in the Midwest. Cooler temperatures varied in length and severity across the continent and occurred as early as ~670 cal yrs BP (AD 1280) and persisted until ~90 cal yrs BP (~AD 1860), at the latest. This climatic episode is known as the Little Ice Age (LIA) (Perry and Hsu, 2000, Mann et al., 2009; Wahl et al., 2012). The LIA is well represented by proxy data and climate models, more so than the MWA, but the exact duration and intensity of the LIA varies by region (Perry and Hsu, 2000; Cronin et al., 2010). The glaciers that melted during the MWA stopped melting at ~600 cal yrs BP (AD 1350), and thereafter began to expand as snowfall accumulated as temperatures lowered during the LIA (Grove and Switsur, 1994). During the LIA, La Niña-like conditions occurred which produced annual temperatures ~0.5 to 1.5 °C cooler than today and increased precipitation (Mann et al., 2009; Cronin et al., 2010; Wahl et al., 2012). At ~500—450 cal yrs BP (~AD 1450—1500), annual sea surface temperatures were the lowest in northern latitudes, whereas globally sea surface temperatures were stable and cool (Cronin et al., 2003). In alpine environments, flooding increased after ~360 cal yrs BP (~AD 1590) and glaciers expanded to dam rivers. Later these dams would fail by glacier recession, causing catastrophic erosion and flooding (Grove and Switsur, 1994). Forest vegetation of the Midwest maintained its previous species makeup with slight variations in the placement of ecotones, forests expanded to reoccupy upland landscapes and was influenced by the cooler and moister climatic regime of the LIA (King and Graham, 1981; King, 1993). Increased flooding inhibited the growth of swampy vegetation within the expanded main river channels; there were thick stands of riparian vegetation, including *Salix* and *Arundinaria*, along the shores (King, 1993).

Upper Mississippian cultures adapted to the LIA climate and associated vegetation changes. Within the VQ, the Caborn-Welborn culture developed (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Pollack et al., 2002; Munson et al., 2004; Muller, 2009). The Caborn-Welborn culture is an Upper Mississippian expression of dispersed, unfortified hamlets and villages in southwestern Indiana and northwestern Kentucky (Muller, 2009; Jones and Johnson, 2012). Artifacts and cultural features of this group have the same characteristics that define the previous Mississippian cultures, and were probably descendants of Angel or Cahokia, but Caborn-Welborn existed after the decline of the large populous mound centers (Cobb and Butler, 2002; Pollack et al., 2002). Variations of dramatic headpots, effigies, elaborate art objects, and shell masks mark the Caborn-Welborn culture (Muller, 2009; Jones and Johnson, 2012). The Caborn-Welborn villages were comparatively smaller than Middle Mississippian settlements were typically located within 15 km of one another, suggesting that there was a significant population decrease by this time (Munson, 1997, 1998, 2000; Perry and Hsu, 2000; Munson and Cook, 2001; Pollack, 2004; Muller, 2009).

North of the Caborn-Welborn settlements were closely related to Oneota of the Great Lakes. To the east of Hovey Lake, the Prather and Newcomb complexes exhibited a mix of characteristics similar to both Angel and Fort Ancient (Jones and Johnson, 2012). The eastern Upper Mississippian populations appear to lack the rigid hierarchical structure that their predecessors had and placed a greater emphasis on maize-bean-squash agriculture (Muller, 2009). On the contrary, there appears to be an absence of Native American settlements in the Cumberland Plateau at this time (Delcourt et al., 1998). Nut-bearing trees and starchy seeds increase in abundance during this period (King, 1993). Pollen values of *Ambrosia* decrease significantly throughout this period, likely due to the reforestation of abandoned agricultural fields (Royall et al., 1991).

Starting at ~350 cal yrs BP (AD 1600), there is some disconnect between the prehistoric and historic populations, because the cultural affiliations of Upper Mississippians identified from archaeology cannot be directly linked to specific Native American tribes described in Euro-American historical sources (Jones and Johnson, 2012). The relatively unpopulated region was located along the traditional warrior path between the southern Midwest Shawnee/Appalachian Cherokee and eastern tribes, which may account for the low population density of Native populations observed at the time of Contact (Kimball Brown, 1979; Delcourt et al., 1998; Cobb and Butler, 2002). The migration of Native American tribes out of the Lower Ohio River Valley was likely due to their retreat from warring Iroquois bearing European arms (Kimball Brown, 1979; Guyette et al., 2003).

2.8 Historic to Present Environment and Archaeology (150—0 cal yrs BP)

The earliest European arrival in the southern Midwest is at ~AD 1650. The region was described as sparsely vegetated primarily composed of *Quercus*-barrens (Kimball Brown, 1979; Guyette et al., 2003). At this time, Native American populations lived in small seasonal hamlets and small villages and utilized whatever wild forest resources still available (Kimball Brown, 1979; Jones and Johnson, 2012). There were remnants of the prior chiefdoms, but political leaders at Euro-American contact were mainly envoys to warring tribes and missionaries, and lacked the power of previous Mississippian chiefs who controlled large population centers (Kimball Brown, 1979). The French fur trade caused the displacement and movement of various tribes (Miami; Potawatomi; Kickapoo; Mascouten; Delaware; and Shawnee) across the southern Midwest between AD 1600 and 1800 (Jones and Johnson, 2012). The Lower Ohio River Valley appears to have been primarily a transportation route at Contact rather than an area of settlement (Muller, 2009). The primary tribal groups in southwestern Indiana at the time of European Contact and the subsequent early Euro-American interval were two Miami subtribes, the Wea and Pinkashaw, which lived in small-nucleated villages (Muller, 2009; Jones and Johnson, 2012). Within the broader region along the Little Tennessee River, there was a brief period of Cherokee occupation in the AD 1600s. The Cherokee occupation of the area is documented in both the pollen record (by a pollen increase of *Prunus*, *Zea mays*, and *Ambrosia*) as well as in the historical record with provincial English forts (Delcourt et al., 1986). Almost all of the Native Americans were killed or displaced during the early days of Euro-American colonization (Delcourt et al., 1986; Muller, 2009). In the early AD 1800s, Native Americans maintaining their homesteads were displaced by various ceded land treaties to the United States government (Guyette et al, 2003). Between AD 1840 and 1930, the population of white settlers increased from ~450,000 to nearly 3,400,000 in the region (Guyette et al., 2003).

The landscape impacts of the Europeans/Euro-American were considerably greater than those of the prior Native Americans, in that they are responsible for the deforestation of considerably larger areas for settlements, building materials and agriculture. Forest fires increased during the first half of the historic period, with an average fire occurrence of ~5.3 years, peak burning of acreage occurred between AD 1650 and 1680 (Guyette et al., 2003). Fires cleared the vegetation and contributed to topsoil erosion during precipitation events, which increased sedimentation significantly from ~0.01 cm/year to ~0.08 cm/year in swamps and lakes throughout the southern Midwest (Delcourt et al., 1979; Wilkins, 1991). Uplands were dominated by row crop agriculture or were abandoned fields colonized by the weeds *Plantago, Rumex* (dockweed)*,* and the invasive Euro-African *Tripolium* (sea aster) (Delcourt et al., 1986; Muller, 2009). Lowland forests were further altered by the draining of many of the wetlands for agriculture, which resulted in an abundance decline of most species, except for *Juglans* and *Acer rubrum*, the latter being an early successional tree species that became more widespread along streams and rivers (Delcourt et al., 1979).

At the end of the LIA at ~AD 1750, warmer conditions returned. If the environment had been relative untouched by humans, then *Quercus* prairie barrens probably took over the drier uplands. This did not occur in most places however, there was widespread cultivation of corn, wheat and other crops in what was now a largely anthropogenic landscape (King, 1981; King, 1993). Fire suppression enacted by 18th and early 19th Century inhabitants caused significant population declines in the remaining "natural" areas with oaks and other fire-dependent species (Guyette et al., 2003). It should be noted that historic fires have not been linked to climate changes and instead are strongly linked to anthropogenic ignitions (Guyette et al., 2003).

By ~AD 1900, aridity peaked, but droughts were less severe than those of the MWA (Cook et al., 2004). In the AD 1940s, *Castenea* (chestnut), a dominant mesic hardwood, was almost eliminated from the Midwest due to blight (Delcourt et al., 1979; Delcourt et al., 1986). Agricultural fields abandoned over the past 100 years have a surprisingly high amount of herbaceous species diversity, but also have high amounts of *Ambrosia*. One study (Jenkins et al., 2000) found that abandoned agricultural fields were recolonized by trees, mainly *Populus* and *Acer* rubrum, between 6 to 9 years after abandonment. In recent decades, Midwest forest stands were occasionally harvested for wood. Regardless if stands are clear cut or single species selected, this logging results in very little arboreal re-growth, and a prevalence of herbaceous species including *Pteridium* (braken fern), *Vaccinium* spp. (i.e. blueberry) and *Ambrosia* (Jenkins et al., 2000). Prior to heavy utilization of pesticides, abandoned agricultural fields (both Native American and early Euro-American) were species rich, with many "weedy" taxa, including *Trifolium* (clover), Ranunculaceae (buttercup family), *Artemisia*, *Urtica* (nettle), *Chenopodium*, *Plantago*, and *Polygonum* (Delcourt et al., 1987). Aside from agriculture and lumbering, after European and Euro-American settlement many new invasive plant and insect species were introduced to the Midwest along with cattle that required large areas for grazing (Delcourt et al., 1986).

Complete fire suppression was enacted in the first half of the 20th Century, which resulted in minimal fires, but when they did occur, they had a greater ferocity due to fuel build-up between fires (Guyette et al., 2003). Ecologists in recent decades have come to appreciate the important role of fire in maintaining prairie, oak barren and other fire-dependent ecosystems, and since the AD 1980s prescribed fires have been utilized to clear underbrush and promote a more natural landscape (Guyette et al., 2003). Hence, we have a better understanding of the changing landscape before, during and after occupation of the Hovey Lake in southwestern Indiana, a case study described in this thesis, can provide valuable information of how humans can extract resources without depleting the species diversity of local floras.

CHAPTER 3: STUDY AREA

The study site, Hovey Lake (37°49'N, 87°56'W), is a 5.67 km^2 backwater, oxbow lake of the Ohio River in Posey County, Indiana, located ~13.2 km southwest of the city of Mt. Vernon (Figure 3.1). The Ohio River Valley is divided into three physiographic regions based on the variations of geology and geomorphology within the region, which from east-to-west are: (1) Appalachian Plateau; (2) Central Lowlands; and (3) the Lower Ohio River Valley. Hovey Lake is located in the southwest corner of the Lower Ohio River Valley physiographic zone within the Wabash Lowlands (Figure 1.1). The Wabash Lowlands is bracketed by the Ohio River to the south and the Wabash River to the west (Alexander and Prior, 1971; Homoya et al., 1985; Muller, 2009). The major landforms of the Wabash Lowlands include an extensive floodplain and a low first-order river terrace in the southern part of the area. Elevated landforms include a higher T-2 river terrace, lacustrine plain, and stream-dissected, ridged uplands in the northern part of the Wabash Lowlands (McWilliams, 1979; Munson, 1997).

Figure 3.1 *Location of the Hovey Lake Village site and Hovey Lake near Mt. Vernon, Indiana between the confluence of the Wabash and Ohio rivers (Google Earth, 2015).*

3.1 Geology and Hydrology

The Lower Ohio River Valley is underlain by thick beds of Mississippian and Pennsylvanian limestone, sandstone, and shale bedrock (Jefferies, 2008; Counts et al., 2014). The topography of this valley as well as areas to the north is subdued and fairly smooth. Significant erosion caused by the numerous glacial advances and retreats of the Laurentide Ice Sheet (LIS) during the Early and Middle Pleistocene in the Northern Wabash Lowlands (~2.58 to 0.5 Ma cal yrs BP) (Clark and Mix, 2002; Larson and Schaetzl, 2001; Counts et al., 2014). This long interval of glacial and interglacial time is referred to as the Pre-Illinoian. Pre-Illinoisan glaciation is a broad term because there is an unknown number of glaciations and intervening interglaciations that occurred (Clark and Mix, 2002; Larson and Schaetzl, 2001; Counts et al., 2014). Multiple Pre-Illinoian glaciations overrode any existing landforms, thereby smoothing the landscape, effectively erasing any evidence of preceding glaciation signatures (Fullerton, 1986; Jefferies, 2008). In some places pre-Illinoian glacial lobes gouged into bedrock, leaving highly irregular bedrock surfaces in some portions of the Lower Ohio River Valley (Fraser and Fishbaugh, 1986). Till deposits from Pre-Illinoian glaciation and the better known Illinoian glaciation (191,000 to 130,000 cal; yrs BP) are irregular, discontinuous, and even occasionally absent from the Lower Ohio River Valley and till thickness is not related to the amount buried bedrock. Geologists and geomorphologists have attempted to identify, describe, and date the Lower Ohio River Valley Pre-Illinoian tills to try to reconstruct the glacial history; however, the Pre-Illinoian tills in this region are well studied and do not have great radiometric control (Fullerton, 1986). Glacial outwash and river sediment deposition is typically more successful to reconstruct the chronology and paleohydrology of the Lower Ohio River (Woolery, 2005; Counts, et al., 2014).

Prior to the Pre-Illinoian glaciations, the ancestral Ohio River was a fairly insignificant stream and very different from what we see today (Wayne, 1952). During the Early Pleistocene, the Lower Ohio River drained westward emptying into the ancestral Mississippi River while the ancestral Upper Ohio River was a series of small streams and tributaries that drained northeast into the Great Miami River and the now extinct Teays (Figure 3.2) (Wayne, 1952; Swadley, 1979; Jacobson et al., 1988). It was between the many Pre-Illinoian advances and retreats that at ~1.5 Ma cal yrs BP the ancestral Upper Ohio River drainage changed to the southwest at the connection point in the region of Madison, Indiana (Wayne, 1952; Muller, 2009). The best evidence for the change of the ancestral Upper Ohio River flow direction is the landscape around Madison, Indiana. The region today overlooks a narrow section of the river valley and the uplands are remarkably undissected compared to the uplands and upland tributaries of the rest of the Upper and Lower Ohio River (Wayne, 1952; Ray, 1957; Jefferies, 2008). It is unlikely that there was enough time for the small ancestral Lower Ohio River to erode at the headwater enough to connect to the ancestral Upper

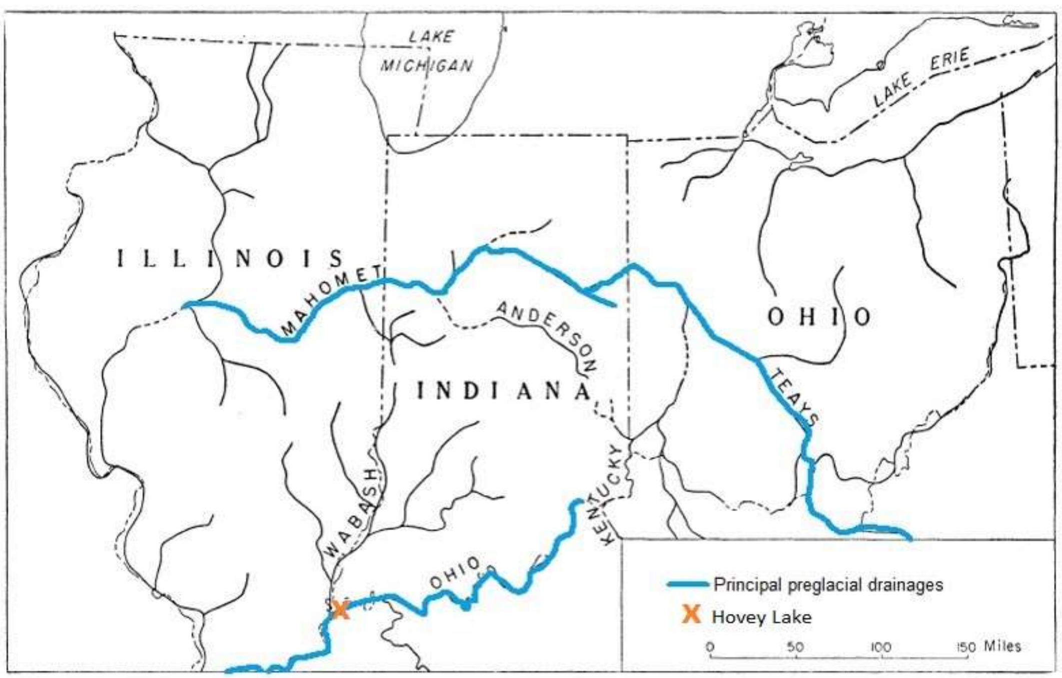

Figure 3.2 The drainages for the Lower (ancestral) Ohio River and Teays River (part of ancestral Upper Ohio River) prior to Pre-Illinoian glaciations ~1.5 Ma yrs BP. Figure adapted from Figure 1, Wayne, 1952.

Ohio River (Wayne, 1952). Rather, it is more likely that Pre-Illinioan glacial advances and proglacial rivers moved significant amounts of sediment and upon glacial retreat, allowed for the two headwaters to connect and the ancestral Upper Ohio River to change course (Wayne, 1952; Ray, 1957).

Underfit stream valleys are prevalent on the north side of the Lower Ohio River Valley and are a remnant of these early Pleistocene glaciations. Underfit stream valleys drain into the modern Ohio River (Figure 3.3) and were the primary source of redeposited sediment and water for the ancient Ohio River (Wayne, 1952; Woolery, 2005; Counts et al., 2014). Whenever Pre-Illionian glaciers retreated, ice dams freed the melt-water, incising into the valleys and uncovering proglacial lake beds (Ray, 1957). Additionally, between glacial advances, loess accumulated in the uplands (Granger et al., 2001).

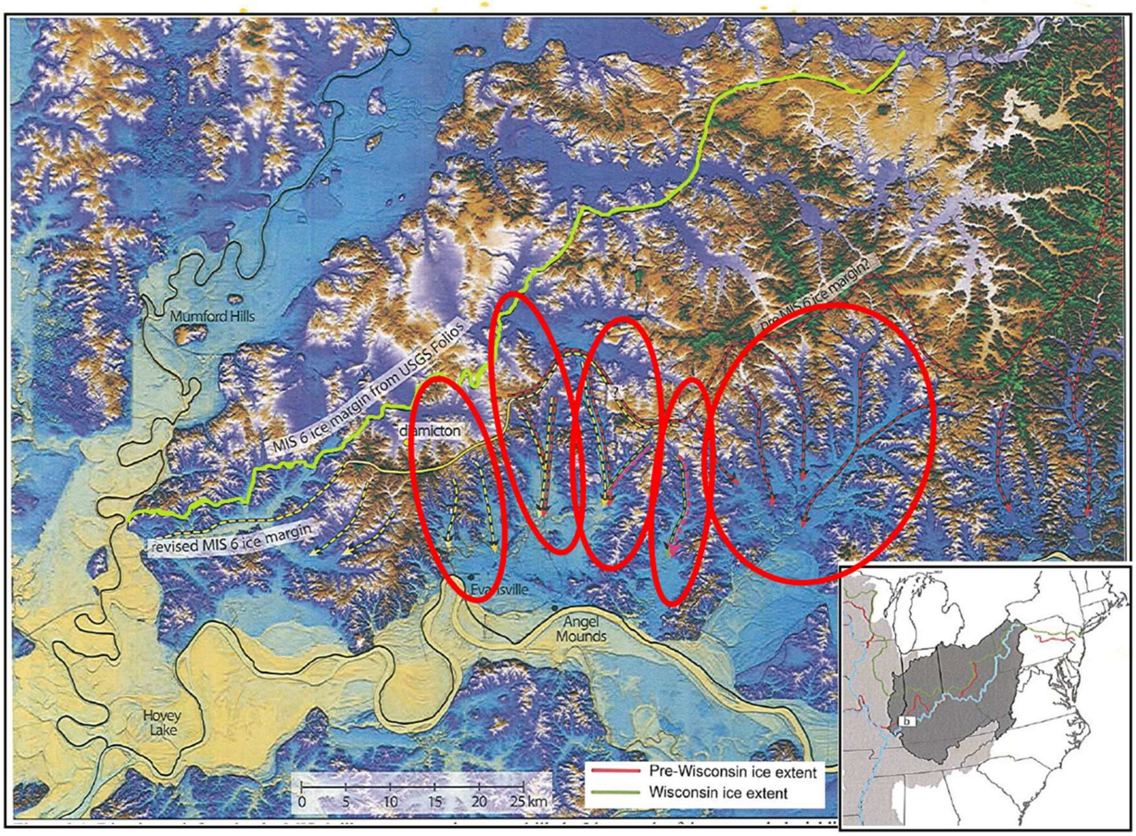

Figure 3.3 *Circled examples of some of the underfit stream valleys near Hovey Lake and their proximity to the Illinoian glacial front just north of the Lower Ohio River. Figure adapted from Figure 3.1, Counts et al., 2014.*

Significant "deep stage" incision events occurred during the interglacial periods, carving through previously deposited till and outwash down to bedrock in some areas (particularly Kentucky and Tennessee). One major, deep incision event occurred during a relatively brief interglacial period after ~0.9 Ma cal yrs BP (Fullerton, 1986; Granger et al., 2001). During this interglacial, soils formed and the landscape was colonized by temperate vegetation from the south and prairie species from the west. Along the Lower Ohio River Valley during interglacial stades, sedimentation increased along the outwash plains on the north side of the ancestral Lower Ohio River while overbank deposits accumulated on the southern border (Fullerton, 1986). As more vegetation colonized the landscape at the end of the Early Pleistocene, the rate of erosion eventually lessened (Fullerton, 1986; Granger et al., 2001).

Two glaciations occurred during the Middle and Late Pleistocene (~780 to 12 ka cal yrs BP), the Illinoian glaciation (~700 ka cal yrs BP) and the Wisconsin glaciation (~110.0 to 12.0 ka cal yrs BP). Sedimentation along the ancestral Ohio River Valley during these glaciations increased overall, though the Illinoian and Wisconsin glaciations had less of a direct geomorphic impact on the Lower Ohio River Valley landscape than the unknown of Pre-Illinoian glaciation (Granger et al., 2001). Again, between glacial advances, loess accumulated on the uplands. During these two glacial periods, the Ohio River tributary valleys were again inundated with northern glacial melt-water (Fraser and Fishbaugh, 1986; Fullerton, 1986). Although the Illinoian and Wisconsin glaciations had some impact on the hydrology and vegetation in the Lower Ohio River Valley, no till from either glaciation and very little outwash, have been identified as far south as the ancestral Lower Ohio River (Fullerton, 1986; Jefferies, 2008; Counts, et al., 2014).

After the final retreat of the LIS ice during the Wisconsin glaciation (~20.1 ka cal yrs BP), the braided Lower Ohio River was over 150 km to the south of the furthest extent of the ice (Tiller, 1991; Dkye et al., 2002; Counts et al., 2014). The ice sheet never reached the southern Lower Ohio River Valley (Figure 3.3), but large quantities of granular outwash aggraded in major sluiceway valleys within the region (Wayne, 1952; Alexander and Prior, 1971; Fraser and Fishbaugh, 1986). Along the retreating LIS ice front, *Picea* (spruce) and other tundra-like species rapidly declined in density and is mirrored by a sharp increase of *Pinus* (pine) (Liu et al., 2013). As the ice from continued to retreat, more temperate species migrated north into the Lower Ohio River Valley.

At the Pleistocene-Holocene transition at ~11.6 ka cal yrs BP, the Ohio River transitioned from the glacially influenced braided/anastomosing stream to a more meandering flow regime (Fraser and Fishbaugh, 1986; Tiller, 1991). The ancient Lower Ohio River meandered across the recently deposited fluvial sediments from upstream outwash and into the glacial outwash deposits. The abandoned braided stream channels were readily colonized by riparian shrub species followed by hardwood forests (Jackson et al., 1997; Liu et al., 2013). The transition from braided to meandering stream flow was not a smooth transition. Increased amounts of precipitation along with glacial meltwater flooded the Lower Ohio River Valley and up to ~30 m of aggradated sediment was deposited (Counts et al., 2014). The overbank deposit episodes often were followed by incision events which created a series of river terraces on both sides of the Ohio River (Wayne, 1952; Alexander and Prior, 1971; Fraser and Fishbaugh, 1986; Counts et al., 2014). In the southern Wabash Lowlands, the Lower Ohio River underwent an active entrenchment episode that formed a low terrace (what is now the modern T-2 river terrace) at ~6.2 ka cal years BP (Counts, 2014). At ~4.3 ka cal yrs BP a major climatic shift from a previously wetter climate to drier climate and formed a second lower river terrace (what is now the modern T-1 river terrace) leaving the T-2 river terrace morphologically unchanged (Tiller, 1991; Counts et al., 2014).

The highest point on the modern Wabash Lowlands landscape is in the northeast uplands, at 174.5 meters above sea level, which gently slopes south by southwestward to the nearly level floodplain at 95.4 meters above sea level at the confluence of the Wabash and Ohio rivers (Potzger et al., 1965; McWilliams, 1975). The Ohio River begins in western Pennsylvania and the watershed drains ~520,000 km^2. The Ohio River empties into the Mississippi River near Cairo, Illinois (Muller, 1996; Jefferies, 2008). On the T-1 terrace and low floodplain, fluvial sediment deposition (overbank sediments) contributes ~1.0 cm of sediment per year to levee development (Alexander and Prior, 1971; Counts et al., 2014). No paleosols were discovered in any of the overbank sediments from prehistoric not historic floods , which attests to the unstable, erosional, and continuous deposition nature of the Lower Ohio River throughout the entire Holocene (Alexander and Prior, 1971). Documented historical floods are clearly visible in magnetic susceptibility tests, which is evident by an increase in iron and other magnetic minerals in the soil from erosion along the Ohio River banks (Counts et al., 2014). However, due to the continuous erosion of these bank sediments, this technique does not extend back in time further than a few hundred years.

Moderate to severe erosion occurs today along the meandering Lower Ohio River in stretches where modern levees are not maintained or artificially built up (Munson et al., 1988; Counts et al., 2014). Hovey Lake was formed as the meandering path of this river continued to erode along the bank until the neck was breached and the meander bend is abandoned for a straighter and deeper part of the river channel (Munson et al., 1988). The Hovey Lake area is often flooded, in historic times as in the past. The Hovey Lake Village Site (12PO10) is situated on the western lower terrace directly adjacent to the lake (Munson, 1997).

3.2 Soils

The soils of the southern Wabash Lowlands reflect the low-relief topography, climate and vegetation of the area, and are influenced by flooding due to close proximity to the Wabash and Ohio rivers. The parent material of the Wabash Lowland soils are a mix of sand and gravel outwash deposited by the melting of the Pre-Illinoian, Illinoian, and Wisconsin glaciers to the north and Holocene-aged alluvium from the meandering Wabash and Ohio Rivers (Alexander and Prior, 1971; Fraser and Fishbaugh, 1979). The upland terrace soils are deep, nearly level to gently sloping and somewhat poorly drained to well drained, and are composed mainly of silt loam formed from alluvium (McWilliams, 1979). Additionally, the uplands are thinly capped with Peoria loess (Fraser and Fishbaugh, 1986; Muller, 2009). The Weinbach-Ginat-Elkinsville soil association is the most common association on the southern Wabash

Lowland upland terraces (Homoya et al., 1985). The higher upland areas are rarely subject to flooding, and are primarily used as cropland today (McWilliams, 1979). The acidic Weinbach (poorly drained) and Elkinsville (well drained) soils are found on the summit and shoulders of the uplands, respectively; Ginat soils (poorly drained) are found in the depressions and drainage-ways of the uplands (McWilliams, 1979; Homoya et al., 1985).

The Nolin-Newark-Petrolia soil association is present on the lower T-1 terrace and floodplain where the archaeological Hovey Lake Village site is located (McWilliams, 1979). This soil association is described as well-drained to poorly drained soils that formed in silty alluvium and are acidic and deep (McWilliams, 1979; Homoya et al., 1985). Although these floodplain soils can be very fertile, the lowlands flood regularly (as indicated by the wooded swampy vegetation and inclusions of course gravels in the soil profile) (McWilliams, 1979). Drainage is necessary for many modern commercial crops, thus some farmers have deemed the lowest relief areas unsuitable for cultivation (McWilliams, 1979; Counts et al., 2014). It is the combined effect of flooding and high regional precipitation (which will be discussed below) that creates the swampy environment with wet, fertile soils, which characterize the Hovey Lake region in the past as well as today (McWilliams, 1979; Coleman and Rogers, 2003).

3.3 Climate

As discussed briefly in the Background and Literature Review (Chapter 2), the climate in the Lower Ohio River Valley has been fairly stable throughout the Holocene. The region is classified as a humid continental climate, though it is very nearly subtropical (McWilliams, 1979; Jefferies, 2008; Muller, 2009). The modern southern Wabash Lowlands has the highest summer temperatures and longest growing season in Indiana (McWilliams, 1979). Summer humidity ranges between 80-100%, with temperatures averaging ~23.5 °C in July (Sceeringa, 2002). In comparison, the amount of winter humidity is not as high, but still fairly humid (30-60%) with an average January temperature of ~-3.3 °C (Coleman and Rogers, 2003; Muller, 2009; Indiana State Climate Office, 2014). Winds average ~16.1 km per hour throughout the warm months, trending primarily from the southwest. During the winter months, colder winds prevail from a northerly direction due to the continental polar air mass (Sceeringa, 2002). Wind speeds of >160.9 km per hour have been measured during tornadoes, which do occasionally occur in this part of the Midwest, typically in early summer (beginning in mid-April) (Sceeringa, 2002). These mid-latitude tornados produce intense downpours of rain that generate flash flooding and hail, which can flattened crop fields (Pauketat, 2004).

The high humidity and precipitation are provided by the northward-moving maritime tropical air mass from the Gulf of Mexico, whereas cooler and drier conditions result from the continental polar air mass that extends from northern Canada. Compared to elsewhere in North America, the average annual precipitation in the Wabash Lowlands is high, ~115.0 cm per year. The month of May is by far the wettest month in the study area, accounting for ~55% of the annual precipitation (~63.0 cm); October is the driest month (<2.0 cm) (McWilliams, 1979; Sceeringa, 2002; Muller, 2009). Today, when winters are particularly dry, the low stream flow concentrates pollutants in the ground water and decreases sedimentation rates in the Ohio River Valley. Conversely, during wetter winters, snowmelt from the plowed fields carries large amounts of sediment that is deposited in the river and backwater lakes (Coleman and Rogers, 2003).

3.4 Vegetation

The modern vegetation of the southern Wabash Lowlands reflects the warm and moist climate. Today, approximately 90% of the land use of Posey County, where Hovey Lake is located, is for agriculture (McWilliams, 1979). The natural vegetation of the southern Wabash Lowlands is a unique, because it is comprised of the overlap of three ecozones. Here there is a convergence of upland forest, bottomland forest, slough, and prairie, and the species found here are a mixture of those of Midwest, Southern, and Great Plains range affiliations (Gordon, 1936; Homoya, 1985). Early vegetation surveys of Indiana were conducted by the General Land Office between AD 1799 and 1846 (Gordon, 1936; Potzger et al., 1956; Lindsey et al., 1965; Homoya et al., 1985). The surveyors divided the state territory first into townships, then subdivided these townships into one-mile square units using witness trees and other physical landforms to mark the boundaries (Potzger et al. 1956). Within each section, the location, name, and diameter of witness trees, comprised of over 80 different taxa, were recorded (Potzger et al., 1956; Lindsey et al., 1965). In addition, the initial land surveys described and listed plant taxa located between witness trees, however the data on these plants were not collected in a standardized method. Areas where there was a large diversity of vegetation led to inconsistent characterizations of the early settlement ("pre-settlement") vegetation of Indiana (Gordon, 1936). The original land surveys mapped the southern Wabash Lowland uplands as occupied by variations of upland *Quercus-Carya* (oak-hickory) forests, with *Juglans-Liquidambar-Acer* (black walnut and/or butternut-sweetgum-maple) hardwoods in the lowlands (Braun, 1950; Potzger et al., 1956).

Given variations in the quality of vegetation data captured in the original surveys of southwest Indiana, mid-20th Century researchers attempted to correlate and integrate the original land survey notes and maps with new field surveys of vegetation that are correlated to data on soil-types, precipitation, temperature, and hydrology. These 20th Century researchers have different and varying interpretations of the dominant tree taxa identified in the original surveys (Figure 3.4). It has been agreed upon that the southern Wabash Lowlands had, at the time of the surveys and prior to widespread Euro-American logging and farming, a vegetation characterized by a dense *Quercus-Carya* "deciduous" forest with various subcategories of forest communities based on soil series and local geomorphology. Deam's (1940) *Flora of Indiana*, among other flora compendiums, are used here to describe and compare the modern vegetation of Indiana to this research's paleovegetation reconstruction.

Modern geomorphology and soil surveys report that mixed mesophytic forests of *Quercus*, *Quercus-Carya*, and *Quercus-Castenea* (oak-chestnut) communities occupy the drier south-facing upland slopes and ridges (Deam, 1940; Lindsey et al., 1965; McWilliams, 1979; Munson, 1997; Jefferies, 2008).

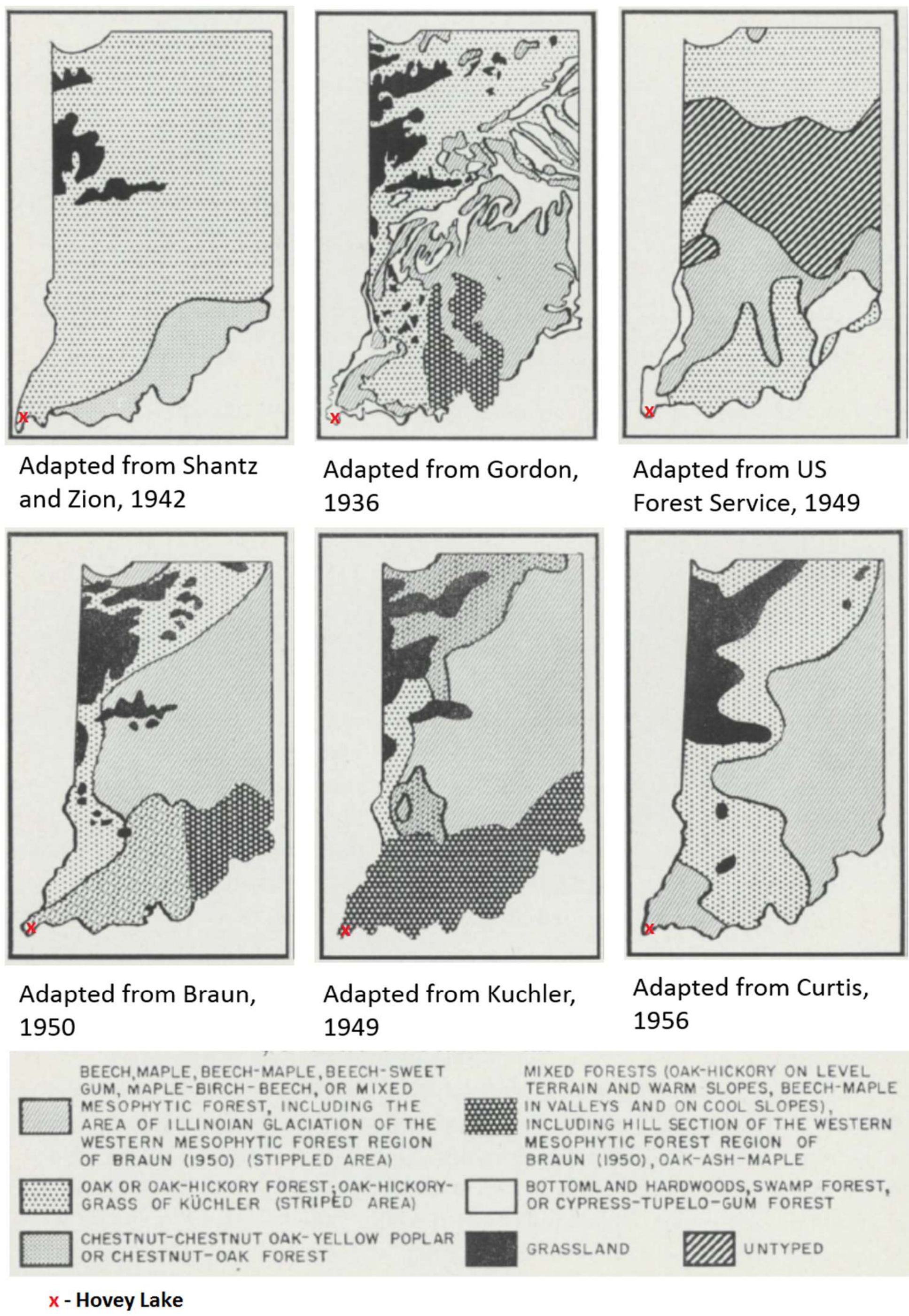

Figure 3.4 *Six comprehensive vegetation maps of Indiana based on 20th Century ecological surveys in conjunction with the original pre-settlement land survey notes. Figures adapted from Figures 4-9, Potzger et al., 1956.*

The tree species that occupy these slopes include *Quercus falcata* (southern red oak), *Q. stellata* (post oak), *Q. marilandica* (blackjack oak), *Q. prinus* (chestnut oak), and *Carya laciniosa* (shellbark). The cooler and moister (mesic), north-facing upland slopes and ridges have forests dominated by *Fagus* spp. (beech species), *Liriodendron tulipifera* (tulip tree), *Acer rubrum* (sugar maple), *A. saccharinum* (silver maple), and *Juglans* spp. (walnuts and butternuts) in addition to the *Quercus* spp. just listed (Potzger et al., 1956; Lindsey et al., 1965; Jefferies, 2008). The understory herbaceous taxa of the uplands include primarily prairie-type species of Poaceae (grass family) (Potzger et al., 1956; Lindsey et al., 1965; Homoya et al., 1985). On the wetter upland soils, like Nolin or similar series (McWilliams, 1979), more diverse populations of deciduous broadleaf species exist. These include *Liquidambar stryacflua* (sweetgum), *Nyssa sylvatica* (black gum), *Salix nigra* (black willow), *Carya illinoensis* (pecan), *Celtis laevigata* (sugarberry), *Quercus palustris* (pin oak), *Q. bicolor* (swamp white oak), *Q. mixhauxii* (swamp chestnut oak), *Q. phello* (willow oak), *Gleditsia triachanthos* (honey locust), *Catalpa speciosa* (catalpa), *Platanus occidentalis* (sycamore), *Fraxinus pennsylvanica* (green ash), and *Populous deltoides* (eastern cottonwood) (Deam, 1940; Homoya et al., 1985; Burns and Honkala, 1990a, 1990b; Jefferies, 2008).

In the swamps and sloughs on the wettest lowland soils, where Hovey Lake is located, the strongest southern influence in the flora is present. Southern and warm taxa are best represented by the presence of *Taxodium distichum* (bald cypress), *Populus heterophylla* (swamp cottonwood), *Gleditsia aquatic* (water locust), and *Fraxinus tomentosa* (pumpkin ash) (Deam, 1940; Lindsey et al., 1965; Homoya et al., 1985; Burns and Honkala, 1990a, 1990b). The southern Wabash Lowlands is the farthest northern natural occurrence of many of these species, particularly *Taxodium* (cypress) (Muller, 2009; Counts et al., 2014). The herbaceous understory also exhibits a strong signal for swampy conditions and species with southern affinities, such as *Hottonia inflate* (American featherfoil), *Dicliptera brachiata* (acanthus), *Asclepias perennis* (milkweed), *Vitis palmate* (catbird grape), species of *Carex* spp. (true sedge), *Hymenocalis occidentalis* (spiderlily), and *Arundinaria gigantean* (giant cane) (Braun, 1950; Burns and

Honkala, 1990a, 1990b; Homoya et al., 1985). The taxonomic diversity of the modern vegetation of Hovey Lake is also seen in the fossil pollen record of Hovey Lake, which is described in detail in the results and discussion chapters. Also evident in the Hovey Lake pollen record are signals for prehistoric Native American impacts on the landscape, which correlate with the archaeological record for the area.

3.5 Archaeology

The Hovey Lake Village Site (12PO10) covers over ~0.12 km^2 on the T-1 river terrace on the west side of Hovey Lake (Figure 3.5) (Munson, 1998). The village was inhabited roughly between ~700 to 300 cal yrs BP (AD 1300 to 1650) by a Middle Mississippian Caborn-Welborn Phase (~550 to 250 cal yrs BP; AD 1400 to 1700) population (Munson, 1997, 1998, 2000, 2003; Munson et al., 2001; Pollack, 2004). The

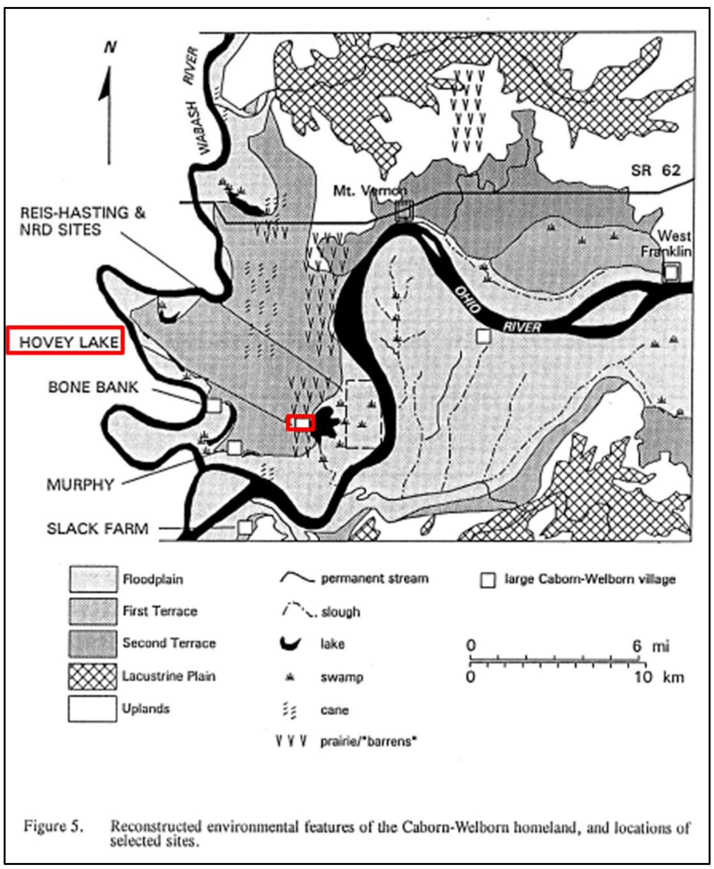

Figure 3.5 The Hovey Lake Village location on a T-1 terrace looking over Hovey Lake and the flood plain. Figure adapted from Figure 5, Munson, 1997.

primary Mississippian Caborn-Welborn Phase occupation is located on top of a Middle Woodland occupation dating to ~1,950 and 1,450 cal yrs BP (AD 1 and 500) (Munson, 1997, 1998; Munson et al., 2004; Pollack, 2004). The Middle Woodland occupation covers a much larger area (over ~0.24 km^2) and extends farther south than does the later, densely packed, Mississippian occupation (Munson, 1997).

The Caborn-Welborn Phase, exemplified by the Hovey Lake Village, developed out of the earlier Middle Mississippian Angel Phase which lasted from ~900 to 500 cal yrs BP (AD 1050 to 1450). The Angel Phase is epitomized by the Angel Mounds archaeology site, located ~56 km east (upstream) of the Hovey Lake Village in southern Indiana. It is not completely understood why the town of Angel Mounds began to depopulate at ~550 cal yrs BP (AD 1400). A combination of internal and external social and political forces likely led to the decline of Mississippian Angel Mounds and the Angel Phase (Pollack, 2004; Pollack and Munson, 2008). The abandonment of Angel Mounds, among many other settlements at ~550 to 350 cal yrs BP (AD 1440 to 1600), marked the beginning of what is known throughout the Midwest as the "Vacant Quarter" (VQ) (Pollack, 2004). The VQ is the time and place when Native populations left the dense, centralized towns and cities and dispersed across the landscape to establish or join smaller, less densely populated communities (Munson et al., 2001). Hovey Lake Village is one such village. Small Middle Mississippian settlements (like during the Angel Phase) typically were satellites towns, villages, hamlets, and homesteads that were both politically and culturally tied to a larger centralized city: Angel Mounds. Upper Mississippian settlements differed during the Vacant Quarter, no one village acted as a place of sociopolitical power over other Caborn-Welborn communities (Pollack, 2004). Undecorated ceramics recovered from Caborn-Welborn settlements show a standard basic form of Mississippian-style shell tempered jars, bowls, bottles, and funnels which were similar to the earlier Angel Phase ceramics. Decorated vessels are characterized by incised or punctured patterns located between the neck and shoulder (Munson, 1984). Very few vessel styles or patterns from other Mississippian groups or phases, such as Onetoa or Caddoan, have been recovered during excavation of Caborn-Welborn sites. It appears that each Caborn-Welborn hamlet or village operated largely independent from one another, with limited trade of goods and people (Pollack, 2004). The Hovey Lake Village site was likely a comparatively small hamlet or village at the time the Angel Mounds and Cahokia (in western Illinois) began to depopulate (Munson et al., 2004) and the Angel populations likely moved downriver to settle in smaller communities bringing with them their cultural traditions. These small early Caborn-Welborn sites include Hovey Lake, Slack Farm (15UN28), Murphy (12PO1), Bone Bank (12PO4), among others along the Wabash and Ohio Rivers in Indiana, Kentucky, and Illinois (Figure 3.6) (Munson et al., 2004). It was within these post-Angel, post-Cahokia communities that the Caborn-Welborn phase existed and developed (Munson, 2003).

Caborn-Welborn settlements were perfectly situated to access a variety of ecosystems nestled on the floodplains and terraces of the two rivers. These populations practiced agriculture by tending to their domesticated *Zea mays* (maize), *Phaseolus vulgaris* (common bean), *Cucurbita pepo* ssp*. ovifera* (ornamental gourd), and *Nicotiana* spp. (tobacco) on the river terraces near the village centers and in the bottomlands along the river as well (Pollack et al., 1996; Munson, 2004). The forests in these locales were cut with stone axes or girdled and then burned to clear the land for growing cultivated plants. Besides planting corn, beans, squash, and tobacco, the Caborn-Welborn people also planted species native to North America that were domesticated earlier, beginning in the Late Archaic ~3,200 cal yrs BP, and termed the Eastern Agricultural Complex (EAC) (Crawford, 1982; Delcourt et al., 1998; Munson, 1997; Smith, 2006, 2007; Scott-Cummings and Yost, 2008). EAC crops, domesticated from native floodplain weeds, include *Chenopodium berlandieri* (goosefoot/lambsquarter), *Helianthus annuus* var. *macrocarpus* (domesticate sunflower), *Polygonum erectum* (erect knotweed), *Iva annua* (marsh elder/sumpweed), and two members of the Poaceae family—*Phalaris caroliniana* (maygrass) and *Hordeum pusillum* (little barley) (Munson, 1997; Smith, 2006, 2007). Wild resources supplemented their diet and were procured from the diverse surrounding landscape, including various nuts (acorns, hickory, pecan, and black walnut), berries (grape and blackberry), fruit (persimmon, paw paw, and plum), and tubers (water lily, lotus, duck potato, ground

Figure 3.6 *Location of the larger Caborn-Welborn sites that covers a ~ 2,000-km² area concentrated at the confluence of the Ohio and Wabash rivers: Hovey Lake, Murphy, Slack Farm, and Bone Bank in relation to the Middle Mississippian, Angel Mounds. Figure adapted from second figure "The Site", IU-Bloomington, Anthropology Department, 2004.*

nut, and wild sweet potato) (Munson, 1997; Munson et al., 2004). Faunal remains in hearths are fairly scarce, but the remains indicate the majority of meat consumed was deer and eastern box turtle, and less frequently elk, bison, raccoon, beaver, turkey, opossum, fox, squirrel, swamp rabbit, cottontail rabbit, muskrat, ducks, geese, marsh rats, gar, catfish, bass, and mussels (Munson, 1997, 1998; Munson et al., 2004).

At the Hovey Lake Village, a sharp contrast in the distribution of midden soils indicates that a daub palisade or fortification wall surrounded the village (Munson, 2003). Within the fortification, a flat central plaza from which an estimated 100 or more residential structures radiated outwards—a settlement design seen in other excavated Caborn-Welborn hamlet and village sites (Munson, 2003; Pollack, 2004). Charred hickory nutshells recovered from hearths, charcoal from post holes, and carbonized residues from pot sherds were radiocarbon dated and suggest the occupation of Hovey Lake Village site ranged ~700 to 300 cal yrs BP (A.D. 1300 to 1650). Munson (2000, 2003) hypothesized that the houses closest to Hovey Lake are the earliest dating to ~550 cal yrs BP (AD 1400). As the settlement grew, more dwellings, middens, burials and cemeteries were built increasingly farther from the plaza and lake trending to the west, with the latest structures built ~312 cal yrs BP (AD 1638) (Munson, 1998). The distinct Caborn-Welborn pottery style and the absence of European glass beads or metal tools confirm the Hovey Lake Village was occupied during the Caborn-Welborn and VQ period (Munson, 2000). Dated material, location, and distribution of artifacts also identify that the primary site occupation period was likely centered closer to around 450 to 425 cal yrs BP (AD 1400 to 1425), but continued for many years until the village was abandoned ~300 cal yrs BP (AD 1650) (Munson, 2000; Pollack, 2004).

Excavation of the village cemeteries and individual residential burials speak to the complex society that lived in the Hovey Lake Village. A majority of burials were discovered in cemeteries beyond the clusters of houses, and were mainly of adults; suggesting adults were buried here as secondary burials (Munson and Cook, 2001). Individual residential burials were also discovered interned below or next to a house foundation or hearth and were primarily burials of women, children, and infants and it is thought that they may not have been moved to a second located due to the time of abandonment for cultural reasons (Munson and Cook, 2001). Additionally, remains buried within secondary burials had less indication of illness or disease, whereas those discovered buried in the residential areas had a higher percentage of mild disease or presumed pathogens (Munson and Cook, 2001). Munson and Cook (2001) suggested that those who died unexpectedly were buried alone within the residential area for a period, and then relocated to outer burials, a practice common among the Mississippian cultures. Among the individuals who exhibit poor health in the residential burials, there is little evidence to suggest that their deaths were due to Euro-American influence—although this topic requires further review by archaeologists and pathologists (Munson and Cook, 2001). Interestingly, grave goods are not especially common in any of the graves studied. Some pottery and shells were buried with the remains, but the graves goods were not particularly ornate, foreign made, or ritualistic in appearance (Munson and Cook, 2001).

By the time Euro-American settlers finally arrived in the Wabash Lowlands in the late AD 1780s there was no evidence of the Hovey Lake Village population, save for a few pot sherds and stone tools discovered by the Euro-American settlers when the topsoil was plowed clear for farming (Bigham, 1998; Munson, 2000). The only Native populations the first Euro-American explorers and settlers encountered were small migratory hunting bands of eastern and northern Piankeshaw and Shawnee (Munson et al., 2004). Munson et al. (2004) suggested that the Caborn-Welborn people at the Hovey Lake Village site, like many other Native populations, did not survive the wave of European diseases that migrated across the continent before Europeans themselves arrived. Other Native populations from the east had more direct contact with early French fur traders (Munson and Cook, 2001) and likely transmitted small pox and other disease. The Hovey Lake Village site first mentioned in historical texts was in the late 1890s by archaeologists scouting out potential sites in the Lower Ohio River Valley. More interesting sites were preserved and documented at nearby Caborn-Welborn sites: Slack Farm in Kentucky and the Bone Bank and Murphy sites in Indiana (Munson, 1997; Munson et al., 2003). The Hovey Lake Village site initially was deemed less important due to lack of ornate grave goods and it was only when construction on a new road in AD 1948 began that the site was reported and listed as an important archaeological site (Munson, 1997; Munson et al., 2003). Beginning in AD 1975, full scale surveys and smaller scale archaeological excavations took place, led by Cheryl A. Munson of the Department of Anthropology at Indiana University-Bloomington. Today the Hovey Lake Village site is still studied by Indiana University-Bloomington and is used as an archaeological field school (IU-Bloomington, 2004). The site is situated on private and state owned land. The lake itself functions as the Hovey Lake Fish and Wildlife state park with over 30 km^2 of open space for hunting, fishing, and trapping (Indiana Department of Natural Resources, n.d.).

CHAPTER 4: MATERIALS AND METHODS

4.1 Sample Collection

Lake sediment cores were collected from Hovey Lake by Dr. Broxton Bird and students from Indiana University-Purdue University, Indianapolis (IUPUI), in May 2013 and June 2014 by use of a modified Livingstone square-rod piston corer (Wright and Cushing, 1965; Wright, 1967). In both years, sediment cores were obtained from the deepest part of Hovey Lake (~1.5 m), as determined by estimating coordinates from historical bathymetry maps and confirming the deepest depth with an electronic fish-finder. This coring was conducted for the purpose of better understanding the sedimentation and flooding of the Lower Ohio River Valley along with the geomorphologic history of the Ohio River and its tributaries. The research was funded by an internal (IUPUI) grant given to Dr. Bird and archaeologist Dr. Jeremy Wilson. Drs. Bird and Wilson kindly allowed sediment samples to be taken and analyzed for pollen and shared information on the core collection, which forms the basis of this thesis research.

In May 2013, a coring platform was created in the chosen location within Hovey Lake by anchoring two inflatable Zodiac boats with a simple aluminum frame lashing the boats together. Once the boats were secured over the deepest part of the lake, a 15.0 cm diameter and 3.0 m long, PVC pipe was manually dropped between the two boats and pushed through the water column into the topmost sediment to aid in coring. Specifically, the PVC pipe facilitated the finding of the core-hole after each 1-m long core-drive extraction, and also acted as the datum from which core drive depths were measured. For every drive recovered from the boats, the sediment core was extruded into a longitudinal half of a 5.0 cm diameter and 1.0 m long PVC pipe (previously split in half and lined with plastic-wrap and tin foil). Each drive was measured for total sediment recovery as sediment can become compacted at greater depths, may contain "slop," or less commonly, have sediment loss from the bottom of the core. "Slop" is when stratigraphically higher sediments from the drill-hole wall falls down into the coring hole and are easily detectable by loose consistency and sometimes being a different color; any slop was removed in the field. The depths of any distinguishable sedimentary changes or inclusions were recorded in a field notebook. The drive samples were then covered with the other longitudinal half of the PVC pipe, sealed with duct tape, and labeled with the driver number, depth range, and an arrow indicating the top of the drive sample.

A second overlapping core (Core B) of sequential drives was collected approximately 1.0 m away from the first (Core A). Core A and Core B drive segments were offset by 30.0 cm in depth. By offsetting the two cores, samples taken in the laboratory could avoid the breaks in core drive segments where lake sediment may be missing, have fallen out, or were contaminated by slop. Sediment from approximately 5.0 m below the water-sediment interface was compacted enough that the crew was unable to extract any more sediment with the manual use of the Livingstone corer. Core A and overlapping Core B segments from the 2013 expedition were used to construct a composite 5.0 m long core. Finally, the coordinate location was saved into a GPS device. The core drive samples were then taken to the IUPUI Paleoclimatology and Sedimentary Laboratory to be photographed, described in detail, radiocarbon dated, geoprocessed for magnetic susceptibility, refrigerated, and later sampled for proxy analyses (geochemistry, elemental stable isotopes, pollen, etc.).

Dr. Bird and his IUPUI crew returned to Hovey Lake in June 2014 to obtain deeper sediment cores using an electric winch-operated coring tower with a Livingstone corer from a larger floating platform, which resulted in deeper penetration and collection of sediment cores. Two large 5.2 m-long inflatable tubes were harnessed to an aluminum NARS Cataraft frame, which became the framework for the coring platform, and upon which a wooden platform was attached (Figure 4.1). A hole had been left uncovered in the center of the wooden platform, through which Livingstone cores were driven when at the coring location. The entire coring platform was assembled on the shoreline and then towed by two inflatable Zodiac boats to the 2013 GPS coordinates and anchored in place (Figure 4.2). Once in the same general location as the previous year, a 15.0 cm diameter and 3.0 m long, PVC pipe was manually pushed through the hole in the plywood platform into the topmost sediment to aid in finding the core-hole after each extraction, and also to use as the datum from which core depths were measured (Figure 4.3). The first Livingstone core drive sampled in 2014 had no sign of sediment disturbance, which means the 2014 cores

Figure 4.1 *A wooden platform harnessed to inflatable tubes and aluminum Cataraft frame pictured here at Anderson Lake, Illinois, June 2014 (Photo by Caitlin Clark, 2014). This platform was also used at Hovey Lake, Indiana in July 2014.*

Figure 4.2 *A coring platform assembled and anchored on Anderson Lake, Illinois, June 2014 (Photo by Caitlin Clark, 2014). This platform set up was also used at Hovey Lake, Indiana in July 2014.*

was extracted from a location very close, but not identical, to where the 2013 cores had been taken. The close proximity is important to correlate proxy analysis between the cores from the two coring locations (2013 and 2014).

The Livingstone corer was manually pushed into the upper lake sediment for the first two drives. These first two drives were discarded in the field as the previous 2013 cores adequately captured the uppermost, modern-aged lake sediments. Core A of the 2014 samples began at 1.41 m below the water-sediment interface. All subsequent drives were saved and obtained with the aid of the electric winch-operated coring tower. The Livingstone corer was positioned within the PVC pipe, and pushed to the desired depth. The Livingstone corer was then clamped onto the coring tower, the inner square-rod piston was pulled out and locked in place, and the piston cable was clamped to the tower in a vise. With

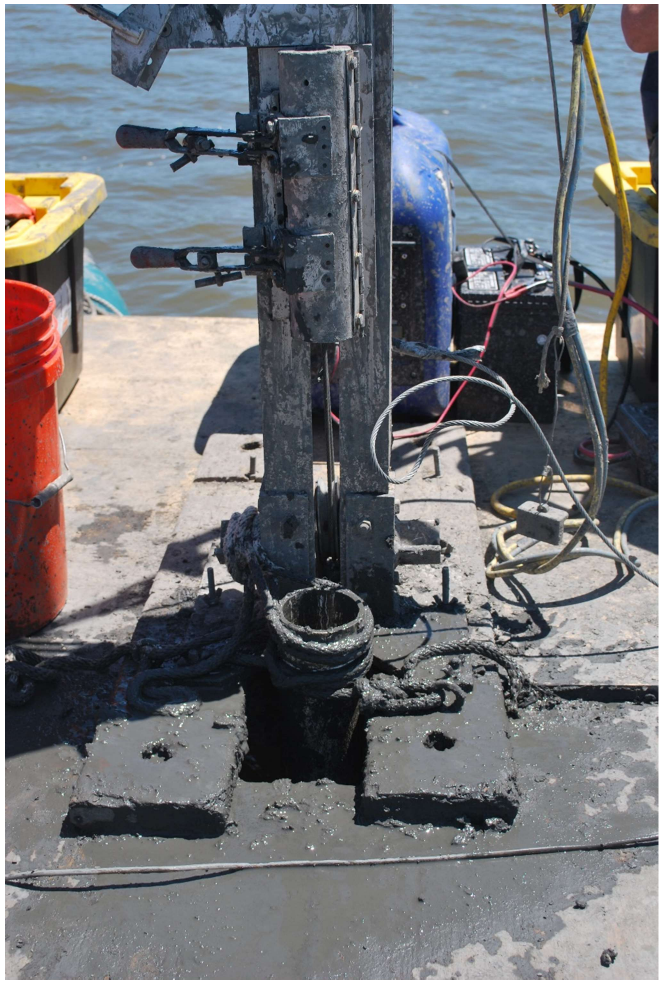

Figure 4.3 The PVC pipe casing anchored to the plywood platform; the top of the pipe was also used as the datum on Anderson Lake, Illinois, June 2014 (Photo by Caitlin Clark, 2014,). This set up was also used at Hovey Lake, Indiana in July 2014.

the piston immobile, the Livingstone casing was pushed down 1.0 m, collecting the targeted drive of the lake sediment. To pull up the core sample, the piston cable was unclamped and re-clamped into a second vise located higher on the coring tower. The coring tower then pulled the Livingstone corer and piston cable together vertically in one smooth motion. As greater depths of lake sediment was obtained, extension rods were added to the Livingstone corer.

Once fully out of the water, the square rod-piston was unlocked and lightly pushed in to gently "compact" the sediment inside the Livingstone corer before actually extruding the sample. The

Livingstone corer was then placed horizontally on the wooden platform and the square rod-piston was then electrically pushed back into the Livingstone to extrude the core sediment into a longitudinal half of a 5.0 cm diameter and 1.0 m long, plastic-wrap lined PVC pipe (Figures 4.4). Sediment cores were measured, described, wrapped, and labeled using the same methods as described above for the 2013 coring expedition. Like in 2013, a second overlapping core (Core B) of sequential drives was collected approximately 1.0 m away from the first 2014 (Core A), and the tops and bottoms of these were offset by 50.0 cm to deal with the core-drive break issues described above. The core drive samples were taken to the IUPUI Paleoclimatology and Sedimentary Laboratory and refrigerated. A 12.0 m long "composite" sediment record was constructed from the 2014 Cores A and B in terms of note-taking, core sediment description, geoprocessing, sample collection and cold storage.

4.2 Sample Processing

The 2013 Cores A and B and the 2014 Cores A and B, were split longitudinally and put into cold storage at the IUPUI Paleoclimatology and Sedimentary Laboratory. The sample sediments were photographed (Figure 4.5 and Figure 4.6) and described for texture, color, and any sedimentary inclusions or notable sedimentary changes. Further inspection of the sediment cores revealed that a few stratigraphic levels contained enough terrestrial plant materials to ^{14}C radiocarbon date. Macrobotanical samples were taken by Dr. Bird in 2014 for dating. Six samples were obtained from the 2013 composite cores and three samples from the 2014 composite cores (Table 4.1). The majority of the macrobotanical samples were wood or charcoal but these macrobotanical samples were too small to be identified to any specific taxa. Based on the results from the ^{14}C radiocarbon analysis, an age model was calculated by Dr. Bird which converted the composite depth of all cores to calendar dates. The model was then used to extrapolate ages between the sediment levels had no direct date (Figure 4.7). The chronology of the sediment cores from Hovey Lake are reported as both calibrated years before present (cal yrs BP) and cal yrs AD (AD). The duel reported dates allow the reader to directly compare the Hovey Lake sediments to both paleoclimate (typically expressed in cal yrs BP) and archaeological data (typically in BC/AD), respectively, and are considered here to be reliable.

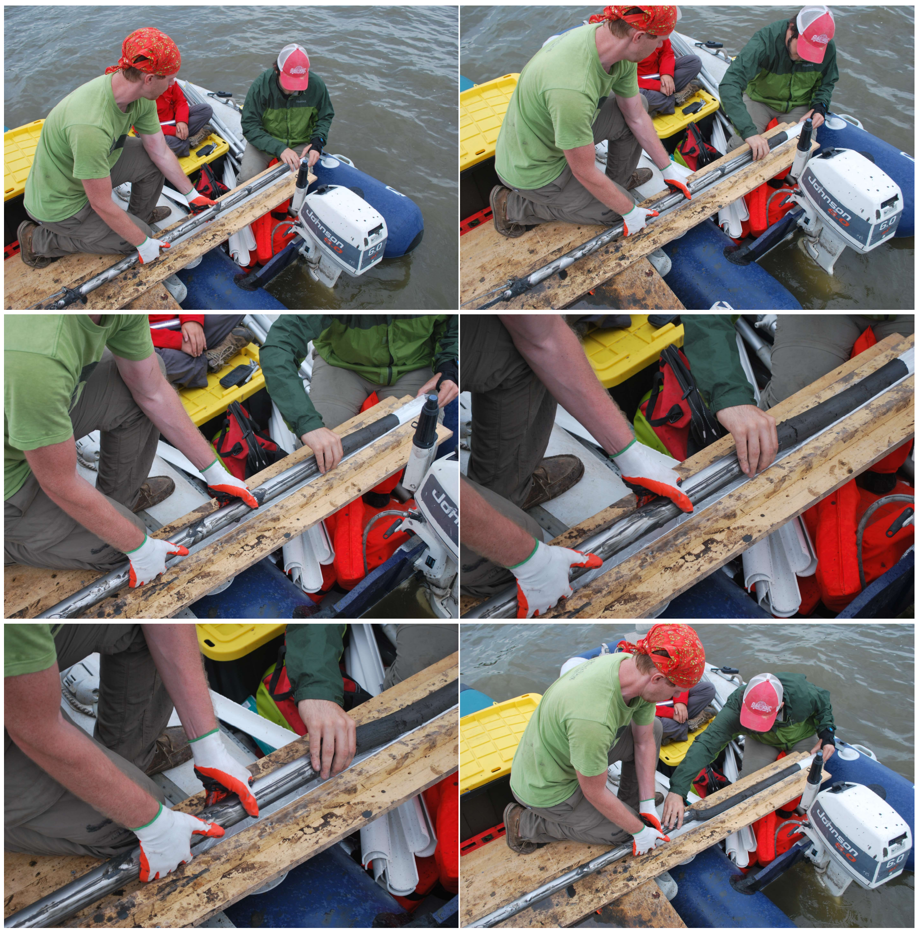

Figure 4.4 *The drive extraction process at Anderson Lake, Illinois, June 2014 (Photos by Caitlin Clark, 2014). This process was also used at Hovey Lake, Indiana in July 2014. Bottom right image is the full drive extraction.*

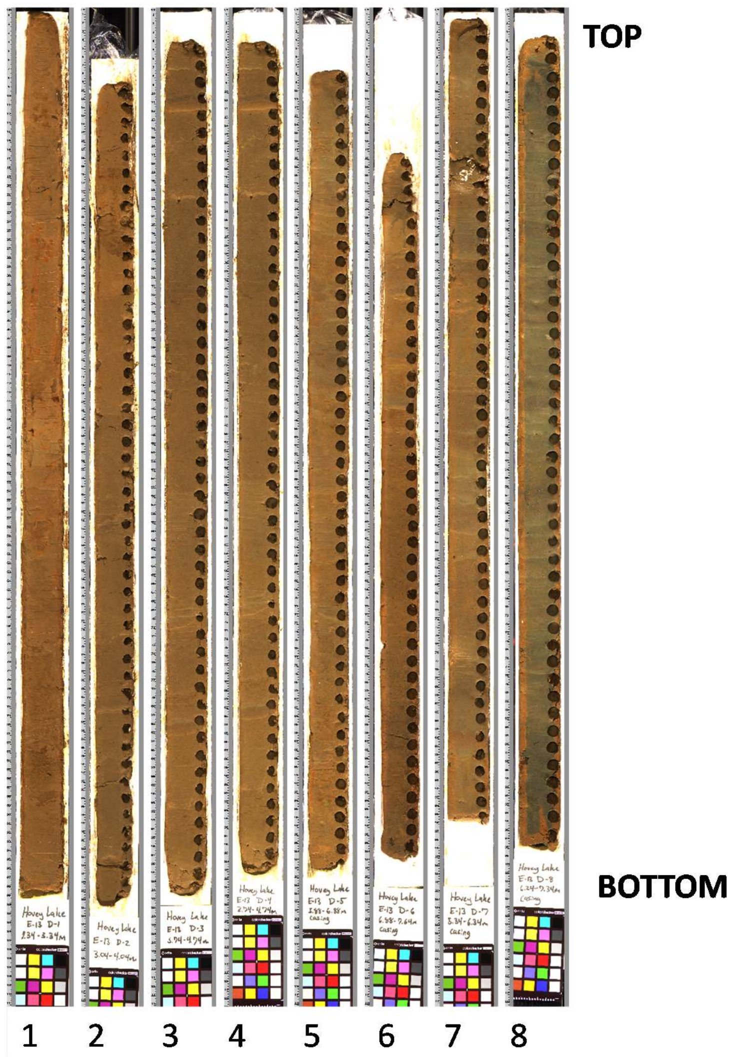

Figure 4.5 *The composite cores of Hovey Lake taken in 2013 representing the topmost sediments dated to Euro-American historic time period (Photos by Dr. Broxton Bird, IUPUI, 2014). Numbers below each core represent drive numbers, the larger numbers are deeper drives.*

Figure 4.6 *The composite cores of Hovey Lake taken in 2014 representing a large time period dating before the arrival of Euro-Americans (Photos by Dr. Broxton Bird, IUPUI, 2014). Numbers below each core represent drive numbers, larger numbers indicate deeper drives.*

Table 4.1: AMS ^{14}C Core Samples and Dates

Sample	Composite Depth	^{14}C Age BP	Median Cal Age BP
	0.0 m		-64
Hovey E13-D2: 7-8 cm	0.685 m	-1160	-40
Hovey E13-D2: 41-42 cm	1.025 m	-1690	-33
Hovey E13-D2: 57-58 cm	1.185 m	-3775	-18
Hovey E13-D4: 73-74 cm	2.57 m	1020	*
Hovey E13-D9: 38-39 cm	4.74 m	270	308
Hovey E13-D9: 57 cm	4.93 m	285	387
Hovey A14-D9: 45-45 cm	9.67 m	1440	1317
Hovey A14-D10: 22-23 cm	10.43 m	3310	3546
Hovey A14-D11: 32-33	11.38 m	930	*

*Not used in age model

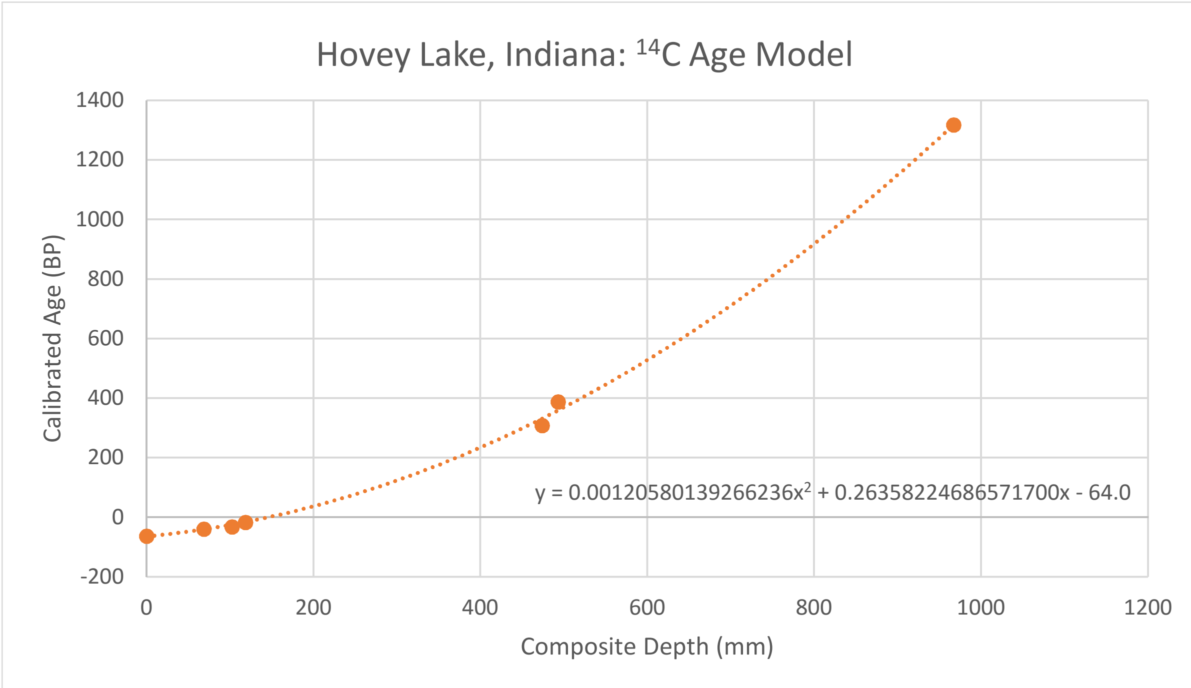

Figure 4.7 *The age model calculated by Dr. Bird, to convert the composite depth of all cores to calendar dates, based on Table 4.1.*

4.3 Pollen Analysis

Samples for pollen analysis for this thesis were not taken from the 2013 core. The upper four drives spanned the last ~360 cal yrs BP (AD 1652) to present. Instead, Dr. Catherine Yansa, Department of Geography, Michigan State University, collected sediment samples from the longer 2014 composite core based on the sediment-age profile. Dr. Yansa collected sediment samples at every 2.0 cm for drives dating after Euro-American land clearance and settlement, and at greater distance intervals for the historic-age sediments where sedimentation rates are extraordinarily high. A total of 45 sediment samples (1.0 cm^3) were prepared for pollen analysis, spanning ~5,790 to ~201 cal yrs BP (~3840 BC to AD 1749), and of these 37 samples form the basis of this thesis research. The sediment samples dated about 30 years apart between ~950 to ~201 cal yrs BP based on the age model (AD 690 to 1749) (Table 4.2). A 30-year sampling

Table 4.2: Hovey Lake 2014 Core Samples Used for Pollen Analysis

Field Drive (m)		**Sample in Drive (cm)**	**Composite mean depth (cm)**	**Age (ca. yrs BP)**	**Field Drive (m)**		**Sample in Drive (cm)**	**Composite mean depth (cm)**	**Age (cal yrs BP)**
3	7.1-8.1	31-32	372.50	**201.49**	6	10.1-11.1	75-76	716.50	**743.88**
		83-84	424.50	**265.17**			89-90	730.50	**771.99**
4	8.1-9.1	7-8	448.50	**296.76**	7	11.1-12.1	1-2	742.50	**796.47**
		27-28	468.50	**324.15**			13-14	754.50	**821.29**
		45-46	486.50	**349.62**			25-26	766.50	**846.47**
		63-64	504.50	**375.87**			37-38	778.50	**871.98**
		77-78	518.50	**396.83**			49-50	790.50	**897.85**
		81-82	522.50	**402.91**			63-64	804.50	**928.47**
		99-100	540.50	**430.72**			75-76	816.50	**955.08**
5	9.1-10.1	15-16	556.50	**456.11**	8	12.1-13.1	1-2	842.50	**1013.95**
		25-26	566.50	**472.28**			27-28	868.50	**1074.44**
		33-34	574.50	**485.40**			49-50	890.50	**1126.90**
		49-50	590.50	**512.09**			77-78	918.50	**1195.35**
		65-66	606.50	**539.40**	9	13.1-14.1	1-2	942.50	**1255.54**
		75-76	616.50	**556.79**	9	13.1-14.1	29-30	970.50	**1418.98**
		81-82	622.50	**567.33**			49-50	990.50	**2001.72**
		97-98	638.50	**595.88**			79-80	1020.50	**2875.84**
6	10.1-11.1	11-12	652.50	**621.36**			99-100	1040.50	**3458.58**
		25-26	666.50	**647.32**	10	14.1-15.1	9-10	1050.50	**3749.96**
		37-38	678.50	**669.94**			19-20	1060.50	**4041.33**
		51-52	692.50	**696.78**			29-30	1070.50	**4332.70**
		61-62	702.50	**716.23**			79-80	1120.50	**5789.56**

**Samples in highlighted in grey are not included in the pollen diagram (Figure 5.1) due to their projected older ages, which significantly predate the Hovey Lake Village.*

resolution was selected for this analysis as 30-year intervals are used in climatological studies to track discernable climate change (WMO, 1989), well as the discernable impacts of Native American on the landscape.

The Hovey Lake pollen analysis preparation, counting, and identification was conducted under the direction of Dr. Yansa at the Pollen Laboratory in the Department of Geography at MSU. Pollen preparation followed Faegri and Iverson (1975) with modification from an unpublished manual of Linda Shane (1998) of the University of Minnesota. Pollen grains were concentrated through the chemical and physical removal of carbonates, clay particles, silicates, peat, and other organics. After each step of the pollen sediment analysis chemical process detailed below, samples were concentrated in a free swinging bucket centrifuge at 3,000 RPM. Excess chemical liquid was decanted, followed by a minimum of four distilled water (dH_2O) rinses (except when dehydration of the samples was desired) and 1 ml of ethanol (EtOH) added to water rinses to settle (wet) any floating pollen grains to the bottom of the test tubes.

The work began with taking 1 cm^3 samples by measuring sediment from the 2014 composite core (already sampled into bags) into a miniscule 1.0 cm^3 glass beaker and placing each individual sample into its own numbered 15-ml polypropylene test tube. After each measurement, the glass vial was sterilized in bleach and washed with water to ensure that the samples were not cross contaminated. The sediment samples were first treated with 10.0 ml of a 10% hydrochloric acid (HCl) solution to dissolve any calcium carbonates. Two ml of ethanol was added to samples to control the hydrochloric acid reaction. Samples were then concentrated in a free swinging bucket centrifuge at 3,000 RPM, the liquid was decanted out, followed by four distilled water and ethanol (1 ml) rinses. Sodium pyrophosphate ($Na_4P_2O_7$) was added to each sample to suspend any clay particles. The test tubes were then placed in a hot water bath for 10 minutes and centrifuged, decanted, and rinsed as above to remove a significant portion of the clay fraction, but not any pollen and spores, which are silt-sized.

A screening step was added after the sodium pyrophosphate, where samples were washed through a 125-µm screen into a 400-ml beaker with distilled water until all of the sediment from the test tube had gone through the sieve. This step is to remove any coarse inorganic and organic materials from the finer particles, such as pollen. The sodium pyrophosphate treatment and the sieving step are not reported in Faegri and Iverson (1975), but taken from Bates et al. (1978) and an unpublished manual from the Limnological Research Center (Shane, 1998), respectively. The screened material, if any, was viewed with a SteroStar ZOOM Reichert binocular microscope under 40x magnification for seeds, charcoal, wood fragments, leaves, and needles. No macrobotanicals were present or distinguishable in any of the samples. To avoid contamination between samples, screens were soaked in a 6% hydrogen peroxide solution for 10 minutes and rinsed with distilled water before used for the next sample. The supernatant in the beaker was slowly transferred back into the test tube (without stirring) and concentrated down by centrifuging and decanting the water. When a few ml of supernatant was left in the beaker an additional squirt of distilled water was added, the beaker was lightly swirled and allowed to settle before being poured back into the test tube. The fine sand left behind in the beaker was discarded. The swirling process allowed any trapped pollen to become briefly suspended while the heavier sand sized particles remain at the bottom of the beaker.

After re-concentrating the screened samples in new 15-ml test tubes, the next step was to treat the samples with 6.0 ml of a 10% potassium hydroxide (KOH) solution and place them in a hot water bath for 20 minutes to remove any humic acids. The samples were then made acidic through a 10% hydrochloric acid solution centrifuge-rinse (a dH_2O-EtOH centrifuge-rinse was not performed at this time). Six ml of a 48% hydrofluoric acid (HF) solution was added to the samples and placed in a boiling hot water bath for 20 minutes to dissolve silicates. After decanting off the hydrofluoric acid, samples were immediately treated with another 6.0 ml of 10% hydrochloric acid and left to soak for 5 minutes before a distilled water centrifuge-rinse followed by an ethanol centrifuge-rinse.

Samples then were then dehydrated with 6.0 ml of glacial acetic acid (CH_3CO_2H). Next, 6.0 ml of an acetolysis mixture (sulfuric acid with acetic anhydrite) was added to each test tube and placed in a boiling hot water bath for 1 to 2 minutes to remove cellulose and other tough organic material. The acetolysis step "cleans" or "etches" the surface of the pollen grains which aids in the identification process. Test tubes were removed from the hot water bath and the reaction was immediately stopped with 6.0 ml of glacial acetic acid. Finally, the samples were dehydrated with an ethanol centrifuge-rinse followed by a tertiary-butanol (TBA) centrifuge-rinse. Samples were transferred into ½-dram glass vials and concentrated by centrifuging. Silicon oil was added to double the height of the concentrated pollen in these vials to prevent samples from drying out and prepare the samples for storage. Samples were left uncapped on a copper warming plate for 12 hours to evaporate excess TBA before finally capped.

Concentrated pollen samples were mounted on glass slides with additional silicon oil and viewed with a LEICA DMLB light microscope at 400x magnification. Grains difficult to identify were viewed at a higher magnification of 1000x to verify any morphological or distinguishing characteristics. Pollen grain taxa were tallied on a Lab-Count Denominator for a minimum of 300 pollen grains. The pollen grains identified consist of tree, shrub, and herb taxa, excluding the shoreline Cyperaceae (sedge family) plants and aquatics, as per standard protocol (Faegri and Iverson, 1975). Pollen grain identification was made by comparing samples to drawings in Kapp et al. (2000) and photographs in McAndrews et al. (1973), as well as familiarity with the MSU Department of Geography's Pollen's Lab slide collection of modern pollen. Taxonomic determinations were made to the lowest taxonomic level possible. Pollen grains typically are identifiable to only the genus level and in some cases, only the family level could be determined. For some pollen grains, identification can be reliably make to species level. Any pollen grains that could not be identified due to poor preservation quality or was obscured by undissolved sediment particles on the slide were counted as "undeterminable." Those grains in good condition but not identified in any key were considered "unknown," as per standard practice and not included in the total pollen sum. The total pollen sum for each lake sediment sample was entered into Tilia 1.7.16, an analysis and plotting software, to determine total percentages per taxon for each sample level (age), calculated based on the level total pollen sum, and this file was exported as an Excel file.

The pollen percentages were plotted as an abundance diagram using Tilia 1.7.16. The CONISS cluster analysis tool in the Tilia program was used to statistically delineate the pollen diagram into pollen zones (see the next Chapter 5: Results). Adobe Illustrator CS2 was employed to color and improve upon the final pollen diagram. Horizontal blue lines were also drawn in to help identify the significant CONISS breaks using Adobe Photoshop.

CHAPTER 5: RESULTS

This section describes the results of the pollen analysis and briefly interprets each zone of the Hovey Lake pollen diagram (Figure 5.1) by detailing significant vegetation changes over time. The pollen diagram shows percentages of pollen grains per taxa in relation to the total pollen sum (based on the sum of trees, shrubs and upland herbs) counted at each depth sampled (Figure 5.2). Only taxa that were the most abundant or those specific taxa that were the most ecologically significant are shown in Figure 5.1. Taxa identified, but observed at a low frequency, were not included in the analysis (see Table B.1 in the Appendices for the full pollen count). Percentages of selected pollen types were plotted against calibrated radiocarbon years before present (cal yrs BP) on the right, and calibrated dates in AD on the left. The purpose for displaying both cal yrs BP and AD dates on the pollen diagram is paleoclimate research is most often reported in radiocarbon or calibrated radiocarbon years, while archaeological dates are often reported in BC/AD. Bars along the left Y-axis (Figure 5.1) identify anthropogenic trends in relation to the pollen data. Bars along the right Y-axis identify climatic episodes in relation to the pollen data.

The Hovey Lake Village was occupied between ~650 to 300 cal yrs BP (~AD 1250 to 1650) as pictured on the left Y-axis of the pollen diagram (Figure 5.1) by the brown bar. The outer range limits for Late Mississippian are from ~1,150 to 350 cal yrs BP (AD 800 to 1600) as depicted on the left Y-axis by the yellow bar. The Medieval Warm Anomaly spans from ~1000 to 700 cal yrs BP (AD 950 to 1250) and is represented by a red bar on the right axis of the pollen diagram. The Little Ice Age spans from ~550 to 200 cal yrs BP (AD 1400 to 1750) and is depicted by a blue bar on the right axis of the pollen diagram. Thirty-seven lake sediment samples (of the total 45 processed and counted) were used in the pollen diagram to capture the time period from before Late Mississippian settlement and the Hovey Lake Village occupation, up until Euro-American settlement.

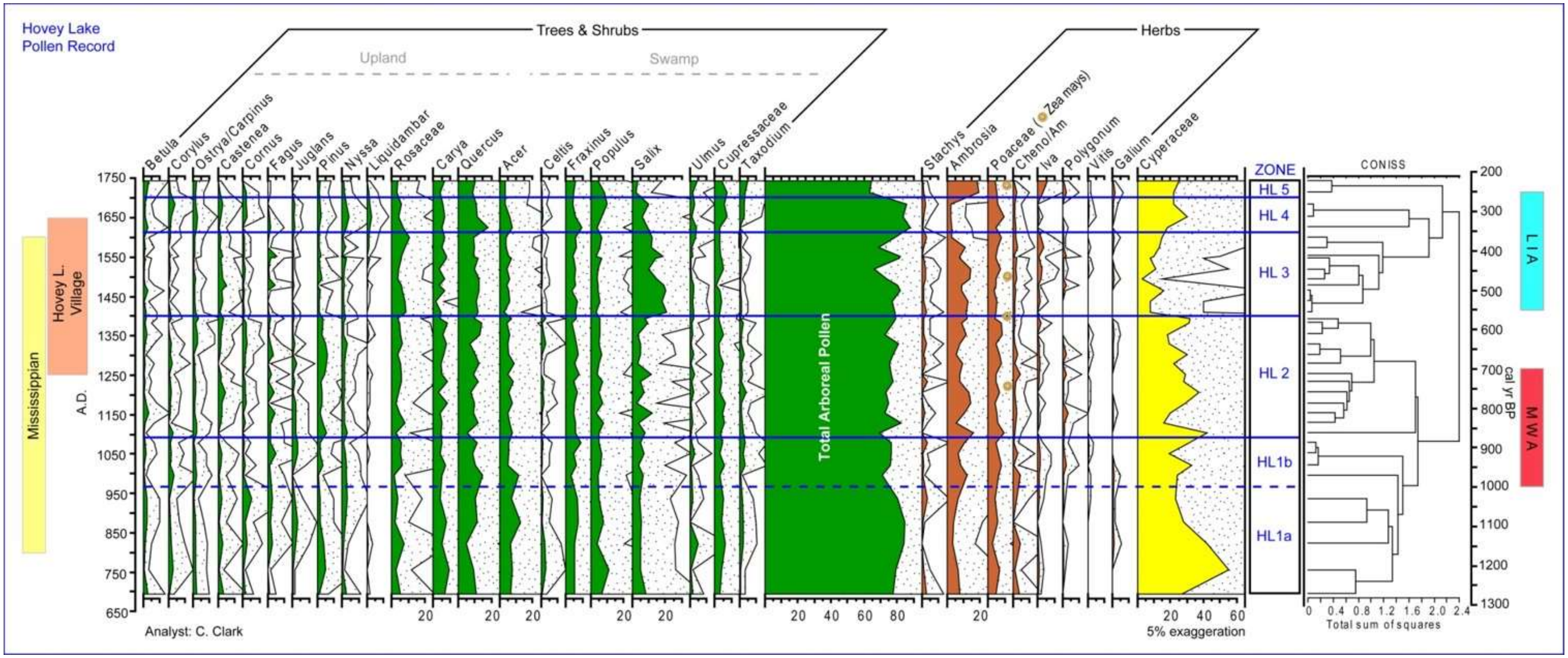

Figure 5.1 *Key taxa from Hovey Lake represented in a pollen diagram created using the Tilia software program. Zones were delineated using the CONISS cluster analysis tool. Counts for all pollen grains are presented in Table B.1 in the Appendices. The diagram focuses on a time period that ranged from before Hovey Lake was occupied by Middle Mississippian groups, until early Euro-American settlers reached the region (~1,050 year duration). See text for full details and interpretation.*

Figure 5.2 *Drives 3-10 from the 2014 Hovey Lake, Indiana composite core (Photos by Dr. Broxton Bird, IUPUI, 2014). The core is generally described as very fine sand and silt; a few inclusions of course sands and gravels likely indicate periods of flooding. Solid red lines on drives 3—9 (200—1,260 cal yrs BP) indicate where the samples utilized in the pollen diagram were taken. Dotted red lines were outside the timeframe of the study and not included in the pollen diagram.*

Pollen zones were determined by the Tilia cluster analysis tool: CONISS, which marks significant changes or shifts of pollen species dominance in the pollen grain percentages. The main taxa discussed are *Carya* (hickory or pecan), *Quercus* (oak), *Acer* (maple), *Fraxinus* (ash), *Populus*, (cottonwood) *Ambrosia* (ragweed), and Poaceae (grass family). Other tree, shrub, and herb species include *Betula* (birch), *Corylus* (hazel), *Fraxinus* (ash) *Ostrya/Carpinus* (hornbeam/hophornbeam), *Castanea* (chestnut), *Cornus* (dogwood), *Fagus* (beech), *Juglans* (walnut), *Pinus* (pine), *Nyssa* (gum or tupelo gum), *Liquidambar* (sweetgum), *Ulmus* (elm), *Salix* (willow), Rosaceae (rose family), and Cuperessaceae (cypress family), as well as other rarer occurring taxa, were observed individually at <2% for each sediment level analyzed.

At Hovey Lake, the focus of the study encompasses a relatively short time frame (1,050 years) and as a result, more subtle vegetation changes occurred than compared to pollen records spanning the Holocene. The results are broken up into five pollen zones based on large shifts in the pollen grain percentages of key taxa: indicative of vegetation change. Zone HL1 1,260—860 cal yrs BP (AD 690—1090); Zone HL2 860-650 cal yrs BP (AD 1090—1300); Zone HL3 650—340 cal yrs BP (AD 1300—1610); Zone HL4 340-250 cal yrs BP (AD 1610—1700); and Zone HL5 250—200 cal yrs BP (AD 1700—1750). The zone boundaries are indicated as blue horizontal lines on the pollen diagram. All samples processed and counted were taken from the 2014 composite lake sediment core, as detailed in Chapter 4: Methods. The lake sediment throughout the core was uniform very fine sand and silt texture, with a few inclusions of coarser sands, likely indicating periods of flooding (Counts et al., 2014).

The pollen data indicate the vegetation surrounding Hovey Lake was a bottomland forest with a large diversity of hardwood and herbs species at least since ~1300 cal yrs BP (AD 650) (and presumably earlier). The assemblage of the taxa in the pollen record is viewed in relation to modern living representatives of these taxa, which have tolerance ranges for temperature, precipitation, and soils, in other words, the "modern analog" principal (Overpeck et al., 1985; Hupy and Yansa, 2008). The fossil assemblage is correlated to the modern assemblages of plants (i.e. plant communities), which, in turn, is used to infer landscape changes through time. All plant habitat and geographic range information for this pollen interpretation is based on Deam (1940) and Burns and Honkala (1990a, 1990b).

5.1 Zone HL1 (945-773 cm depth): 1,260—860 cal yrs BP (AD 690—1090)

Zone HL1 has the maximum average pollen percentages of all zones for the following taxa: *Quercus* (10%), *Acer* (8%), *Populus* (6%), *Fraxinus* (6%), and *Carya* (6%). This diverse deciduous tree assemblage likely represents a community of both upland and lowland species within the southern

Wabash Lowlands. *Quercus* and *Carya* pollen grains cannot be identified to the species level, and likely originated from the uplands that surrounded the Wabash Lowland (Jato et al., 2007). *Acer* spp. pollen grains were most often identified as *A. saccharinum* or *A. negudo* (silver maple or box elder). Both of these species today occupy wetlands or shorelines of rivers and lakes, although *A. negundo* can inhabit upland regions so long as the soils are mostly mesic (Burns and Honkala, 1990b). The *Populus* spp. (*P. deltoides*, eastern cottonwood or *P. heterophylla*, swamp cottonwood) and *Fraxinus* (both *F. nigra*, black ash, and *F. pennsylvanica*, green ash) pollen grains likely represent swampy species from the area immediately around Hovey Lake. Trees and shrubs make up an average of 78% of the arboreal pollen (AP) grains in the entire zone and likely represent the mostly "pristine" forest before Mississippian occupation. Zone HL1 covers a total time span of 400 years and is subdivided into two subzones: Zone HL1a 1,260—990 cal yrs BP (AD 690—960) and Zone HL1b 990—860 cal yrs BP (AD 960—1090). Zone HL1 is subdivided based on the first significant rise in *Ambrosia* percentages, the drop in Cyperaceae (sedge family), and the slight decline in AP at the boundary between Zone HL1a and HL1b.

5.1.1 Zone HL1a: 1,260—990 cal yrs BP (AD 690—960; 945—833 cm depth)

Subzone HL1a spans 270 years and is primarily characterized by high values of AP which averaged ~81% of the total pollen sum. The majority of the AP is *Quercus* and *Acer,* where *Quercus* averages 9% and *Acer* 8%. Percents of *Carya* (7%) and *Populus* (7%) are also fairly high in this subzone. At ~1,074 cal yrs BP (AD 876): *Acer* pollen values increase sharply from 6.5% to 12.5%, while *Quercus* and *Carya* pollen grains stay constant. *Fraxinus* increase from 5% to 7.5% in the pollen spectra, and *Populus* values oscillate from 6.5% to 11% at ~1,175 cal yrs BP (AD 755) then decrease to 8% by the end of Zone HL1a. Total Rosaceae pollen values are low, averaging 4% of the total pollen sum.

Taxodium (bald cypress) is present from the beginning of this pollen record, indicating a warm and wet climate throughout the southern Wabash Lowlands. Herb pollen grains make up ~19% of the total pollen sum in this zone, with high percentages of *Ambrosia* (5.7%) and Poaceae (4.8%) of the total pollen sum. Although Cyperaceae is not included in the total pollen sum (as is convention as aquatic spices may skew the data to represent an entirely or mainly hydric landscape), the beginning of this zone is distinguished by an abundance of Cyperaceae at ~950 cal yrs BP (AD 1000) that progressively declines (Figure 5.1). It is important to acknowledge changes of aquatic taxa values to note how immediate vegetation surrounding bodies of water increases or decreases, however the interpretation of the abundance values should be treated with caution.

5.1.2 Zone HL1b (833—773 cm depth): 990—860 cal yrs BP (AD 960—1090)

Subzone HL1b spans 130 years and is distinguished from the previous subzone by a slight increase in *Quercus* pollen (from 9% to 11%), some taxa decrease slightly from the previous subzone, but only by about 1%: *Carya* (7% to 6%) *Acer* (8% to 7%), and *Populus* (7% to 6%). It is unlikely that these indicate any abundance change of key taxa in the local taxa. There are other challenges. *Populus*, cannot be identified to species level base on pollen morphology, but according to the ecology and range distribution of this genus the pollen probably came from *P. deltoides* or *P. heterophylla*, which are both common swamp species today. *Acer,* likewise, was difficult to distinguish, but the grains identified were either *A. negundo* or *A. rubrum* based on ecological interpretations. *Fraxinus* percentages remained stable during this time at ~6%. The total average AP percent for this second subzone is ~75%.

What does distinguish this zone from the subzone before is the *Ambrosia* percentages that increased from 6% to 9% and there is a more subtle shift of Poaceae from 4% to 6%. Herbs identified in this subzone include *Ambrosia*, Poaceae, and *Galium* (bedstraw), and increased from the prior subzone to make up ~25% of the total pollen sum, which may be an indicator of a warming trend potentially explained by the start of the Medieval Warm Anomaly (MWA) at ~1000 cal yrs BP (AD 950). The expansion of herbs may also be due to a climatic shift towards warmer and drier conditions; however, archaeological evidence from this region indicates this also may be a time of increased Native American activity (e.g. Munson, 1997; Pollack, 2004; Muller, 2009).

Subzone HL1b is also distinguished from the previous subzone most notable by the first appearance of higher values of native weedy herbs. These weedy plants together make up ~4% of the total pollen sum—which is high for a deciduous forest—and are species known to have domesticated by Native Americans as EAC crops but are serve as evidence of forest disturbance (Asch and Asch 1985; Smith, 2007). Potential EAC species identified in this subzone are: Chenopodiaceae-Amaranthaceae (shortened to Cheno-Am) (lambsquarter/goosefoot family-amaranth family), *Iva annua* (marsh elder), and *Polygonum erectum* (knotweed). Cheno-Am pollen is particularly common in this subzone at ~2%. Pollen grains from the Chenopodiaceae and Amaranthaceae cannot be distinguished from one another, or even to the genus or species level. *Chenopodium berlandieri* (goosefoot), *Iva*, and *Polygonum* was cultivated by Native Americans as early as 3,900—3,490 cal yrs BP (1950—1540 BC) in the region (Smith, 2006; 2007), and some of the these pollen grains may have been from cultivars, though this cannot be definitely determined. Pollen grains identified from Poaceae (~6%) may potentially have come from *Phalaris caroliniana* (maygrass) and/or *Hordeum pusillum* (little barley), which are wild species thought to have been harvested or cultivated by Native American populations. Similar to Cheno-Ams, Poaceae species-type cannot be truly known because pollen grains of Poaceae cannot be distinguished to genus or species level, with the exception of maize (*Zea mays*) and other long-grown cereal crops, which considerably larger (+50 µm). The Poaceae identified in this subzone are most likely from wild weedy species.

Given these caveats in interpreting pollen data, identification of EAC crops in this zone (HL1b) is tentative at best. The supporting archaeology dating to this time suggest that Zone HL1 (both subzones HL1a and HL1b) represents the "background" pollen levels before the establishment of the Hovey Lake Village. Zone HL1 consisted of mixed *Quercus*-*Carya*-*Acer* upland and *Fraxinus*-*Populus*-*Salix* lowland deciduous forest with some weedy species.

5.2 Zone HL2 (773—669 cm depth): 860—650 cal yrs BP (AD 1090—1300)

The second zone spans 210 years and continues to have high nonarboreal pollen (NAP) values, averaging ~25% of the total pollen sum. The NAP for this zone include continued high average pollen percentages of *Ambrosia* (~11%), and Poaceae (6%), and similar values (~4%) for weeds that potentially came from EAC crops. The local presence of Native American farming is confirmed in this zone by the recovery of one single *Zea mays* pollen grain at ~744 cal yrs BP (AD 1206). It is very likely that this single *Z. mays* pollen grain originated from Hovey Lake Village fields given the comparatively short distances the large grains *Z. mays* can travel, (usually no more than 100 m) (Lane et al. 2010). Of the trees and shrub taxa identified in this zone, the uplands were dominated by *Quercus* (10%), *Acer* (7%), and *Carya* (5%). Values of these uplands taxa species decreased slightly from that of Zone HL1. *Populus* (6%) and *Fraxinus* (6%) remained the dominant lowland swampy taxa with a small increase of *Salix* from 6% to 7%. *Pinus* slightly increased from 2% to 3.5% in the middle of this zone, but all of the *Pinus* values are too low to indicate any real local presence of this taxon, given that *Pinus* is a prolific pollen producer (Faegri and Iverson, 1975; Hupy and Yansa, 2008). The most likely explanation is that the *Pinus* pollen identified at Hovey Lake was blown in from other areas (Burns and Honkala, 1990a).

Zone HL2 is described as a mixed *Quercus-Acer-Ambrosia* upland and *Fraxinus-Populus-Salix* lowland forest. The *Ambrosia* pollen grain percentage increase is a signal of vegetation disturbance due to a warming and drying climate or the beginning of anthropogenic disturbance at the Hovey Lake Village.

5.3 Zone HL3 (669—481 cm depth): 650—340 cal yrs BP (AD 1300—1610)

Zone HL3 encompasses 290 years and is distinguished by a sharp rise in *Salix* percentages from 7% to 13% (Figure 5.1). Even though *Salix* pollen grains cannot be distinguished to species, based on ecological interpretations, these pollen grains were probably of *Salix nigra* (black willow), as its one of the dominate willow species that inhabits Indiana today (Deam, 1940; Burns and Honkala, 1990b). The significant rise in *Salix* occurred at the start of Zone HL3 and is a potential indicator of a cooler/wetter

Little Ice Age (LIA) climate at ~550—200 cal yrs BP (AD 1400–1750). The other swampy taxa identified in this zone include high values of *Populus* and Cuppressaceae. *Ambrosia* (10%) and EAC taxa (<4%) maintain higher percentages of NAP values, along with the continued appearance of high Poaceae percentages at ~7%. Of all the Poaceae pollen grains counted, two *Zea mays* were identified from samples that date to ~647 and 431 cal yrs BP (AD 1303 and 1519). These two *Z. mays* grains likely originated from domesticates grown by the inhabitants of the Hovey Lake Village (Munson, 1997; Muller, 2009).

There is a very slight increase of AP taxa (up to 77% of the total pollen sum) with slight changes in specific taxa dominance, likely attributed to the increase in precipitation and wetter climatic conditions associated with the LIA climate (Mann et al., 2009). Upland taxa such as *Quercus* (10% to 11%) and *Carya* (5% to 6%) slightly increased. Other upland taxa remain constant in their abundance, but make up very little of the total pollen sum. Of the lowland taxa, *Fraxinus* and *Acer* values (from 6% to 5% and 7% to 5%, respectively), were slightly more abundant, while *Populus* percentages throughout this zone remained steady at ~6%.

Zone HL3 consisted of mixed *Quercus*-*Carya* upland and *Salix* dominated lowland deciduous forest with some weedy species (*Ambrosia*) indicating disturbance and evidence of *Z. mays* domestication.

5.4 Zone HL4 (481—413 cm depth): 340—250 cal yrs BP (AD 1610—1700)

Zone HL4 only spans 90 years, and falls within the LIA climatic period (Mann et al., 2009). What distinguishes this zone is the clear indicators of reforestation, depicted by the abrupt near-disappearance of *Ambrosia* and increase in total AP percentages (from 77% to 86%). This increase in forest cover is likely due to the decline of the Native American population at the Hovey Lake Village, as reported in the archaeological record (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). *Ambrosia* values dropped to the lowest percentage in the record from ~10% to 2.5% of the total pollen sum. Poaceae increased slightly from 6% to 7%, and may be attributed to grasses recolonizing disturbed areas. None of the Poaceae pollen grains identified were large enough to belong *Zea mays*, which suggests *Z. mays* agriculture was no longer implemented at the Hovey Lake Village. Weedy taxa such as Cheno-Ams, *Iva*, and *Polygonum* were at their lowest average at <2% of the total pollen sum during this zone. These species likely were outcompeted by the returning forests on the edges of disturbed agricultural fields rather than belonging to domesticated EAC

The effect of the LIA was not as pronounced during Zone HL3. *Salix* remained the dominant lowland taxa, but dropped significantly from the previous zone, from ~13% to ~9%. Other lowland species such as *Populus* and *Fraxinus* increased very little (~1%) from the previous zone. Overall AP tree and shrub taxa values increased most significantly during this zone. *Quercus* pollen increased from 11% to 14%, *Fraxinus* from 5% to 7%, *Populus* from 6% to 7%, and *Acer* from 5% to 6%. NAP taxa dropped significantly from 10% to 2%.

The landscape around Hovey Lake during Zone HL4 was likely a mixed *Quercus-Carya-Acer* upland and *Salix-Fraxinus-Populus* lowland deciduous forest with very little weedy species compared to previous zones.

5.5 Zone HL5 (481—413 cm depth): 250—200 cal yrs BP (AD 1700—1750)

The final zone in the Hovey Lake pollen diagram is the shortest in time, ranging 50 years. Zone HL5 is significant to show the landscape impact of early Euro-Americans in the southern Wabash Lowlands. The total AP average was 64% of the total pollen sum, which was the lowest of all zones. This indicates that the deforestation by Euro-American settlers may have been more severe than that caused by either Native Americans or the MWA. *Ambrosia* was the dominant NAP during this time period and increased from 2.5% to 19% and Poaceae slightly increased from 5% to 6%, both which are good indicators of anthropogenic land clearance. A single *Zea mays* pollen grained was identified at ~206 cal yrs BP (AD 1744) and is a sure indicator of maize agriculture presence on the landscape. EAC taxa are at their maximum average at ~8%, again they were likely weeds growing along plowed fields and towns as Native Americans were largely removed from the area and there is no record of Euro-Americans cultivating EAC crops. Both the upland and lowland mosaic forest diversity remained about the same as earlier zones. Overall AP taxa decreased in abundance: *Quercus* declined from 14% to 9.5%, *Carya* remained constant at 6%, *Fraxinus* decreased from 7% to 5%, *Acer* decreased from 6% to 4%, and *Populus* decreased from 7% to 6%. The most drastic AP taxa declined was *Salix*, which declined considerably from the LIA spike, from 9% to 3% of the total pollen sum. There were some minor increases in AP, but this trend is restricted to the swampy taxa, such as *Taxodium* (increased from 2% to 4%) and Cyperaceae (increased from 5% to 8%). This may indicate that the wet areas surrounding Hovey Lake were not immediately cleared or farmed. The surrounding uplands were intensely farmed beginning in the middle 18th Century (Bigman, 1997), which explains the significant decline in overall tree and shrub pollen grains and the significant rise in weedy taxa and early disturbance species like Cheno-Ams, *Iva*, and *Ambrosia*.

Zone HL5 had significantly decreased AP values, but the uplands were likely a mixed *Ambrosia-Quercus-Carya* and *Populus-Fraxinus* lowland deciduous forest.

In summary, over ~1,050 years, between 1,260 to 200 cal yrs BP (AD 690—1750), subtle, yet important, vegetation changes occurred around Hovey Lake in the southern Wabash Lowlands. The overall makeup of the forests surrounding Hovey Lake did not undergo a significant reorganization. The forest remained largely a deciduous forest with only slight changes in particular taxa. Changes in taxa abundance provides supporting evidence that climatic and anthropogenic changes to the local occurred during this time. The following Discussion section (Chapter 6) will delve further into the interpretations and possible implications of these results.

CHAPTER 6: DISCUSSION

This chapter provides a broader interpretation of the pollen data obtained from Hovey Lake, located in the southern Wabash Lowlands of southern Indiana, and addresses the research questions (listed in the Introduction, Chapter 1) that guides this thesis research. This thesis focuses on documenting past human impacts on vegetation at a landscape level by discerning between these anthropogenic impacts from those probably caused by climate change. The focus is on the Midcontinent USA from ~1050 to 200 cal yrs BP (AD 900 to 1750) and begins by characterizing the paleoclimate, paleoenvironments and archaeology relating to Native American-environment interactions. The second section includes a comparison of the Hovey Lake pollen and archaeological records. Clearly discerning prehistoric Native American impacts on vegetation through pollen analysis first requires finding pollen grains of domesticated crop plants, those of *Zea mays* (maize) or other domesticated species (Behre, 1981; Smith, 2007). However, indirect evidence of land clearance is inferred from declines in arboreal pollen of trees and shrubs compared to those of non-arboreal weeds within this naturally forested environment. The section concludes with an evaluation of the importance of integrating the knowledge of geography and archaeology, thereby stressing the need for interdisciplinary collaborative research to better address unsolved questions about past human-environment interactions.

6.1 Vegetation, Climate, and Human Impacts in the Hovey Lake Area over the Last 1,200 Years

Overall, the pollen data from Hovey Lake contains two dominant ecological patterns. One is explained by the site's location at the merging of three diverse ecological regions: that of the Midwest (north); tall-grass prairie (west); and southern subtropical floras. The second pattern highlights the stable forest history over the past 1,200 years that reflects the humid, temperate climate and highly fertile soils of the area, which are conducive to prolific plant growth. The pollen record of Hovey Lake indicates that the regional vegetation variation underwent very subtle species-specific fluctuations within a mesic, broadleaf deciduous forest, as opposed to a total reorganization of forest dynamics in response to climatic and/or anthropogenic forces. This section attempts to distinguish between these two driving mechanisms.

Each pollen zone integrates an interpretation of the paleoclimate based on pollen grain percentages (this study; Figure 5.1) and from other paleoclimate proxy data from sites within the Midwest region. As described in Chapter 4, the chronology for the Hovey Lake pollen record was provided by Dr. Broxton Bird, Indiana University-Purdue University (IUIPUI), Indianapolis. Six pieces of charred material recovered from different levels of the Hovey Lake sediment cores were large enough to radiocarbon date and the results were the basis for an age model. The age model correlated sediment levels with calibrated radiocarbon years before present. Additionally, the Hovey Lake pollen record is briefly compared to archaeological data and pollen records from archaeological sites as well as to other pollen records lacking an archaeological context in the Midwest USA (Schoenwetter, 1971; King and Allen, 1977; King, 1981; Smith, 1984; Royall, 1988; Royal et al., 1991; Ollendorf, 1993; McLauchlin, 2003; Grimley et al., 2009; Liu et al., 2013; Munoz et al., 2014) to present a new reconstruction of local human-environment interactions.

To note, the archaeological literature regarding Native American cultures in the southern Wabash Lowlands prior to ~950 cal yrs BP (AD 1000) is incomplete. Vast areas of the lowlands were cleared and plowed for agricultural fields in the early and mid-19th Century, which along with the construction of residential roads and a state highway (SR 69) have destroyed many archaeological sites (Munson, 1997, Pollack, 2004). The majority of archaeological sites in the southern Wabash Lowland are relatively small compared to other Midwestern sites (e.g. Cahokia Mounds or Fort Ancient Mounds), and so these smaller sites received less attention by archaeologists. Also, the pollen records of other sites in the Midwest are widely dispersed and only a few of them were focused on reconstructing prehistoric Native American land use, thereby limiting comparison between records (and the inferred paleovegetation changes) in the region over time. Therefore, correlation between the data obtained in this study compared to the limited archaeological and palynological data from other sites in the region (published by other researchers) are presented with caveats in the context of Hovey Lake's pollen zones.

Eight pollen samples lie outside Figure 5.1 before Subzone HL1a. These samples were not included in the Hovey Lake pollen diagram because they are too old, according to the age model, and range from ~4790 to 1419 cal yrs BP (2840 BC to AD 531). Based on the geologic law of superposition these eight samples are definitely older than Subzone HL1a. Given that only eight samples were analyzed for this time interval, their interpretation is rudimentary (coarse-sampling, and hence poor temporal, resolution) (see Table B.1 in the Appendices for full pollen grain species and count). The taxa and their abundance (i.e. pollen values/percentages) of these older levels are nearly identical to those of Subzone HL1a (described below). The dominant arboreal taxa from ~4790 to 1419 cal yrs BP, in descending order of abundance (percentages), are *Quercus* (oak), *Acer* (maple), *Populus* (cottonwood), *Carya* (hickory/pecan), *Salix* (willow), *Fraxinus* (ash), and Cupressaceae (cypress family). NAP values are primarily comprised of *Ambrosia* (ragweed) and Poaceae (grass family), both at ~5.6—5.7%, which is very similar to those of Subzone HL1a and therefore indicates that this basal Subzone HL1a, shown in Figure 5.1, accurately captures the nature of the vegetation prior to detectable Native American impacts on the landscape.

6.1.1 Subzone HL1a: 1,260—990 cal yrs BP (AD 690—960)

The vegetation of Hovey Lake during this and the subsequent zones was predominately a deciduous forest that experienced subtle shifts in the relative abundance of species that indicate past vegetation responses to both climate and anthropogenic forcing. The pollen Zone HL1 is divided into two subzones based on a slight shift in the abundance of *Ambrosia* (ragweed), while other zones exhibit greater shifts (higher percentage changes) in the pollen grain abundance of two or more taxa.

During Subzone HL1a, the dominant species that inhabited the upland surrounding Hovey Lake, as interpreted from this pollen record, were *Quercus* and to a lesser extent *Carya* . Palynologists recognize certain species, *Quercus* in particular, of having a high rate of pollen production—that it over produces pollen with respect to the number of trees in the area (Davis, 1967; Kapp and Davis, 2000). *Quercus* was the most common tree in the Hovey Lake landscape even after accounting for this fact. Similarly, *Pinus* (pine) is an overproducer of pollen, even most so than oak (Kapp and Davis, 2000), so the low values (<5%) for pine) in this subzone suggest that these pollen grains were not from local trees, but rather were blown into the lake from some distance. Many species of pine occupy sandy soils in the Upper Midwest and Southeastern United States that could have provided this pollen. Supporting this interpretation is the notable absence of *Pinus* in the southern Wabash Lowlands today (Burns and Honkala, 1990a), whereas the rest of the taxa identified in the pollen record exist in the area today. In contrast, the low pollen grain values for the other upland tree and shrub taxa are considered to have derived from trees that occupied the area surrounding Hovey Lake, or fairly close by. These taxa included *Betula* (birch), *Corylus* (hazelnut), *Ostrya/Carpinus* (hornbeam/hophornbeam), *Castenea* (chestnut), *Cornus* (dogwood), *Fagus* (beech), *Juglans* (walnut), Rosaceae (rose family), *Nyssa* (gum), and *Liquidambar* (sweetgum). Note, *Nyssa* and *Liquidambar* are southern (subtropical) taxa whereas the rest are native to deciduous broadleaf forests of the Midwest today.

The Hovey Lake pollen record does not provide an obvious detectable signal for either anthropogenic or climate change affected the vegetation of the area during Subzone HL1a from 1,260—990 cal yrs BP. The Hovey Lake Village site was populated as early as 700 cal yrs BP (AD 1250), based on the radiocarbon dates obtained from burned posthole structures and charred nutshells (Munson et al., 2004; Pollack, 2004), which postdates Subzones HL1a and HL1b. So archaeological data for the time span of these lowest two subzones in the Hovey Lake pollen record comes from more distant sites and potentially prior occupation(s) in the area where the village was later built, along the shore of Hovey Lake. Mississippian and earlier Woodland-style lithics were recovered from scattered locations throughout the floodplain between the southern Wabash and Lower Ohio rivers (Munson, 1997; 1998; 1999; Munson and

Cook, 2000). Even though these data are limited, it is suggested the floodplain and river terraces around Hovey Lake were occupied by small Middle Woodland populations at ~1,950—1,450 cal yrs BP (AD 1—500) prior to Subzone HL1a. Munson et al. (2004) proposed later low-density, semi-sedentary populations of Late Woodland/Emergent Mississippian populations inhabited the area, where they gathered a variety of plants and hunted game. At this time, the impact of these populations was probably confined to (1) removing trees from the T-1 and T-2 river terraces for their wood, to be used for fuel, building materials, and tool making, and (2) gathering oak acorns and the nuts of hickory and other mast-bearing hardwoods (Munson et al., 2004).

The prevalence of *Quercus* and *Carya* in Subzone HL1a may be due to climate, as oaks and hickories do well during warmer intervals, such as during the Medieval Warm Anomaly (MWA) of ~1,000-700 cal yrs BP. The MWA was originally identified and described as a distinct warm period in northern Europe. Later, oxygen isotope records and other proxy records identified the anomaly in North America and elsewhere around the globe (Grove and Switsur, 1994; Cronin et al., 2003; Mann et al., 2009). The MWA in North America is characterized by warmer summer temperatures and decreased annual precipitation, leading to severe droughts and a range of vegetation changes across the United States (Mann et al., 2009; Cronin et al., 2010; Booth et al., 2012). While the pollen values of *Quercus* and *Carya* indicate a warm climate in general, alone they cannot confirm a warming peak clearly indicative of the MWA. Greater abundance of certain herbaceous species that inhabit uplands, particularly Poaceae and *Ambrosia* can also suggest warmer temperatures, but they can also indicate forest disturbance (fire, deforestation). The pollen values of both Poaceae and *Ambrosia* in this subzone are fairly stable and low (4.9% and 5.8%, respectively) compared to later zones, hence these herbaceous taxa likely represent the understory of the upland surrounding Hovey Lake, rather than an expansion of prairie during a time of warmer and drier conditions or significant forest clearance due to fire or humans.

Additional herbaceous species that occupied the understory of the forested upland at this time included *Galium* (bedstraw), *Stachys* (hedgenettle), and Chenopodiaceae-Amaranthaceae (lambsquarter-amaranth family; “Cheno-Am” for short). Although *Chenopodium* (goosefoot or lambsquarter) pollen grains are indistinguishable from pollen of the rest of the Amaranthaceae family (which now includes the former Chenopodiaceae family), it is possible that *Chenopodium* was locally present at this time as a weed, rather than a domesticate indicative of human activity of the Eastern Agricultural Complex (EAC) (Delcourt et al., 1998; Smith, 2006, 2007). Three grass species were cultivated by prehistoric Native Americans in the region—*Hordeum pusillum* (little barley), *Echinochloa* (barnyard grass), and *Phalaris caroliniana* (maygrass) (Smith, 1992; Delcourt et al., 1998). However, considering the low Poaceae values, it is unlikely that any of these Poaceae pollen grains identified were cultivated species. In summary, the upland arboreal pollen (AP) and non-arboreal pollen (NAP) provide no clear or definite signal of Native American landscape impacts (although it is possible) and neither does it indicate that the climate was significantly different from present, which is generally warm and moist.

The swamp taxa identified from the pollen of subzone HL1a support this interpretation. *Acer*, *Populus*, and *Fraxinus* dominated the swamps surrounding Hovey Lake and immediate vicinity. Based on the modern ecology of the species occupying the Wabash Lowlands today it is more likely that the *Acer* pollen grains came from *Acer rubrum* (swamp maple) and/or *A. negundo* (box elder), both lowland taxa. The *Populus* pollen grains identified are probably those of *P. deltoides* (eastern cottonwood) and/or *P. heterophylla* (swamp cottonwood), both of which occupy mesic to hydric habitats at present. Considering the low relief of the region, the gradual decline in *Populus* pollen percentages during this subzone may indicate that the areal extent of *Populus* (which prior to this zone may have extended into the uplands) contracted over time due to a lowering of the water table associated with reduced precipitation (Burns and Honkala, 1990b). Gradual warming and drying associated with the MWA, can explain how more xeric taxa (e.g. *Quercus* or *Carya*) outcompeted *Populus* and restricted the latter to riverbanks and the lakeshore. However, this paleoclimatic interpretation is tenuous, as the upcore change in the *Populus* pollen percentages (6.5% to 11%) at ~1,175 cal yrs BP (AD 755) then decrease to 8% at top of this subzone may be too slight to interpret a drying trend. *Fraxinus* pollen grains identified from this zone are most likely those of *F. nigra* (black ash), *F. pennsylvannica* (green ash), and/or *F. tomentosa* (pumpkin ash), all of which are species that presently grow along streams and lakes in the southern Wabash Lowlands (Burns and Honkala, 1990b; Muller, 2009).

Other lowland taxa that occurred in lesser abundance include *Celtis* (hackberry), *Salix*, and *Ulmus*. In addition, *Taxodium* (bald cypress) was locally present; its identity confirmed by some of the better preserved Cupressaceae (cypress family) pollen grains being clearly *Taxodium*. So *Taxodium* had previously migrated from the swamps of the subtropical southern coastal plain (Wanner et al., 2008), northwards to the southern Wabash Lowlands, its current northern range limit, sometime before Subzone HL1a, and confirms that the climate at this time was indeed warm and wet. Note *Taxodium* still occupies the shallow waters of the Hovey Lake shoreline today, and expanded into the lakebed any time the lake-level dropped. The trend in the *Taxodium* and *Populus* pollen values are too weak to indicate a decline in moisture from an initial high water table, possibly the decline in Cyperaceae (sedge family) provides a stronger signal, but at no point did the climate become semi-arid or prairie-like as it did farther west in western Illinois during the MWA (Schoenwetter, 1971; Smith, 1984; Munoz et al., 2014).

Species of Cyperaceae (sedge family) today are found in almost every environment, but are most often associated with wetlands and marshes (Dean, 1940; Braun, 1950). Therefore, Cyperaceae in the Hovey Lake pollen record is interpreted as derived from wetlands plants that surrounded the lake, most likely those of sedges and possibly bulrushes. Although Cyperaceae pollen grains are not factored into the total pollen sum, it is important to consider abundance changes of this wetland taxa, which rose whenever the shoreline area expanded and pollen grains dropped whenever the water table dropped, as was identified by pollen and plant macrofossil and associated geochemical analyses of a shallow wetland in North Dakota (Yansa et al., 2007). The highest levels of Cyperaceae in the Hovey Lake record occur in this subzone, peaking at ~1,200 cal yrs BP (AD 750), and declining afterwards. Other pollen records in the Midcontinent, such as those located along the Little Tennessee River Valley and the Central Mississippi River Valley that today have a climate generally similar to that of the Wabash Lowlands, also indicate a gradual warming and drying trend at this time in Subzone HL1a (Delcourt, 1979; King, 1981; Smith, 1984; Delcourt et al., 1986; Royall, 1988; Royall et al., 1991; Wilkins et al., 1991; Delcourt et al., 1998, 1999; Liu et al., 2013). Other proxy records, such as radiocarbon dates on charcoal (tracking fire frequency), oxygen isotopes of cave speleothems, and Mg/Ca ratios from lacustrine ostracods, all indicate a gradual warming trajectory during the MWA, that peaked starting at ~1000 cal yrs BP (AD 950) (Mann et al., 2009; Cronin et al., 2010). The signals for declining moisture for subzone HL1a (1,260—990 cal yrs BP) however are weaker in the Hovey Lake pollen record than they are for most other proxy records in the Midcontinent (Cronin et al., 2010; Booth et al., 2012; Wahl et al., 2012). The weaker signal for declining moisture levels at Hovey Lake may be because of the lake's location in the central Midwest along several major rivers or the signal may seem less drastic because of the fine focus of pollen zones.

There is no direct archaeological evidence for Native American utilization of the lowland trees. *Acer*, *Populus*, *Taxodium*, *Fagus* and *Fraxinus* are sturdy hardwoods, and potentially were used for building material and fuel sources by any Woodland inhabitants of the Hovey Lake shore (Green and Munson, 1978; Delcourt, 1979; Burns and Honkala, 1990b). The amount of pollen grains from these trees decrease from the Middle Woodland period, according to Delcourt (1979), and it is likely that these species were specially selected for construction. Other lowland herbaceous species of Subzone HL1a included *Iva* (marsh elder), *Polygonum* (knotweed), *Plantago* (plantain), and *Vitis* (grape), the last represented by a single pollen grain. In addition to being native to the southern Wabash Lowlands, both *Iva* and *Polygonum* are also important EAC taxa, but they are more likely part of the native vegetation.

In summary, the presence of *Nyssa*, *Liquidambar*, *Taxodium*, *Ambrosia*, and Poaceae in the pollen data for Subzone HL1a indicate a warm climate, comparable to that of present. This subzone has the highest average percentages of arboreal pollen (AP) of all zones (Figure 5.1), peaking at 81% of the total pollen sum, which suggests a moist climate conducive to tree growth during this time. The pollen data of Hovey Lake tentatively indicates a slight drying trend towards the end of the zone (1,260—990 cal yrs BP), which agrees with regional proxy records investigated by other researchers that better document a shift to a warmer and drier climate associated with the MWA. However, the Hovey Lake area had moister soils than other published sites within the Midwestern region for this time, as indicated by the lowland mesic to hydric trees (*Populus*, *Fraxinus, Taxodium*, and *Acer*) as well as sedges and other wetland herbs. Differences in the interpretation of moisture between that of Hovey Lake and other sites may be due to local topographic and hydrologic conditions.

Pollen records from the Central Mississippi River Valley that are focused on paleoecological and paleoclimatology reconstructions typically are at a coarser temporal resolution than was done in this thesis research (Smith, 1984; Royall, 1988; Royall et al., 1991; Delcourt et al., 1999). (In contrast, pollen records from lakes/wetlands adjacent or correlated to archaeology sites often are analyzed and interpreted at a finer temporal resolution and these are discussed in detail in the next section (Section 6.2). The pollen investigations that targeted paleoclimate reconstructions extended back millennia, and are described as analogous to the general modern vegetation in each region. Only the topmost zone of these other pollen records overlap in time with the entire Hovey Lake pollen record, which is divided into multiple zones. These prior pollen studies (those dedicated solely to paleoclimatological reconstructions) provide only crude reconstructions of vegetation change at a multi-centennial or even millennial scale, and can't be directly compared to the individual zones and subzones identified for Hovey Lake.

Pollen records west of Hovey Lake are from the Powers Fort Swale, Old Field site, Cupola Pond, and several sites along the Crowley's Ridge in southeast Missouri, as well as Volo Bog and Chatsworth Bog

Table 6.1: Summarized Ecological Pollen Records West of Hovey Lake, Indiana Used for Comparison. Note only the zone(s) that overlap with the Hovey Lake pollen diagram are listed in this table.

Source	Location	Zone time range (years before present)	Primary pollen identified (in descending order)
King, 1981	Chatsworth Bog, IL	8300—0	*Quercus*, Poaceae, *Ambrosia*, Tubliflorae, Chenopodiaceae, *Carya*, *Pinus*
	Volo Bog, IL	7900—140	*Quercus*, *Betula*, Poaceae, *Ambrosia*, *Ulmus*, *Carya*
Smith, 1984	Cupola Pond, MO	4550—0	*Quercus*, *Nyssa*, *Cephalanthus*,
Royall, 1988	Powers Fort Swale, MO	4500—0	*Quercus*, Cupressaceae, *Salix*, *Ambrosia*, *Ulmus*, *Liquidambar*, *Planera*, *Gleditsia*, *Acer*, *Nyssa*
Royall et al., 1991	Powers Fort Swale, MO	4500—0	*Quercus*, Cupressaceae, *Salix*, *Ambrosia*, *Ulmus*, *Liquidambar*, *Planera*, *Gleditsia*, *Acer*, *Nyssa*
Delcourt et al., 1999	Crowley's Ridge (many sites), MO and AR	2000—1000	*Pinus*, *Quercus*, *Carya*, *Liquidambar*, *Ulmus*, *Salix*, *Arundinaria*, *Juglans*
		1000—0	*Pinus*, *Quercus*, *Carya*, *Salix*, *Arundinaria*, *Liquidambar*, *Ulmus*, *Ambrosia*,

in western Illinois (Table 6.1). In southeastern Missouri, the topmost pollen zones of these sites are generally characterized as *Quercus* and Cupressaceae-*Salix* (Cypress family-willow) at both Powers Fort Swale and Old Field site,

while *Nyssa-Cephalanthus* (tupelo or gum-buttonbush) forests dominate the final zone at Cupola Pond. All of these sites showed decreasing values of *Quercus* and increasing values of hydric taxa like *Fraxinus*, *Ulmus*, *Liquidambar*, *Acer*, and southern *Pinus* (Smith, 1984; Royall, 1988; Royall et al., 1991). At Volo Bog and Chatworth Bog in western Illinois a similar trend occurs. The values of *Quercus* decreases at both Volo Bog and Chatsworth Bog, but only Volo Bog is characterized as a *Quercus* and *Betula*-dominant deciduous forest (King, 1981). These trends in the pollen data from sites within the Central Mississippi River Valley are interpreted as vegetation response to a larger cooling trend during the Late Holocene, after the warmer Middle Holocene. Although these data for the Late Holocene seem to refute the Hovey

Lake pollen data, it must be remembered that the values from these earlier paleoecological studies encompass a much longer time frame. And, more importantly, these pollen records are from sites located farther west, which had a drier climate in the past as today and so the vegetation there would more responsive to any precipitation declines than the vegetation in the Hovey Lake area.

Most of the published pollen records from Tennessee and Kentucky with a paleoecological/paleoclimatological emphasis were also conducted at a coarser temporal resolution than done in this research. Similarly, here one pollen zones in these records is equivalent to the entire pollen record of Hovey Lake, but some studies do separate out the topmost zone identified as when Euro-Americans settled in the Midwest. Pollen records from sites east/southeast of Hovey Lake are from Jackson Pond and Cliff Palace Pond in Kentucky, and Icehouse Bottom, Black Pond Tuskegee Pond, and Anderson Pond in Tennessee (Table 6.2) (Delcourt, 1979; Delcourt et al., 1986; Wilkins et al., 1991; Delcourt et al., 1998; Liu et al., 2013). For the time interval coeval with the Hovey Lake record, the pollen data from Jackson Pond in central Kentucky identified the main taxa as *Quercus* and *Carya* with lesser values of other deciduous trees (e.g. *Fraxinus*, *Acer*, and *Fagus*) that inhabit the region today (Wilkins et al., 1991; Liu et al., 2013). This pollen assemblage is very similar to that of Cliff Palace in eastern Kentucky, where the forest is characterized as a mixed mesophytic that included *Quercus*, *Castenea*, and southern affiliated *Pinus* (Delcourt et al., 1998). Interestingly, these authors reported small percentage values of *Iva*, *Helianthus*, *Chenopodium*-type, and *Plantago* were also identified at Cliff Palace, which could be from EAC cultivation, although they were likely wild species. During the time interval equivalent to Hovey Lake's Subzone HL1a, all of the eastern and central Tennessee pollen records identified *Quercus* and *Carya* as the dominant tree taxa. At sites along the Little Tennessee River in eastern Tennessee, the pollen record indicates that the majority of the pollen grains identified were *Quercus*, *Carya*, *Juglans*, *Betula*, *Pinus*, and *Arundinaria* (cane) (Delcourt, 1979; Delcourt et al., 1986), which is very similar to Subzone HL1a. Trace amounts of *Chenopodium*-type, *Plantago*, and *Iva* pollen grains were also reported for Black

Table 6.2: Summarized Ecological Pollen Records East of Hovey Lake, Indiana Used for Comparison. Note only the zone(s) that overlap with the Hovey Lake pollen diagram are listed in this table.

Source	Location	Zone time range (years before present)	Primary pollen identified (in descending order)
Delcourt, 1979	Anderson Pond, TN	5000—0	*Quercus*, *Fraxinus*, *Carya*, *Alnus*, *Cephalanthus,* Cyperaceae, *Arundinaria*
	Mingo Pond, TN	12,500—0	*Liquidambar*, *Quercus*
Delcourt et al., 1986	Little Tennessee River Valley (Black Pond, Icehouse Pond, Tuskegee Pond), TN	2500—1000	*Quercus*, *Pinus*, *Betula*, *Fraxinus, Arundinaria*
		1000—250	*Quercus*, *Castanea*, *Pinus*, *Liquidambar*
		250—0	*Ambrosia*, Poaceae, *Quercus*
Wilkins et al., 1991	Jackson Pond, KY	7300—120	*Quercus*, *Carya*, *Fraxinus*, *Salix, Liquidambar*
		3900—120	*Carya*, *Quercus*, *Fraxinus*, *Salix*, *Liquidambar*
Delcourt et al., 1998	Cliff Palace Pond, KY	3000—200	*Quercus*, *Castanea*, *Pinus*, Poaceae
Liu et al., 2013	Anderson Pond, TN	11,600—0	*Quercus*, *Carya*, Poaceae, *Pinus*, *Ambrosia*
	Jackson Pond, KY	11,600—0	*Quercus*, *Fraxinus*, *Acer*, *Carya*, *Cephalanthus*, Poaceae

Pond and Tuskegee Pond, which on their own would be attributed to the native vegetation, except for several occurrences of *Zea mays* (maize) pollen in Tuskegee Pond, which may indicate at least some human cultivation of EAC taxa during the Late Woodland (Delcourt et al., 1986).

The data from these other pollen records indicate that maize and possibility EAC taxa were utilized by Woodland populations in the region, possibly more so in Kentucky and Tennessee than along the Central Mississippi River, but their impacts on the vegetation appear minimal (Delcourt et al., 1986; Simon and Parker, 2006; Smith, 2007; 2009). No discernable anthropogenic paleoenvironmental signals are evident at Hovey Lake in Subzone HL1a, which agrees with the local archaeological data (Munson, 1997; 1998; 2000; Munson et al., 2004). The few EAC species that do appear in the pollen record at this time (e.g. Cheno-Am, *Iva*, *Polygonum*) are likely native understory plants rather than those planted and maintained by humans. The high percentages of *Quercus* and *Carya* are due in part to the over-production of pollen of these trees compared with other AP and NAP taxa (Davis, 1967; Jato et al., 2007), but also may be a result of the fairly warm temperatures and dry soils on the uplands, rather than due to human selection of these species for wild nut resources or timber.

6.1.2 Subzone HL1b: 990—860 cal yrs BP (AD 960—1090)

Subzone HL1b begins at ~990 cal yrs BP (AD 960) during the the Medieval Warm Anomaly (MWA) which started at ~950 cal yrs BP (Mann et al., 2009). The subzone is distinguished from the previous subzone by a slight increase in overall NAP (non-arboreal, herbaceous taxa) pollen grains, most notably those of *Ambrosia*, and a corresponding slight decrease in overall arboreal pollen (AP). While the upland and lowland forest communities are very similar to Subzone HL1a, there are subtle floristic changes. The most abundant trees are still *Quercus* and *Carya*, which both decline slightly upcore in this subzone. More noticeably is the greater decrease in *Acer*. *Acer* is a mesic species which along with slightly higher weedy NAP values indicate a warmer/drier climate of the MWA and less likely human disturbance impacting the vegetation. As before, there was a low abundance of *Betula*, *Corylus*, *Ostrya/Carpinus*, *Castenea*, *Cornus*, *Fagus*, *Juglans*, *Pinus*, *Nyssa*, and *Liquidambar* and other upland tree and shrub taxa. The upland understory included Cheno-Am, pollen values of which remain unchanged from before (HL1a), as well as very low values of *Stachys*, *Iva*, and *Galium*.

Ambrosia, and to a lesser extent Poaceae, are the most distinctive aspect of this subzone. Possibly small open patches occurred in the forest at this time. Both *Ambrosia* and Poaceae are known to be early successional plants. They are often the first species to recolonize an area in the midcontinent region when temperatures are exceptionally warm and especially when there is too little precipitation for tree seedling growth, as well as after a fire, or around cleared or abandoned (or rotated) agricultural plots (McMillan and Klippel, 1981; Smith, 1992; Delcourt et al., 1998). Archaeological data from sites surrounding Hovey Lake indicate that during the time of subzone HL1b there were low density Native American groups in the region (Munson 1997, 1998, 2000; Fortier and McElrath, 2002). Small groups of Early Mississippian populations probably utilized the resource-rich Hovey Lake uplands and lowlands to hunt and gather resources, but did not occupy the area for long periods allowing the marginal weedy species to occupy the cleared space briefly before arboreal taxa reclaimed the landscape (Delcourt, 1979; Jenkins and Parker, 2000).

Human utilization of the nuts of *Quercus* and *Carya* prior to the establishment Hovey Lake Village did not significantly alter the values of these species in the pollen record. Any management of the forests (nut-tree propagation) by humans may have allowed for weedy taxa, such as grasses and herbs, to take hold along paths or trails to high producing trees (Delcourt et al., 1998; Munoz et al., 2014). However the lack of significant archaeological data corresponding to this time suggests that the Hovey Lake floodplain was not significantly inhabited during this subzone (Munson 1997, 1998, 2000). Also, the continued relatively low values of EAC taxa confirm that anthropogenic forces were generally minimal during this subzone. *Chenopodium*, *Iva*, *Polygonum*, and Poaceae spp. are all native species of the Wabash Lowlands and their presence likely reflects wild populations of these weeds at this time (Deam, 1940; McWilliams, 1979). It is *possible* that EAC crops were planted on a small scale in the floodplains and terraces of Hovey Lake and more broadly in the southern Wabash Lowlands, but it is unlikely given the low pollen grain values. More like the presence of these EAC taxa are acting as weedy disturbance species. Other midcontinent pollen records, such as at the Cliff Palace Pond in Kentucky (Delcourt et al., 1998), at Fort Ancient in Ohio (Essenpries, 1978; McLauchlan, 2003), and various sites along the Central Mississippi River Valley (Simon and Parker, 2006) indicate populations were long cultivating weedy EAC species. Evidenced by the increase in seed size, a characteristic of plant selection and planting (Yerkes, 1988, Fritz, 1990; Simon and Parker, 2006; Smith, 2006). This selection of and cultivation of EAC was not happening at Hovey Lake.

The lowland tree and shrub vegetation in the Hovey Lake area was comprised primarily of *Populus*, *Fraxinus*, *Acer*, and *Salix.* Low pollen percentages of *Celtis*, *Ulmus*, Cupressaceae, *Taxodium*, and *Vitis* suggest that these were minor components in the local flora. *Salix* was still a common taxon in the area and its pollen values are similar to those in the previous subzone HL1a. The declining pollen values of *Populus* and *Fraxinus* values during HL1b can be attributed to the areal extent of these lowland species became more restricted to the lowest lying areas and along water ways, as observed recently by Burns and Honkala (1990b) under warmer and drier conditions.

The MWA, discussed in Chapter 2 (Background and Literature Review), is generally believed to have begun before this subzone, but reached its peak during Subzone HL1b and the following zone, Zone HL2 (Cronin et al., 2003; Mann et al., 2009). The MWA was a time of warmer temperatures and decreased precipitation, with decadal and multidecadal variability in moisture, attributed to the interactions of ENSO events, changes in the North Atlantic Oscillations, and the North Atlantic thermoaline circulation (Cronin et al., 2003; 2010; Mann et al., 2009; Booth et al., 2012). Vegetation responses to the MWA varied geographically because of spatial and temporal variations in these teleconnections, particularly in how they impacted the movement of the tropical Gulf of Mexico air mass, in addition to the influence of latitude and elevation (Benson et al., 2007; Mann et al., 2009). At Hovey Lake, the low topography and proximity to the Lower Ohio River, in addition to abundant moisture transported from the Gulf of Mexico can explain why there was a minimal drying effect on the local vegetation at the beginning of the MWA and Subzone HL1b. Similarly, along the Central Mississippi River Valley, at the time equivalent to Subzone HL1b, the vegetation was dominated by Cupressaceae-*Salix*, *Nyssa*-*Cephalanthus*, and decreasing *Quercus*-*Carya* deciduous forests depending on the amount of relief at each site; with a notable increase of NAP including weedy taxa (Table 6.1) (King, 1981; Smith, 1984; Royall, 1988; Royall et al., 1991; Delcourt et al., 1999). Meanwhile in Kentucky and Tennessee, the forests were predominately *Quercus*-*Carya* with smaller numbers of *Acer*, *Fagus*, *Fraxinus*, and *Salix* (Table 6.2) (Wilkins, 1991; Delcourt et al., 1998; Liu et al., 2013). In contrast, there was a vegetation response to the MWA in mid-Michigan, where mesic-adapted *Fagus* populations declined while fire-tolerant taxa such as *Quercus* and *Pinus* increased (Booth et al., 2012).

The only detectable impacts of the MWA warming/drying in the study area south of the Great Lakes region is in the finer resolution pollen grain records conducted adjacent to archaeological sites, at Cahokia (e.g. Schoenwetter, 1971; Munoz et al., 2014) and Fort Ancient (e.g. McLauchlan, 2003) (see Section 6.2.2 and 6.2.4 respectively). The pollen increase in NAP prairie taxa, such as Poaceae and *Ambrosia*, are particularly higher at Cahokia in western Illinois than at Hovey Lake for the interval equivalent to Subzone HL1b, because (1) Cahokia was established as a settlement at this time (Section 6.2.2) and (2) western Illinois (Cahokia) is farther west than southeastern Indiana (Hovey Lake) and naturally would be more susceptible to the warming and drying impacts of the MWA (Lopinot and Woods, 1993; Benson et al., 2007; Munoz et al., 2014). East of Hovey Lake, in Ohio, Kentucky, and Tennessee relatively smaller populations of early Mississippians (and remnant Hopewellian Fort Ancient settlements) were scattered across the landscape. This is evident in the pollen record as steady, albeit low, values of EAC domesticates and high values of weedy disturbance taxa (Delcourt et al., 1985; McLauchlan 2003).

Given that during Subzone HL1b pollen values of EAC taxa are low, there is a lack of hard archaeological evidence for crop cultivation, and in light of the other pollen records in the Midcontinent USA, climatic change was the driver of vegetation shifts from 990—860 cal yrs BP (AD 960—1090) at Hovey Lake. Moreover, the slight decrease of upland tree and shrub pollen values in this subzone is interpreted as a weak response to peak MWA warming rather than a result of agriculture or woodland management implemented by Native populations. In other places in the midcontinent, this is not necessarily the case. The vegetation changes surrounding Hovey Lake were likely to be greater in the uplands than in the lowlands, because of the more reliable moisture levels of the low-lying swamps fed by seasonal overbank flooding of the Wabash and Lower Ohio Rivers (Alexander and Prior, 1971; Coleman and Rogers, 2003), which could have buffered the swamp vegetation from reduced precipitation and increased temperatures associated with the MWA.

6.1.3 Zone HL2: 860—650 cal yrs BP (AD 1090—1300)

Zone HL2 begins at 860 cal yrs BP (AD 1090) during the height of the MWA (Cronin et al., 2003; Cook et al., 2004; Mann et al., 2009). AP percentages gradually decline from the previous zone, while NAP average percentages continue to increase throughout the zone, indicating the dry and warm conditions of the MWA. The dominant trees in the uplands were still *Quercus* and *Carya*, which can be attributed to the warm temperatures of the MWA. Macrobotanical data from the adjacent Hovey Lake Village (~700—300 cal yrs BP; AD 1250—1650) for the same time interval indicate that the early Hovey Lake Village inhabitants gathered oak acorns and the nuts of hickory and other mast-bearing hardwoods, as well as collected wood for fuel, building materials, and tool making (Munson, 1997; Munson et al., 2004). The rest of the pollen grains identified were *Betula*, *Corylus*, *Ostrya/Carpinus*, *Castenea*, *Fagus*, *Juglans*, *Nyssa, Pinus*, *Liquidambar* and *Cornus*. Notably, *Liquidambar* and *Cornus* all but disappear from the record at this time, each represented by only one or two pollen grains per sample. This pollen decline probably relates to the drier conditions, as modern *Liquidambar* and *Cornus* are limited in areal extent by the amount of annual precipitation in upland settings (Burns and Honkala, 1990b).

While the Hovey Lake pollen data do support a general trend towards somewhat warmer and drier conditions, no severe droughts are apparent. Nor is there any other evidence suggesting that during the height of the MWA the southern Wabash Lowlands or Hovey Lake dried up. This is not surprising given the low topography of these areas in the regional landscape (Munson 1997, 1998, 2000, 2003; Munson and Cook, 2001; Munson et al., 2004; Alexander and Prior, 1971). The water tables may have been low during this time, but not to a significant extent due to moisture from the Gulf/Atlantic maritime tropical air mass moving north and flooding within the broader Ohio River watershed. This interpretation is supported by the pollen data from Hovey Lake, where the very slight declining pollen values of *Acer*, *Populus*, and *Fraxinus* suggest that the MWA did impacted these species mildly, but not to a significant extent. These species are all hardy hardwoods that can withstand large temperature and precipitation fluxes as well as are able to occupy various topographic locations, though they most often prefer locations near streams or lakes (Burns and Honkala, 1990b).

Salix pollen values increase slightly in Zone HL2. Although differentiating *Salix* pollen grains is not easy, these grains are most likely *Salix nigra* (black willow), which is the only willow species that inhabits that area today. Today, *S. nigra* typically grows closest to water sources, and can withstand temperature fluctuations, so long as it receives adequate soil moisture, such as by overbank flooding in river (Burns and Honkala, 1990b). The values of the remaining lowland trees, *Celtis* and *Ulmus*, remained relatively unchanged and at low abundance during Zone HL2. The lowland herbaceous species identified in this zone are *Polygonum* and very small amounts of *Galium*, *Plantago*, Rhamnaceae (buckthorn family), *Sium* (waterparsnip), *Urtica* (nettle), and *Vitis*, and all likely comprised the native vegetation immediately surrounding Hovey Lake.

What marks HL2 as a distinct pollen zone is the increase of certain NAP species, particularly *Ambrosia*, which peaks at 11% of the total pollen sum, the highest percent prior to Euro-American settlement (18.8%) and at least double that of subzone HL1a (7.4%). This notably high value for *Ambrosia* is likely due, in part, to the MWA, and can be roughly correlated to the warmer temperatures and drier conditions of the time across the North American continent (Jackson and Overpeck, 2000; Cook et al., 2004; Cronin et al., 2010; Wahl et al., 2012). Proxy data from across the continent support the MWA in North America beginning at ~1000 cal yrs BP (AD 950), prior to Zone HL2, and subsiding by ~700 cal yrs BP (AD 1250) (Mann et al., 2009). Wahl et al. (2012) modeled pollen records from lakes in Wisconsin against sea surface temperatures (SST) to conclude that the upper Midwest experienced anomalous high pressure during this time, reminiscent of a positive North Atlantic Oscillation/Atlantic Multidecadal Oscillations, which resulted in decadal- and centennial-long summer droughts. Likewise, macrobotanical and pollen data from California, Southwest Colorado, and Illinois (Jackson and Overpeck, 2000), as well as ostracod and SST proxy data from Maryland (Cronin et al., 2003, 2010) support the interpretation of decreased precipitation and subsequent summer droughts being common across the North American continent during the MWA.

Change in sediment particle size from the lakes surrounding Cahokia in western Illinois were also used to model flooding frequency (the larger the particle size, the more force was required to transport them downstream). During the time of Zone HL2 and the MWA, the frequency of large flooding along the Central Mississippi River Valley was significantly lower than after 750 cal yrs BP (AD 1200), and is potentially the transition period to the beginning of the Little Ice Age (LIA) at ~550 cal yrs BP (~AD 1400) (Munoz et a., 2015). Coarse temporal-resolution pollen records (as mentioned in section 6.1.2. above) do not show the effects of the MWA on local vegetation and the pollen record from these studies is the same as mentioned for Subzones HL1a and HL1b. The finer resolution records from western Illinois at Horseshoe Lake near Cahokia, on the other hand, show that there is a rapid decrease in total AP, particularly of *Quercus* and *Carya*, and lesser amounts of *Juglans*, *Fraxinus*, and *Salix* (Table 6.3). It is thought that the floodplains and upland forests were cleared of vegetation, replaced initially with EAC crops, and later followed by domesticates such as *Z. mays*, *Cucurbita* spp. (gourd and squash), and *Phaseolus* spp.(bean) at this time (Munoz et al., 2014). *Ambrosia* and Poaceae pollen grain values make up the majority of the NAP and may be a result of the warming climate on the eastern edge of the Great Plains as well as land clearance (Benson et al., 2007; Munoz et al., 2014).

To the east along the Middle Ohio River Valley, during Zone HL2 the overall vegetation was the same as presented in Tables 6.2. *Quercus-Carya* AP significantly increased, indicating the forests were in the process of reclaiming the landscape after the declining population density at Fort Ancient (Table 6.3) (McLauchlan, 2003). South of the Fort Ancient region at Black Pond, Tennessee, *Quercus* and *Pinus*

Table 6.3: Summarized Archaeological Pollen Records Used for Comparison. Note only the zones that overlap with the Hovey Lake pollen diagram are listed in this table.

Source	Location	Zone time range (years before present)	Primary pollen identified (in descending order)
Ollendorf, 1993	Cahokia, IL (Horseshoe, Gilmore, and McDonough Lakes)	2000—0	*Quercus*, Poaceae, Cheno-Am, *Carya*
McLauchlan, 2003	Fort Ancient, OH (North and South Fort Ponds)	~2030—1710	*Ambrosia*, Chenopodiaceae, Poaceae, *Quercus*, *Carya*, *Polygonum*
		~1710—0	*Quercus*, *Carya*, *Ambrosia*, Poaceae, *Acer*, *Fraxinus*, *Ulmus*
Munoz et al., 2014	Cahokia, IL (Horseshoe Lake)	1350—750	Poaceae, *Quercus*, *Ambrosia*, Amaranthaceae, *Carya*
		750—600	*Quercus*, Amaranthaceae, *Ambrosia*, Poaceae, *Carya*, *Fraxinus*
		600—100	*Quercus*, *Ambrosia*, Poaceae, *Carya*, *Fraxinus*, *Salix*
		100—0+	*Ambrosia*, *Quercus*, Poaceae, *Fraxinus*, *Salix*

decreased overall, but still made up the majority of AP values while NAP values of *Ambrosia*, *Zea mays*, *Galium* increased (Delcourt et al., 1986). At Tuskegee Pond, Tennessee *Quercus* and *Pinus* increased while *Ulmus*, *Salix*, *Betula*, and *Fraxinus* decreased (Delcourt et al., 1986). The pollen record for this time period from these two Tennessee lakes are different and can be attributed to their location and proximity to the Little Tennessee River. Black Pond is situated in the uplands while Tuskegee Pond is located in the lowlands on the T3-river terrace close to the river (Delcourt et al., 1986). What Black Pond and Tuskegee Pond tell us is that in the uplands along major waterways the amount of NAP taxa increased, while in the lowlands mesic and xeric AP taxa increased and more hydric species were restricted. These proxy data, along with other paleoclimate and paleoecological models, identified distinct and significant drought periods during the warm and dry MWA at: ~950 cal yrs BP (AD 1000), ~800 cal yrs BP (AD 1150), and ~700—650 cal yrs BP (AD 1250-1300) (Grove and Switsur, 1994; Cronin et al., 2003; Cook et al., 2004;

Benson et al., 2007; Wahl et al., 2012). Note that the exact timing and spatial extent of these droughts did vary across the Midcontinent of North America and even within the same watershed (Delcourt et al., 1986; Cronin et al., 2003; Mann et al., 2009; Booth at al., 2012).

At Hovey Lake during Zone HL2, the high *Ambrosia* pollen grain percentages may be solely related to the warmer/drier climate *if* the values declined after the MWA ended when precipitation levels increased, a pattern observed in other proxy records within the region (e.g., Booth et al., 2012). However, *Ambrosia* percentages remain high even after Zone HL2 and after the MWA ended, indicating continued human occupation in the Wabash Lowlands and greater anthropogenic use of this landscape during Zone HL2 as well as HL3, 650—340 cal yrs BP (AD 1300—1610). EAC cultivation of Poaceae, Cheno-Am, and *Polygonum* likely occurred, though the pollen values for these species are low. Clearing land for EAC species is positively correlated to the increase of weedy taxa that grow on disturbed landscapes such as *Ambrosia* growing around crop fields during HL2 (Barbor et al., 1998).

The majority of Zone HL2 encompasses the time period prior to the earliest date that the Hovey Lake Village was established as early as ~700 cal yrs BP (AD 1250). The village continued to expand over the next few hundred years (Munson et al., 2004). Charred macrobotanical remains from hearths excavated at the site reveal that both wild and cultivated plant foods were consumed when Hovey Lake Village was occupied (Smith, 1992; Munson, 1996). Charred macrobotanicals recovered included nuts of *Quercus*, *Carya*, and *Juglans* and the recovery of these particular species strongly suggests they were utilized as a regular food resource (Munson 1997, 1998, 2000; Delcourt et al., 1998; Smith, 2007). Therefore, a certain amount of anthropogenic influence took place outside the established village space during this time.

A single *Zea mays* pollen grain was identified at 744 cal yrs BP (AD 1206) in the Hovey Lake pollen record, which reveals that just before the founding of the Hovey Lake Village (Munson et al., 2004), a Mississippian population practiced agriculture or carried domesticated *Z. mays* with them into the immediate region. It is possible that maize was planted locally at the inception of the village adjacent to Hovey Lake, given the broader archaeological record that indicates that this cultigen was a main food resource at other Mississippian sites in the region. Alternatively, the appearance of the single *Z. mays* pollen grain in Zone HL2 may not be a result of local deposition, and instead fluvially transported from another watershed where agriculture was practiced, such as the well-established Angel Site (12PO7) upriver or from another Mississippian village that practiced maize agriculture (Clay, 1997; Pollack et al., 2002). At mentioned briefly above and discussed more thoroughly in the next section, there is concrete evidence of agriculture practiced at Angel Mounds during this time (Pollack, 2004; Counts et al., 2014). However, the excellent preservation of the single *Z. mays* pollen grain identified in Zone HL2 suggests that it was not transported long distance by the Ohio River or other streams. Long distance wind transport of *Z. mays* is another possible (though unlikely) explanation. *Z. mays* produces a large quantity of wind-pollinated pollen grains, but they are very large (40—120 µm) and hence most do not travel farther than a few hundred meters from the parent plant (Paterniani and Stort, 1974). Based on the short dispersal distance of most maize pollen and the integrity of the pollen grain identified it probably was not carried by water, animal, insect, or human, and instead only a very short distance by wind. Therefore, it is most likely that *Z. mays* agriculture was being practiced in the southern Wabash Lowlands, if not exactly adjacent to Hovey Lake, prior to the founding of the village. Support for the interpretation of maize cultivation within the immediate area or watershed is the very high percentages of *Ambrosia* and the lower AP values during this zone.

In summary, the climate during HL2 reflects the drying and warming effects of the MWA. *Quercus* and *Carya* increase in their areal extent in the forested uplands and the more hydric-mesic taxa, such as *Populus*, *Fraxinus*, and *Acer*, decreased in the lowlands. *Salix* is one of the few wetland taxa to increase, but this shoreline shrub would expand in coverage so long as soil moisture through groundwater recharge was good, irrespective of precipitation regimes. There is some evidence for limited, early anthropogenic impacts on the landscape. Weedy taxa increases that include *Ambrosia* and some EAC taxa that are indicators of disturbance, and supported by the single occurrence of a single *Zea mays* pollen grain. The archaeology clearly documents maize and EAC agriculture by Mississippian populations at this time, supporting the equivocal pollen data.

6.1.4 Zone HL3: 650—340 cal yrs BP (AD 1300—1610)

Zone HL3 provides the strongest evidence in the Hovey Lake pollen record for Native American impact on the surrounding environment. This zone spans the entire length of occupation at the Hovey Lake Village, from ~650 to 300 cal yrs BP (~AD 1300 to 1650) (Munson et al., 2004). The pollen data on their own are not conclusive evidence for local agriculture. Nonetheless the palynological results still provide supportive evidence to the archaeological record for the practice of farming by local inhabitants. Two *Z. mays* pollen grains were identified in Zone HL3 at 647 and 431 cal yrs BP (AD 1303 and 1519), respectively, which were most likely of local origin, given the argument above for Zone HL2. *Ambrosia* values are also as high (~9.8%) as in the previous zone (10.7%). The continued high *Ambrosia* pollen is likely indicative of the Hovey Lake villager's presence on the landscape as more and progressively more land was cleared of trees. Possibly, some of the pollen of the remaining weedy herbs may be derived from EAC cultigens but they are more likely to be indicators or disturbance.

These weak signals for Native American agriculture in the pollen record of Hovey Lake are strongly supported by macrobotanical evidence recovered by Munson (1997, 1998, 2000, 2003); Munson and Cook (2001), and Munson et al. (2004) that clearly document the Hovey Lake Village inhabitants practiced *Z. mays* agriculture. These excavations recovered charred *Z. mays* kernels from a maize storage building along with the remains of *Cucurbita* spp. and *Phaseolus* (Munson 1997, 1998, 2000, 2003; Pauketat, 2004; Pollack, 2004). These domesticates would have been planted and tended to on the upland river terraces and in the lowlands of the Lower Ohio and southern Wabash rivers. Macrobotanical data such as charred *Juglans* nutshells and carbonized *Z. mays* kernels recovered from underground silos obtained from other

Caborn-Welborn archaeological sites dating to the same time period, such as Bone Bank (12PO4) and the Murphy Site (12PO1), report similar findings (Delcourt, 1987; Munson, 2003; Smith, 2006). The regional archaeological data indicate that these small Caborn-Welborn (Upper Mississippian) populations had an impact on the landscape, but Caborn-Welborn activities appear less intense than the ecological impacts produced by larger Mississippian population centers, such as Cahokia, or that induced by later Euro-Americans.

The coarse-temporal, paleoecological-focused pollen records from central Illinois and southeastern Missouri, west of Hovey Lake are the same as listed above and in Table 6.1; however few of these records do parse out minor trends. The authors of the Crowley's Ridge pollen record in southeastern Missouri did not discuss changes in AP percentages, but their data showed that *Ambrosia* pollen grain values reached an all-time high at ~20% of the total pollen sum at ~600 cal yrs BP (AD 1350). Over the next 400 years in this record, the amount of *Ambrosia* dropped to ~7% and peaked again at the arrival of Europeans at ~200 cal yrs BP (AD 1750) (Royall et al., 1991). This increase of weedy *Ambrosia* peaking at the end of the MWA is likely both attributed to the climatic event as well as the increasing presence of Mississippians practicing *Z. mays* agriculture in the region. The trend for decreasing *Ambrosia* after ~600 cal yrs BP (~AD 1350) can be attributed to the depopulation and dispersion of Mississippian population during the Vacant Quarter (Cobb and Butler, 2002). This pattern in the pollen data is consistent with the pollen study done at Horseshoe Lake in western Illinois near Cahokia (Table 6.3) (Munoz et al., 2014; Munoz et al., 2015). At Cahokia, both the pollen record and the archaeological record indicate that the large city was abandoned approximately at 600 cal yrs BP (AD 1350) and its vast populations relocated, perhaps some inhabitants even made it to Hovey Lake Village (Benson et al., 2007; Munoz et al., 2014; Munoz et al., 2015). The pollen record coupled with the size of the particles being medium-sized indicate that large-scale flooding returned to the region after ~550 cal yrs BP (AD 1200) within the Central Mississippi River Valley (Munoz et al., 2015).

East of Hovey Lake in Kentucky and Tennessee during Zone HL3 the general forest makeup is the same as mentioned above and in Table 6.2. Farther north at the main Fort Ancient city, the pollen record of two human-dug ponds indicates that the forests there were reclaiming the landscape, given the high pollen values of *Quercus*, *Carya*, and some *Fagus* (Table 6.3). Fort Ancient was already abandoned during Zone HL3 and it is clear from the pollen records of these ponds (McLauchlan, 2003) that after humans abandon a site the landscape quickly reverts to secondary plant succession and returns to a more natural state within a few hundred years.

Considering the solid archaeological evidence for some agricultural activity by Hovey Lake Villagers, it is surprising that the AP pollen values did not decrease significantly in Zone HL3, given that timber was likely cut for village housing and wood collected for firewood. The taxonomic composition of the arboreal vegetation underwent minimal change during this zone, and it was mainly confined to the uplands where *Quercus* and *Carya* became slightly more abundant. A possible explanation is that the upland forest in the area may have already been managed in some manner by Middle and Late Woodland populations in Zones HL2, HL1b, HL1a, and earlier; and hence did not undergo a substantive change upon local human settlement intensification by the Caborn-Welborn. There was an abundance increase in weedy species in Zone HL3, which suggests that there was anthropogenic forest disturbance during this zone and less disturbance beforehand.

My interpretation of human utilization of upland forest resources during Zone HL3 is supported by macrobotanicals recovered from excavations as stated above (Munson, 1997, 1998, 1999), which included carbonized nutshells of *Carya* spp., *Juglans nigra* (black walnut), and *Quercus* spp. These nutshells indicate that the Hovey Lake Village population supplemented their diet with the nuts of upland tree taxa in addition to practicing *Zea mays-based* agriculture (Munson, 1997, 1998, 1999; Munson and Cook, 2001; Pollack, 2004).

The above interpretation of Upper Mississippian agriculture and forest modification, at least to a limited extent, is supported not just by the archaeology but also indirectly by the regional climate patterns, as this zone post-dated the MWA (ended at ~700 cal yrs BP; AD 1250). The climate intervals during Zone HL3 included a brief (unnamed) episode of moderate temperatures, followed by the Little Ice Age (LIA), which lasted from 550 to 200 cal yrs BP (AD 1400 to 1750) (Mann et al., 2009). A warm-dry climate could explain the pollen data trends discussed so far (moderately high *Ambrosia*, some *Iva* and Poaceae, slightly more *Quercus* and *Carya*), but instead the climate during Zone HL3 is interpreted from a range of paleoclimate data sources as cooler and moister, particularly during the LIA. Some areas in northern America experienced a longer lag effect, so that the LIA cooler and wetter climate was not experienced until ~450 cal yrs BP (AD 1500), such as in northern Wisconsin (Wahl et al., 2012). But most fine-resolution pollen records from the central Midwest (Illinois, Indiana, Ohio, Kentucky) show that vegetation began to respond to the LIA beginning at ~550 cal yrs BP (~AD 1400) (Benson et al., 2007; Mann et al., 2009; Munoz et al., 2015). Hence, the most probable explanation is that humans had a more significant impact on the local vegetation of the Hovey Lake area with respect to the NAP type abundance, in particular, then did the shift towards cooler temperatures and greater precipitation that should have caused a decline in NAP if climate was the sole driver of vegetation change.

Paleoclimate data indicate that the LIA was a global cooling event brought on by the Maunder solar minimum, where sunspots became very rare and lessened the amount of solar radiation received on earth (Perry and Hsu, 2000; Cronin et al., 2010). At this time the majority of the world's glaciers expanded in size (e.g. Grove and Switsur, 1994; Wanner et al., 2008), and precipitation increased in the North American midcontinent (e.g. Coleman and Rogers, 2003). Proxy data from the analysis of tree-ring, pollen, and ostracods suggest that precipitation and moisture availability varied across North America, depending largely on latitude and proximity to coastal air masses bringing moisture inland (Wanner et al., 2008; Cronin et al., 2010), but was largely cooler and wetter (e.g. Coleman and Rogers, 2003; Cronin et al., 2010; Booth et al., 2012).

There is a weak signal in the Hovey Lake pollen record for a cooler and wetter local climate during Zone HL3. This signal is interpreted by the doubling of *Salix* (probably *S. nigra*) pollen grain values from ~6-7% in the prior zones to an average of 12.7% in Zone HL3. *S. nigra* is most often associated with hydric environments, though it can expand into more mesic soils in uplands and on slopes when precipitation is increased (Burns and Honkala, 1990b), which is the tentatively suggested here. The interpretation of an areal expansion of wetland arboreal vegetation during the LIA is weakly supported by the slight pollen increase in *Ulmus* and *Celtis*, although the value of the other lowland trees (*Fraxinus*, *Populus*, and some *Acer*) remained approximately the same as before (Zone HL2).

An interesting anomaly is the trend of the Cyperaceae pollen values, which did not increase along with *Salix*, as expected during a wetter and cooler period. Cyperaceae values drop significantly from averages of 9.0% (Zone HL2) to 5.0% (Zone HL3) despite sedges and bulrushes being commonly found in lowlands near bodies of water such as Hovey Lake today. There is currently no recovered archaeological evidence in the southern Wabash Lowlands for the use of *Carex* rope in basket making or lashings, but it is possible that the native Cyperaceae surrounding the lake and village were used in this manner, and by being harvested the pollen production of these wetland plants would have been reduced.

In summary, the pollen data of Zone HL3 document the strongest landscape impact of Native Americans in the Hovey Lake record, but these results are still weaker than the local archaeological data or from the pollen records adjacent to the earlier Mississippian settlements like Cahokia and Fort Ancient. However, the Hovey Lake pollen record clearly documents occupation of the adjacent village and local agricultural subsistence activities (growing of *Zea mays*). The recovery of two *Z. mays* pollen grains in Zone HL3 documents the local growing of maize, despite the low pollen count, which is typical of palynological studies of sediments analyzed from wetlands/lakes adjacent to archaeological sites (such as at the ponds at Fort Ancient) (McLauchlan, 2003). Given that *Z. mays* can be traded in rather than grown locally, the pollen study described in this thesis does verify that Hovey Lake Villagers planted corn adjacent to the lake. Another contribution provided by this pollen research is that it clearly identified open patches in the forest that were occupied by *Ambrosia* and other weedy taxa, and that *Quercus* and *Carya* benefited by the creation of more open canopy conditions, which independently supports the archaeological data. The pollen of *Ambrosia* and EAC taxa are due to human impacts rather than lag effects of a warmer and drier MWA climate, because other paleoclimate data from the Midwest region and elsewhere in the world indicate that the climate was cooler and moister, including that of the well documented LIA. Possibly the increase in *Salix* may indicate the expansion of this lowland shrub, which does well in moist and cool soil conditions.

6.1.5 Zone HL4: 340—250 cal yrs BP (AD 1610—1700)

Although Zone HL4 is a shorter time frame, lasting only 90 years, its pollen data provide an important contrast to Zone HL3 and previous zones of the Hovey Lake record. Specifically, Zone HL4 demonstrates the recovery of forests after local human impact on the landscape is greatly diminished. The total AP values rise from ~75% of the total pollen sum in Zone HL3 to ~90% in Zone HL4, and easily is explained by the abandonment of the Hovey Lake Village. Radiocarbon dates of burned residential and storage buildings and archaeological data suggest that the Hovey Lake Village was completely abandoned at the beginning of this zone, at 300 cal yrs. BP (AD 1650) (Munson et al., 2001, 2004; Muller, 2009). Given that the area was depopulated for ~90 years before the arrival of the first Euro-American settlers, the vegetation patterns reconstructed represent mainly plant succession. The climate was similar to before, as the LIA continues for the duration of Zone HL4, until ~250 cal yrs. BP (AD 1700) (Mann et al., 2009).

Zone HL4 indicates that the upland was covered by primarily *Quercus*, as indicated by values at ~13.6% of the total pollen sum, and secondarily by *Carya* (averaging ~6%) during this time. Even though these two species have been dominant throughout the entire Hovey Lake pollen record, in this zone they are at their highest values. At first glance, this finding is surprising as the climate was still cool and moist, as expected by the LIA, and these taxa do well in warmer and drier conditions. However, oaks and hickories are the best species to colonize open patches, such as abandoned cropland, as their seedlings require much light as compared to shade-adapted taxa that do better under in late-successional, closed-canopy forests (Jenkins and Parker, 2000). *Betula*, *Corylus*, *Cornus*, *Fagus*, *Pinus*, and *Nyssa* are the other upland taxa that become slightly more abundant in Zone HL4. The upland taxa that slightly decreased from Zone HL3 include *Ostrya/Carpinus*, *Castenea*, *Juglans*, *Liquidambar*, and Rosaceae.

Not surprisingly, the upland herbaceous NAP values decrease significantly in this zone. *Ambrosia* is the most significant NAP taxa to decline, to only ~2.5% of the total pollen sum. This *Ambrosia* decline makes Poaceae the primary upland understory taxa, even though grass values increased very little from the previous zones. No *Zea mays* pollen was identified, which along with other pollen signals indicate the absence of local agriculture. Likely the Poaceae of Zone HL4 were natural grasses that reclaimed the landscape previously been cleared by the inhabitants of the Hovey Lake Village rather than potentially belonging to the EAC species.

The pollen record from Horseshoe Lake at Cahokia, Illinois during the time of Zone HL4 shows a continued slowed increase in the percentages of AP taxa, mainly *Quercus* and *Carya*, with a significant decrease in *Ambrosia* and Amaranthaceae (amaranth family which today includes Chenopodiaceae) pollen grain percentages (Table 6.3) (Munoz et al., 2014). Poaceae pollen grains interesting increased near Cahokia. The extent of deforestation at Cahokia was likely the most significant amount of prehistoric deforestation in the region (Lopinot and Woods, 1993; Pollack, 2004). Although the trees near Cahokia began to reclaim the landscape over the few hundred years after the abandonment of the site, these trees would have been encroaching on a fairly open landscape of various species of Poaceae (Barbour et al., 1998; Munoz et al., 2003). At the former site of Fort Ancient, long since abandoned, the forest assumed its “natural” state and was still dominated by *Quercus* and *Carya* (Table 6.3).

Salix, *Populus*, and *Fraxinus* dominate the lowland taxa in Zone HL4. *Salix* values continued to be the most abundant of the lowland species identified, but the overall *Salix* percentage dropped from ~12.7% in Zone HL3 to ~8.7% in Zone HL4, a decrease not significant enough to equate with changes in the local environment. The other lowland taxa identified, including *Populus*, *Fraxinus*, *Acer*, *Ulmus*, and Cupressaceae, increased only 1-2% from that of the previous zone. Cyperaceae values increased overall in this zone, from 5.0% in Zone HL3 to 7.7% in Zone HL4, but were not quite as abundance as earlier, that of Zone HL1a. One interpretation is that the greater Cyperaceae abundance reflects the spread of wetland herbs under the continued cool-moist climate of the LIA. Wu et al. (2015) proposed vegetation responds slower to a shift to cool-moist conditions, than to warmer-drier events (such as the MWA), which may explain the delay in Cyperaceae expansion. Large scale flooding along the Central Mississippi River Valley increased at the approximate onset of the LIA and sediments from the banks of the great river indicate more flooding during this period (Munoz et al., 2015).

In summary, the robust archaeological record of complete abandonment of Hovey Lake Village a few decades into the beginning of Zone HL4, at 300 cal yrs. BP (AD 1650) (Munson and Cook, 2004), is fairly well supported by the pollen data. In the Hovey Lake area, a *Quercus-Carya* dominated forest reclaimed previously cleared and managed land. Correspondingly, *Ambrosia* declined in areal extent, and no pollen grains of *Zea mays* were recovered. The climate during this zone was cool and moist exhibiting the effects of the LIA, as firmly documented by paleoclimate data from the region and beyond (Grove and Switsur, 1994; Cronin et al., 2003; Mann et al., 2009; Cronin et al., 2010; Wahl et al., 2012; Munoz et al., 2015), and by the greater local abundance of Cyperaceae, probably sedges and bulrushes.

6.1.6 Zone HL5: 250—200 cal yrs BP (AD 1700—1750)

The final pollen zone of the Hovey Lake pollen diagram represents of the return of human settlement to the southern Wabash Lowlands, but this time by Europeans followed by Euro-Americans. French explorers and fur trappers set up trading posts in the early 18th Century in the region (Bigham, 1998), and so were likely the first Europeans to set foot in the Hovey Lake area. These Frenchmen did not influence the vegetation as later Euro-American settlers did. The former were much more interested in the extraction of native animal resources than the land or resources themselves (Bigham, 1998). Yet, these very first Euro-American presence on the landscape is apparent in the pollen record by signs of deforestation. The biggest indication of European and Euro-American presence in the pollen record is the appearance of non-native species, species that were originally only found in Europe, Asia, African, or Australia. In lieu of non-native species, many pollen records identify the Euro-American pollen zones by very high percentages of *Ambrosia* and crop plants (e.g. *Zea mays* and Poaceae grains, some of which were from cereal crops) with a correlated decline of AP values and reduced tree species diversity. This type of assemblage indicate that the landscape was likely cleared of the native forest for crops and the cleared land allowed *Ambrosia* to dominate the disturbed landscape, and/or certain tree species were selectively harvested in great numbers.

The first written documentation regarding the southern Wabash Lowlands state that the land was "pristine" and no Native villages or settlements existed in the area except for scattered individual homesteads of small, mobile family bands (Bigham, 1998; Pollack, 2004). Permanent, large-scale Euro-American settlement did not begin in the area until the early 19th Century (Brown, 1979; Bigham, 1998), well after the extent of this pollen diagram's research, and this would have more greatly influenced the deciduous forests of the southern Wabash Lowlands and adjacent areas.

The average AP percentages for Zone HL5 plummet to their all-time low, to ~64% of the total pollen sum, indicative of forest clearance, and there is a corresponding spike in the values of *Ambrosia* and other NAP taxa, some of which from domesticated crops. First, the French traders constructed modest dwellings and possibly small garden plots along the Lower Ohio and southern Wabash Rivers—since the fastest way inland was by water (Bigham, 1998). Later, larger numbers of Euro-American settlers cut down more forest to build several settlements and plant extensive areas of row crops, including maize and wheat (Bigham, 1998; Smith, 2007). When the AP to NAP averages of Zone HL5 are compared to the previous zones it becomes apparent that the Euro-American settlers clear cut more of the native deciduous forests in the Hovey Lake and adjacent areas than did the prior French traders and, before them, the Native Americans (Bigham, 1998; Smith, 2007).

Of the remaining forest at Hovey Lake, the dominant upland species were still *Quercus* and *Carya*, but they were less common than previous, given that the pollen values are significantly reduced compared to earlier zone. *Betula*, *Corylus*, *Ostrya/Carpinus*, *Pinus*, *Nyssa*, and Rosaceae are still present in the pollen record, and like before, they existed as uncommon occurrences in the remaining forest patches. Less than 10 pollen grains each for the entire zone were identified as *Castenea*, *Cornus*, *Fagus*, *Juglans*, or *Liquidambar*, which indicate that these trees became very rare when the upland forest became fragmented as small patches due to Euro-American land clearance. Over time, secondary succession of tree species likely occurred, but again town inhabitants and farmers strongly controlled the species composition of the vegetation.

Ambrosia values rise to their highest average value at ~18.7% of the total pollen sum in this zone, the highest for the entire pollen record, clearly indicting extensive land clearance and more than any time prior in the area. Although *Ambrosia* dominates the upland understory, the two other common herbs are *Iva* and Poaceae. *Iva* is more abundant in this zone than compared to prior zones, which is expected, as it is a weed that requires disturbed soil and open light conditions, as does *Ambrosia*. The Poaceae values surprisingly decreased from the previous Zone HL4 (when human impact was likely minimal), especially since wheat and other European crops (rye, barley) are in the grass family. Why the amount of Poaceae pollen grain values decreased when historical and paleoenvironmental (pollen) reasoning suggests that the values should increase is an anomaly. The pollen of domesticated cereal crops can be identified and are often the leaders in this Poaceae increase, but none of these cultigens were found in this zone, which is unexplained.

The lowland forest was dominated by *Fraxinus*, *Populus*, and Cupressaceae, albeit they have lower percentages than all previous zones, suggestive of some minimal clearing of swamp trees by Euro-Americans. The floodplains along the Lower Ohio River Valley were very fertile due to the frequent alluvial sediment by flooding that could improve soil fertility (McWilliams, 1979). There is a slight pollen grain increase of both *Taxodium* and *Ulmus* indicating that lowland trees closest to the water were less effected by human activity. Until more advanced methods for draining the soils developed in the 19th Century much of the initial landscape closest to the river was untouched by the first Euro-American settlers. Values of Cyperaceae also remain high, as they often grown on the lowest relief and in poorly-very poorly drained areas, indicating that the herbaceous vegetation of the swamps were minimally impacted, which is not surprising as these flooded areas were seen as unsuitable for farming (McWilliams, 1979).

The last zone of almost every pollen record, both those of coarse and fine resolution, is dedicated to the European/Euro-American settlement period. Most paleoecological pollen records indicate that by the 150 cal yrs BP (AD 1800) the cool Late Holocene climate, sometimes called the Neoglacial, had ended in the Midwest (King et al., 1981), although large-scale floods continued to occur in the Midwest (Munoz et al., 2015). Before modern flood control infrastructure developed in the early 20th Century, floods devastated the landscape along the low relief floodplains on the Ohio and Mississippi rivers. These historic floods are well documented in the written record and are visible in magnetic susceptibility (alluvial sediment) records (Counts et al., 2014; Munoz et al., 2015). On the other hand, pollen records do not necessarily reflect flooding, but they *do* document the effect of historic land use. At Horseshoe Lake near Cahokia in western Illinois, the final (topmost) pollen zone displays a significant drop in all AP taxa. The *Quercus* and *Carya* pollen values drop by almost half, while *Ambrosia* and Amaranthaceae increased significantly. Upland forests were rapidly cut down for agricultural plots (Table 6.3) (Munoz et al., 2014). *Salix* and other lowland taxa do not change as drastically, likely due to location on the landscape, in the swamps, and that they are shrubs and not trees prized for their lumber. At Tuskegee Pond and Black Pond in Tennessee, *Quercus* decreased along with the lesser values of *Liquidambar* and Cupressaceae; AP taxa like *Pinus* on the other hand increased and may be linked to the selective choosing of hardwoods over coniferous trees at this time (Delcourt et al., 1986). At the Cliff Palace Pond and Jackson Pond in central Kentucky, overall AP decreased and *Ambrosia* and Poaceae increase significantly just as they did at Hovey Lake, Horseshoe Lake, and Cupola Pond (Wilkins, 1991; Delcourt et al., 1998). Likewise each of these pollen records have evidence of *Zea mays*, high values of Poaceae which were likely domesticated barely or wheat, and non-native species.

In summary, the vegetation changed profoundly due to European and Euro-American deforestation and settlement, than it did earlier by the Native Americans who lived along Hovey Lake for several hundred years. The species composition and dominance of taxa did not change, the *Quercus*-*Carya* were still the most common upland tree taxa and the lowland inhabited by predominately *Fraxinus*, *Populus*, and Cupressaceae (some identified as *Taxodium*), but the vegetation became considerably more open due to forest clearance. *Ambrosia* reached its highest values of the entire Hovey Lake record, nearly 19%, which is almost double that at the height of Native American deforestation. Surprisingly the Poaceae values decline slightly, when both maize and European cereal crops belong to this family, which cannot be explained. The anthropogenic signal is most dominant in this zone, as the climate was likely just as cool and moist as before during Zone HL4, given that the LIA was still in effect. Climate forcing on the vegetation cannot be clearly detected in Zone HL5 due to the overwhelming dominance of human influence.

6.2 A Comparison of the Paleoenvironment and Archaeology Data of Hovey Lake Village (12PO10) to Those of Other Mississippian Sites

This section explores the similarities and differences between the pollen record of Hovey Lake and archaeological reconstructions of anthropogenic disturbances to local and regional environments, as reported for the Hovey Lake village (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004), and other Mississippian sites in the Midwest USA. As discussed in Chapter 2, Mississippian populations (~1,200 to 350 cal yrs BP; ~AD 750 to 1600) occupied much of the Middle Mississippi and Lower Ohio River Valleys and lived in settlements of various sizes; their impacts on the environment would have differed depending on population size, intensity of land use, and the timing of settlement occupation. Both the Medieval Warm Anomaly (MWA) (~1,000—700 cal yrs BP; AD 950—1250) and the Little Ice Age (LIA) (~550—200 cal yrs BP; AD 1400—1750) occurred during the (Early and Late) Mississippian cultural periods, but not all settlements discussed here were occupied during these climatic anomalies.

There are limitations to this discussion of past human-environment interactions in the Midwest USA due to constraints on data quality and quantity and the spatial coverage of sites investigated. A majority of pollen research has been conducted at locations far from individual settlements, and therefore provide a regional context of environmental change rather than a reconstruction of vegetation change in close proximity to an individual settlement that can directly infer past land-use. The pollen study of Hovey Lake, described in this thesis, recognized five zones with two subzones that identified more subtle changes in climate and land use in the immediate area of a Mississippian settlement. Prehistoric anthropogenic disturbance is interpreted by having consulted archaeological site reports from the adjacent Hovey Lake Village (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004; Pollack, 2004), and comparing the timing of occupation to the pollen signatures of deforestation and the probable planting of domesticated crops. The extent of this discussion of archaeology will summarize the literature related to this village, and more broadly that of other Mississippian settlements in the region, compared to interpretations of the local vegetation of the Hovey Lake area based on pollen, and correlated in time via calibrated radiocarbon dating.

Discussed first are the sites with the closest cultural affiliation and timing of occupation to the Hovey Lake Village: those of other Caborn-Welborn Phase (Upper Mississippian) villages (~550 to 300 cal yrs BP; ~AD 1400 to 1650) that are concentrated at the Wabash-Ohio River confluence in southwestern Indiana and western Kentucky (Pollack, 2004; Jefferies, 2008). Then an appraisal will be made with the data on the Angel Mounds Site (12VG1) in south-central Indiana, an eastern Middle Mississippian mound city located east of and upriver from the Hovey Lake Village, which exemplified the larger Angel Chiefdom (~950 to 550 cal yrs BP; ~AD 1000 to 1400) (Muller, 2009; Counts, et al., 2014). A comparison will also be made between the archaeological record of the Hovey Lake Village to the largest settlement in the eastern United States, Cahokia Mounds (11MS2). Cahokia is a Middle Mississippian city situated in the American Bottom in west-central Illinois along the Central Mississippi River Valley (~1,050 to 600 cal yrs BP; ~AD 900 to 1350) (Lopinot and Woods, 1993; Benson et al., 2007; Jefferies, 2008). Recent pollen and other proxy analyses conducted on a lake core adjacent to Cahokia (Munoz et al. 2014; Munoz et al., 2015) will be contrasted to the Hovey Lake pollen record to assess relative land use by differing Mississippian populations in more detail. Finally, the archaeology and paleoecology of Hovey Lake Village and lake will be compared to the Fort Ancient Site (33WA2). Fort Ancient is an eastern Terminal Late Woodland and Early Mississippian cultural occupation situated in the Middle Ohio River Valley of south-central Ohio (~950 to 550 cal yrs BP; ~AD 1000—1400) (Essenpries, 1978; Wilkins, 1991; Simon, 2000), and associated pollen analysis of sediments from human-excavated ponds at this site (McLauchlan, 2003).

6.2.1 Other Caborn-Welborn Villages: Slack Farm Site (15UN28), Murphy Site (12PO1), and Bone Bank Site (12PO4)

The Caborn-Welborn culture, centered at the confluence of the Ohio and Wabash Rivers (Figure 6.1), is thought to have emerged between ~350 to 150 cal yrs BP (~AD 1600 to 1800) (Pollack, 2004; Muller, 2009). This culture emerged after the depopulation of many of the larger Middle Mississippian cities and large centralized towns around 550—500 cal yrs BP (AD 1400—1450), including Cahokia and Angel Mounds, where people dispersed across the Midwest (Butler and Cobb, 2002; Pollack, 2004; Pollack and Munson, 2008). This diaspora is believed to have created a “Vacant Quarter” (VQ) (discussed in

Chapter 2, Background and Literature Review, Section 2.5; Figure 6.1). The VQ is a misleading term, as the area was not empty, but rather had lower population densities and dispersed settlements, including those of the newly emerged Caborn-Welborn (Butler and Cobb, 2002; Pollack, 2004; Pollack and Munson, 2008).

The exact cause and spatial distribution of this major shift in settlement patterns are unknown and several hypotheses have been proposed. The predominant hypothesis, however, is that there was a slow and gradual exodus from the larger settlements, likely attributed to resource politics. People dispersed across the Lower Ohio and Upper Mississippian River Valleys and established smaller villages and hamlets, such as the Hovey Lake Village, Murphy, Bonk Bank, and Slack Farm sites (Pollack, 2004).

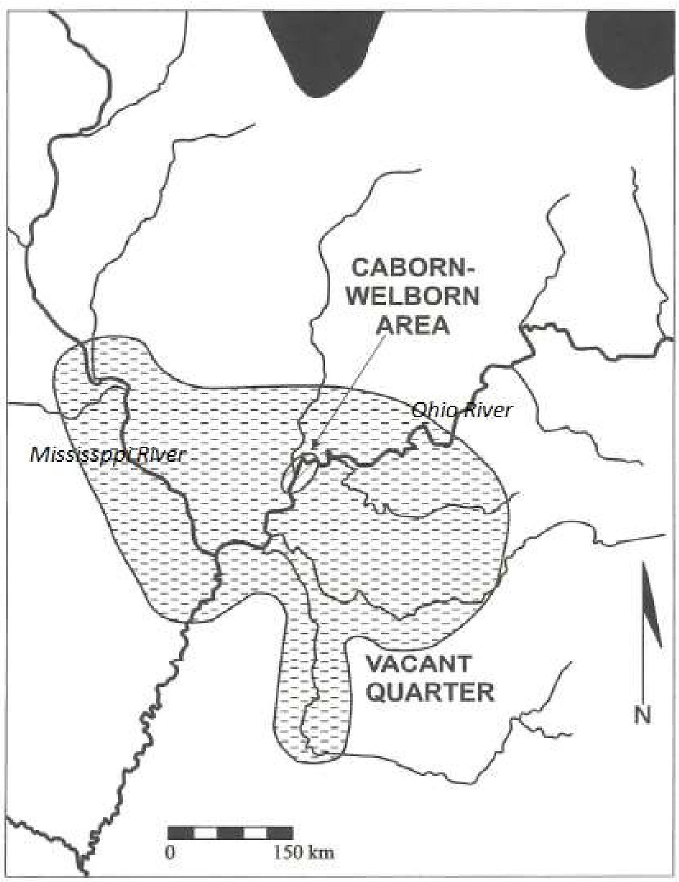

Figure 6.1 *The extent of Caborn-Welborn (~550 to 300 cal yrs BP; ~AD 1400 to 1650) settlements within the Vacant Quarter (~350 to 150 cal yrs BP; ~AD 1600 to 1800). Figure adapted from Figure 1.1, Pollack, 2004.*

The remainder of this section will focus on three Caborn-Welborn sites: the Slack Farm Site (15UN28), Bone Bank Site (12PO4), and Murphy Site (12PO1), as these have the most extensive archaeological investigations of this culture, as well as are sites comparable in size to that of the Hovey Lake Village.

No other pollen records for the VQ region in which Hovey Lake is situated exist. The only direct comparisons of prehistoric land use that can be made are based solely on archaeological data from within this region, and consideration of pollen records from outside the VQ (but situated within the Midwest). With the exception of this thesis study, limited paleoenvironmental data centered on the Caborn-Welborn Phase and the VQ are primarily due to: 1) the short time frame of the VQ period between the fall of Middle Mississippian settlements and the arrival of Euro-Americans (i.e. fine temporal resolution), and 2) the small size of the Mississippian Caborn-Welborn Phase settlements, which have not been studied as thoroughly as Mississippian cities such as Cahokia and Angel Mounds (large populations and associated large earthworks, palisades, as well as specialized ceramic and artifact styles) that have attracted archaeological and associated paleoenvironmental interest for over a century (Pollack, 2004; Pollack and Munson, 2008; Muller, 2009).

Based on this thesis' pollen research at Hovey Lake within the VQ, and other Midwestern pollen records from outside the VQ, we know that the Caborn-Welborn populations experienced a Little Ice Age (LIA) climate that was generally cooler and wetter than today. At Hovey Lake, the greater precipitation and associated higher water table allowed for an overall increase in AP taxa, including greater pollen abundance of lowland trees. The latter expanded further from the Lower Wabash River to other low-lying areas and perhaps even to mid-slope positions (Zones HL3 and HL4). The pollen records from outside the VQ suggest that the forests were likely a mix of Midwest, prairie, and southern taxa, similar to that documented in the Hovey Lake pollen record. The lower floodplain and lowland forest in the region during the Caborn-Welborn Phase was likely primarily comprised of *Salix*, *Acer*, *Fraxinus*, and *Nyssa*, as well as *Arundinaria* along the river banks (King, 1977; Delcourt, 1979; Smith, 1984; Royall, 1988; Royall et al., 1991; Wilkins et al., 1991; Delcourt et al, 1998; Wanner et al., 2008). Uplands were likely dominated by *Quercus-Carya* forests with lesser amounts of *Juglans*, *Betula* and *Fagus*, with an understory of *Chenopodium*, *Ambrosia*, and *Iva*. Without individual paleoenvironmental reconstructions at each Caborn-Welborn site it is difficult to interpret how much anthropogenic disturbance occurred at each site. It can be assumed that the environment of most Caborn-Welborn site was very similar to that of Hovey Lake with only minor differences in local vegetation due to site-specific variations in species preferences for different topographic, edaphic and hydrologic conditions.

The archaeological record reveals that Caborn-Welborn settlements were characteristically nucleated around a flat central plaza and were generally of similar or slightly smaller estimated population compared to that of Hovey Lake (Munson, 1997, 1998, 2000, 2003; Munson et al., 2001; Pollack, 2004; Muller, 2009). Caborn-Welborn sites generally do not have any earthen mounds which were characteristic of preceding Middle Mississippian and Woodland sites. The exception to the mound-less Caborn-Welborn settlements is the Murphy Site. Similar to Hovey Lake, there was a substantial Woodland occupation period at Murphy, which covered a larger area than the boundaries of the Caborn-Welborn Phase settlement at the site location. However, Murphy differs from other Caborn-Welborn settlements by the presence of three mounds located to the north and southwest of the Caborn-Welborn plaza, just beyond the residential structures. The Murphy mounds were built prior to the establishment of the Mississippian Caborn-Welborn Phase at the Murphy Site. The age of these mounds is uncertain because burned macrobotanicals from the mounds were radiocarbon dated and calibrated to ~3,620—3,370 cal yrs BP (~1670—1420 BC), which predates the Late Woodland; yet, the area around the mounds had a high concentration of Late Woodland ceramics (Munson, 1998). Hence, the dated material from the mounds may not be associated with the mounds themselves, and more research is required to more definitively date the mounds at the Murphy Site. Archaeologists largely consider mound building along the Ohio River Valley to have ceased after the collapse of Cahokia and Angel Mounds during the VQ, so despite the presence of mounds at the Murphy Site, these were likely not built by Caborn-Welborn Phase populations, possibly because of the smaller human populations at this time.

Although the Caborn-Welborn populations did not build mounds as did their predecessors, they did continue to practice intensified agricultures in all of their settlements. There are carbonized macrobotanical remains at almost all Caborn-Welborn settlements that indicate local cultivation of plants including *Zea mays*, C*ucurbita* spp., *Nicotiana* (tobacco), and starchy and oily seed plants of the EAC such as *Phalaris caroliniana*, *Chenopodium berlandireri* (goosefoot), *Helianthus annuus* (sunflower), and *Iva annua* (Pollack et al., 1996). Nitrogen values from Caborn-Welborn skeletal remains at Hovey Lake Village and Bone Bank indicate a slight decrease in *Z. mays* consumption than compared to previous Middle Mississippians (Pollack and Munson, 2008). It has been suggested that the slight decrease in maize consumption in the diet of Upper Mississippians in general, and particularly those in the VQ, is due to a loss of the highly centralized hierarchies that politicalized the growing and consumption of maize in the large Middle Mississippian city of Cahokia (Yerkes, 1988), and presumably elsewhere.

Based on carbonized macrobotanicals recovered from archaeological excavations at these three Caborn-Welborn sites, wild resources were likely gathered from the surrounding forest when available. The majority of wild resources recovered from Caborn-Welborn settlements are charred or partially charred *Juglans nigra* nutshells, but also include small amounts of *Juglans cinerea* (butternut), *Carya illinoinesis* (pecan), *Quercus* spp. (acorn), and *Fagus* spp. (beech) nut shells. There were presumably a variety of wild fruit and berries also available for the Caborn-Welborn peoples, though very little macrobotanical remains of these plants have been found, likely due to preservation problems. As inferred from the macrobotanicals documented at other sites within the broader region, the following fruits and berries may have been consumed by Caborn-Welborn people at this time: *Vitis palmate* (wild grape), *Diospryous* (permission), *Asimina* (pawpaw), and *Prunus Americana* (wild plum) (Pollack, 2004). In summary, these documented and inferred species of both wild and domesticated plants may indicate how much agriculture, and therefore forest disturbance was taking place at each Caborn-Welborn settlement, even if there are no companion paleoenvironmental (pollen) studies completed so far for the Slack Farm and other two sites.

6.2.1.1 Slack Farm (15UN28)

Slack Farm is one of the largest Caborn-Welborn villages, covering over 0.14 km^2 (Pollack et al., 1996). The site was first recorded in 1868 by Sidney S. Lyon who surveyed and excavated many archaeological features, but the site was essentially ignored for over a hundred years. The primary site excavation was conducted in 1988 by Cheryl A. Munson and David Pollack, of the University of Kentucky and the Glenn A. Black Laboratory of Archaeology at Indiana University, to assess the extent of damage by looters the previous year (Pollack, 2004). Excavations revealed discrete clusters of residential dwelling, hearths, ceramic artifacts, and associated burials radiating from a central plaza. The central plaza is located on a terrace at the base of the Ohio River bluffs looking over the large floodplain on the Kentucky side of the confluence of the Ohio and Wabash Rivers confluence, less than 10 km south by southwest of Hovey Lake (Figure 6.2) (Pollack, 2004). Younger residential buildings and a Caborn-Welborn-age cemetery were identified along the outer perimeter of the village indicating that the village expanded outward over time (Pollack et al., 1996). Unlike at the Hovey Lake Village, burials appear to be more concentrated below the bluff, and very few mortuary remains were identified below or next to houses (Munson and Cook, 2001; Pollack, 2004). Unfortunately, Slack Farm was heavily looted in the AD 1980s, and local, state, and federal actions were subsequently taken to preserve what was left of the site (Pollack et al., 1996; Pollack, 2004). Due to the ransacking, much of the locational context of graves and grave goods, including ceramics, and other diagnostic evidence, have been lost. Some areas of the site remained relatively untouched by looters, but the majority of datable material was recovered from disturbed looter

Figure 6.2 Location of Hovey Lake Village, Indiana and Slack Farm, Kentucky (Google Earth, 2015).

pits. According to the radiocarbon dates obtained from burned residential structures, charcoal macrobotanicals from hearth, and skeletal remains from the expansive mortuary complex, Slack Farm was occupied for the entire Caborn-Welborn period (Zones HL3 to HL4 of this thesis) (Pollack and Munson, 1998; Pollack, 2004).

Taking into consideration the similar size and settlement organization of Slack Farm (~0.14 km^2) and Hovey Lake Village (~0.12 km^2), the climate, taxonomic composition of the vegetation, and the amount of forest disturbance were likely extremely comparable. Large quantities of preserved and spoiled *Zea mays* kernels were recovered from 30 great "underground silos" at the Slack Farm site (Pollack, 2004). One underground silo could have fed 7 to 12 individuals for a year, based on a 2,300 to 3,500 caloric diet, indicating that a fair amount of land would have been cleared of native vegetation to plant *Z. mays*. Pollack (2004) further estimated that at least 65% of the diet of Slack Farm residents consisted of corn. Yet, the population did not rely on maize alone, as a few charred nut shells of *Carya* and *Juglans* were also recovered from thermal features (Munson, 2003). Although the residents of Slack

Farm relied primarily on hickory and walnut nuts and especially maize, macrobotanicals also indicate that they supplemented their diet with the nuts of other tree species as well as berries. They also cultivated varieties of EAC taxa, although very little macrobotanicals of these domesticates have been recovered from Slack Farm (Pollack, 2004). Assuming that the forest on the terrace surrounding Slack Farm, as well as the floodplain below was cleared and utilized to plant crops, a high amount of anthropogenic disturbance occurred at this site, and thus was comparable to that of the Hovey Lake Village.

6.2.1.2 Murphy Site (12PO1)

The Murphy Site is a large village (~0.12 km^2) located in the southern Wabash Lowlands of Indiana at the confluence of the Ohio and Wabash rivers (Figure 6.3). The site is ~5 km southwest of the Hovey Lake Village and directly across the Ohio River from Slack Farm, ~3.5 km south on the opposite Ohio River terrace (Munson, 1997, 1998). Very little of the site has been excavated due in part to the poor preservation of the site as a result of erosion, flooding, excessive looting, and over two centuries of plowing. The site was first reported in AD 1906 by Warren Moorehead, based on Clifford Anderson's AD 1898 excavation, as a location with multiple burial concentrations and three mounds, but it was not until further excavation in the AD 1940s that a more detailed description of the site and artifacts was recorded by Eli Lilly, Glenn Black, Paul Weer, and E.Y. Guernsey (Munson, 1997, 1998). This more recent site excavation was conducted in the intention to better understand the cultural and temporal setting of the Caborn-Welborn in the Lower Ohio River Valley. Decades later, about 100 m^2 of the Murphy Site were excavated by a team from the Glenn A. Black Laboratory of Indiana University led by Cheryl A. Munson (1997, 1998). In this research, few macrobotanicals acceptable for radiocarbon dating were recovered, however, three samples of charred *Z. mays* kernels from different refuse pits and hearth yielded good dates, providing ages expected for a Caborn-Welborn site. Ceramic residue samples from the inside of a jar associated with a hearth feature were also dated and yielded ages calibrated to the Caborn-Welborn

Figure 6.3 Location of Hovey Lake Village and Murphy Site, Indiana (Google Earth, 2015).

Phase (Munson, 1998). Additionally, a number of cores and sample test pits revealed the general outline of the site.

The Murphy Site has a small central plaza surrounded by a few residential buildings that become more dispersed further away from the plaza. A few burials in scattered locations were located in a large U-shaped arc on the southern perimeter of the site, many of which were heavily looted in the early 20th Century. Dated material, such as burned residential structures, charred *Z. mays* kernels, and residue from the inside of a pot, indicate that the small village was occupied for the entire VQ period (Zones HL3 and HL4) (Munson, 1997, 1998; Pollack, 2004). The forests surrounding Murphy were clearly utilized long before the settlement was established; however the amount of disturbance has not been fully quantified.

The Woodland population that likely constructed the earthen mounds at the Murphy Site probably had a similar impact on the forest of the Wabash River floodplain as did the Woodland population in the Hovey Lake area (during Zone HL2). A slight increase of disturbance taxa, such as Poaceae and *Ambrosia*, is seen in the Hovey Lake pollen record, which may indicate human occupation of the landscape with some disturbance. As described above in this chapter, there was not a significant increase in the areal coverage of *Ambrosia*, nor was there a notable decrease in AP taxa during the Woodland occupation at Hovey Lake, and presumably these vegetation trends happened at Murphy. Although there are no data (because of the lack of a pollen record associated with Murphy), it is possible that there was more anthropogenic disturbance at this site due to clearing trees to create mounds. Very little evidence of intensified agriculture was found at Murphy during the Woodland settlement and it is assumed that this population would have primarily hunted. Nutshells (from *Carya* and *Juglans* species) and *Chenopodium berlandireri* seeds were recovered from the earthen mounds contextually attributed to the Woodland period (Munson, 1997, 1998, 2000; Munson et al., 2004). Additionally, more intensified cultivation of the local wild species is possible considering more time was spent at the Murphy Site in order to construct the mounds (Munson, 1997, 1998, 2000; Munson et al., 2004).

The Murphy Site inhabitants consumed the same wild and cultivated species as did the other Caborn-Welborn residents, with the addition of a considerable amount of *Zea mays*. Burnt kernels and cobs recovered from a refuse pit indicate that *Z. mays* was heavily utilized by these residents, suggesting that the villagers planted *Z. mays* rather than acquired by trade (Pollack, 2004). Therefore, the macrobotanical collection from the Murphy Site is comparable in quantity and taxonomic composition to that of the Hovey Lake Village, and hence one can assume that some forest clearance occurred at the Murphy Site in order to plant and maintain crops. The Murphy Site covers a slightly smaller area than that of Slack Farm, and so Pollack (2004) suggested that the population density of Murphy was also only slightly less than the other (larger) site (Pollack, 2004). Murphy thus had a population that was roughly comparable to that of the Hovey Lake Village (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). Given the similar settlement size, archaeological evidence, and close proximity of these three sites, the forest surrounding Murphy probably experienced a similar amount of disturbance as what occurred at the other two sites.

6.2.1.3 Bone Bank Site (12PO4)

Bone Bank is the final large Caborn-Welborn village discussed, covering over 0.14 km^2 and is located on the western first terrace overlooking the Wabash River floodplain in southwestern Indiana. Bone Bank is ~5.4 km from Hovey Lake (Figure 6.4) (Munson, 1997, 1998, 2000, 2003). The site was first studied by a French scientist, Charles Alexander Lesueur from AD 1825—1827, then by G.M. Levette in AD 1873. By AD 1898, Clifford Anderson stated Bone Bank had stopped yielding any artifacts (Munson, 1997). Surveys in the AD 1970s and 1980s revealed this was not true, and in the AD 1990s more survey work was conducted by the Glenn A. Black Laboratory, led by Cheryl A. Munson, to map what remained of the site. This survey work, followed up by more intensive excavations, discovered numerous looter pits and a few refuse pits containing a few flakes, ceramic sherds, broken faunal bones, and both charred and uncharred botanical remains (Munson, 2000, 2003). Most of the uncharred macrobotanical remains recovered from features were of weedy species that grow in the region today, but also included some non-native species. The charred macrobotancial materials consisted of *Zea mays* remains, *Curcubita* spp. rinds and seeds, as well as starchy and oily seeds, such as *Chenopodium*, *Polygonum*, *Iva annua*, *Echinochloa*, and *Phalaris*. These species are all members of the EAC and it is possible that they were cultivated at Bone Bank, although they are also native to the region.

The reports of Munson (1997, 1998, 2000, 2003) and Munson et al. (2001) provide the following details on the Bone Bank site. The central plaza of this site is located ~2.5 m from the Wabash River and today is at great risk for destruction by erosion due to the slowly meandering river. Historically the Bone Bank site was used as a landmark for navigating the Ohio and Wabash Rivers, as skeletal remains from burials at the site were exposed on the river cut banks. At the time Bone Bank was occupied by Caborn-Welborn, the Wabash River was located farther west-southwest by at least 2 km from this river's current location. The meandering nature of the river has encroached on the central site's foundations.

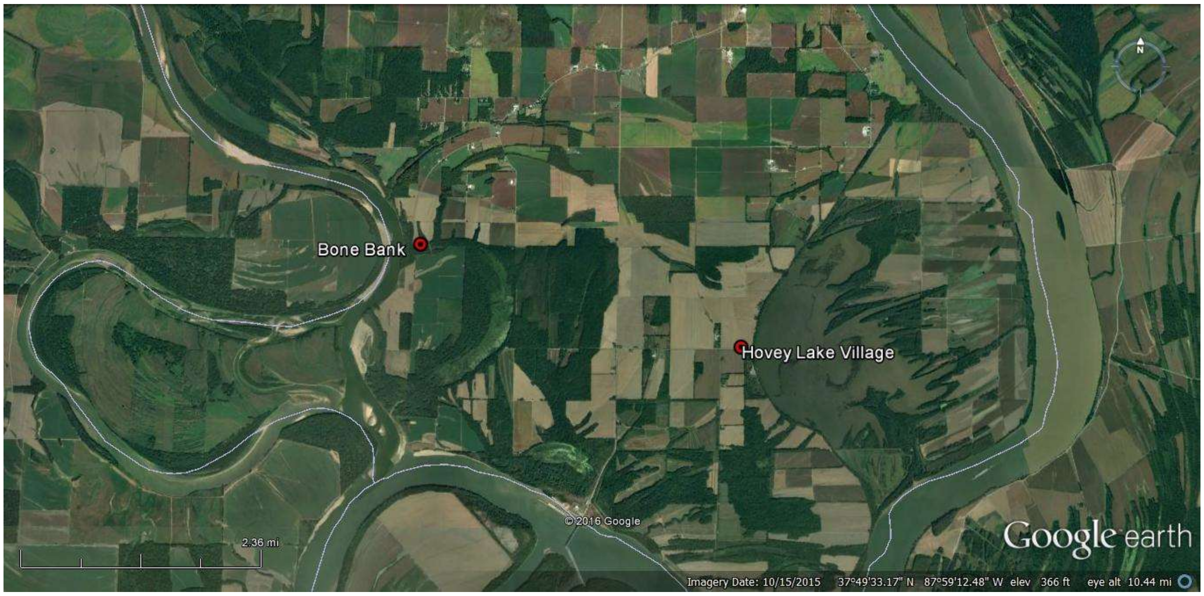

Figure 6.4 Location of Hovey Lake Village and Bone Bank, Indiana (Google Earth, 2015).

Abandoned meandering Wabash River channels and tributary creeks created to a number of small oxbow lakes and sloughs that have eroded and deposited sediments over portions of the site. The Cypress Slough is the main slough that runs through the eastern portion of the site and developed and separated the site into two distinct regions. The section of the Bone Bank site south of the slough has only a scattering of cultural deposits with no evidence of residential structures, whereas a few such structures and the central plaza are located in the northern part of this slough (Munson, 2000).

Bone Bank, like all Caborn-Welborn sites, has a central flat plaza with residential and storage buildings radiating outward and to the east and south. Few human burials have been recovered at the site, as many of these burials were eroded and washed down river or looted (Munson, 2000, 2003). Cultural deposits are sparse across the site and appear most concentrated ~150 m around the central plaza, which is attributed to significant transport and redisposition of sediments due to severe erosion on the surrounding highlands as well as by looting (Munson, 1997). Based on calibrated radiocarbon dates obtained from charcoal material collected at the site and on the northern side of the slough, Bone Bank was occupied before ~700 cal yrs BP (~AD 1300) during the end of Zone HL2 and the entirety of Zones HL3 and HL4 at Hovey Lake. Bone Bank was very likely occupied by earlier Woodland populations who inhabited a larger area of the site, but hillslope erosion and the action of the meandering Wabash River have obscured and mixed much of the evidence (Munson, 2003). The stratigraphy of the concentrated buried cultural deposits on the higher terrace levels, which were affected less by erosion, indicate the site was likely abandoned at the same time that Hovey Lake Village was vacated, at around 300 cal yrs BP (AD 1650) (Munson, 2000, 2003).

The size and village of organization of Bone Bank are unknown because of erosion, but probably were similar to that of Slack Farm and Hovey Lake, and had a similar amount of forest disturbance. Excavation at Bone Bank have exposed *Zea mays* kernels, cupules, germs, and glumes from thermal features and storage pits, yield Mississippian ages (620—510 cal yrs BP [AD 1330—1440], 675—560 cal yrs BP [AD 1275—1390], and 690—565 cal yrs BP [AD 1260—1385]) (Munson, 2003). Also, a *Chenopodium* seed with a date of 1250—950 cal yrs BP (AD 700—1000), which is older than Caborn-Welborn-phase deposits, was also recovered. Additional cultivar remains obtained include two difference types of squash rinds that are well documented throughout the eastern Woodlands (e.g. Smith, 2007). Both oily and starchy seeds of the EAC were also recovered from these Mississippian-age deposits at Bone Bank: *Chenopodium berlandireri*, *Polygonum erectum*, *Phalaris caroliniana*, *Iva annua*, and *Hordeum pusillum* (Munson, 2003). The high amount of recovered domesticated and cultivated macrobotanicals points at the Bone Bank Site points toward a significant amount of local forest disturbance to maintain the wide array of cultivated foodstuffs during the Mississippian period. Additionally, wild plants were used to supplement the diet of Bone Bank residents. Nutshells of *Carya* spp., *Juglans nigra*, and *Quercus* were found in lesser amounts in earlier excavated strata compared to the larger amount of macrobotanical maize kernels and glumes from later strata that the Bone Bank population likely consumed (Munson, 2003). Other cultural phases in the Midwest show a similar trend of increasing maize consumption and a decreasing use of EAC cultigens and wild nuts over time. The other significant cultural phases are outside of the Caborn-Welborn phase and occurred earlier; these larger sites will be discussed below.

6.2.2 Angel Mounds Site (12VG1), Indiana

The Angel Mounds Site (occupied between ~950 to 550 cal yrs BP; AD 1000 to 1400) is a large (~0.45 km^2) Middle Mississippian town located ~46 km upstream from Hovey Lake (Figure 6.5). Various archaeologists and geoarchaeologists heavily excavated the site since AD 1937 (Counts et al., 2014). The site, discussed briefly in Chapter 2, was established prior to ~850 cal yrs BP (~AD 1000) and has 13 mounds within an impressive daub palisade structure that surrounds the town on all sides except for the southern side which is bordered by the Ohio River (Counts et al., 2014). The site has extensive residential areas, cemeteries, and stockades with small Angel Phase hamlets and individual homesteads. Angel Phase settlements radiate up to 120 km from the Angel Mounds palisade enclosed center (Pollack, 2004). The people of Angel Mounds practiced intensified *Zea mays* agriculture and grew *Cucurbita* spp. and the EAC taxa *Helianthus annuus*, *Iva annua*, and *Chenopodium berlandireri* (Pollack and Munson, 2008). A number of storage pits excavated at the site indicate that *Z. mays* was the main food staple, but it remains a mystery as to where the crop fields were located, whether within or outside the palisade (Monaghan, conference keynote presentation, June 1, 2014).

Prior to the collapse of Angel at ~550 cal yrs BP (AD 1400) that contributed to the VQ, this Middle Mississippian site was the cultural center of the Lower Ohio River Valley (Pollack, 2004; Counts et al., 2014). Unfortunately, many of the mounds at the site were completely leveled by archaeological excavations during the early and mid-20th Century, which created an extensive (and largely unevaluated) collection of pot sherds, ceramic vessels, and partial skeletal remains with poor contextual information. At the time of initial excavations in the AD 1940s and 1950s, macrobotanical material was less desired by archaeologists over ceremonial artifacts like ceramics or skeletal remains and so were not collected

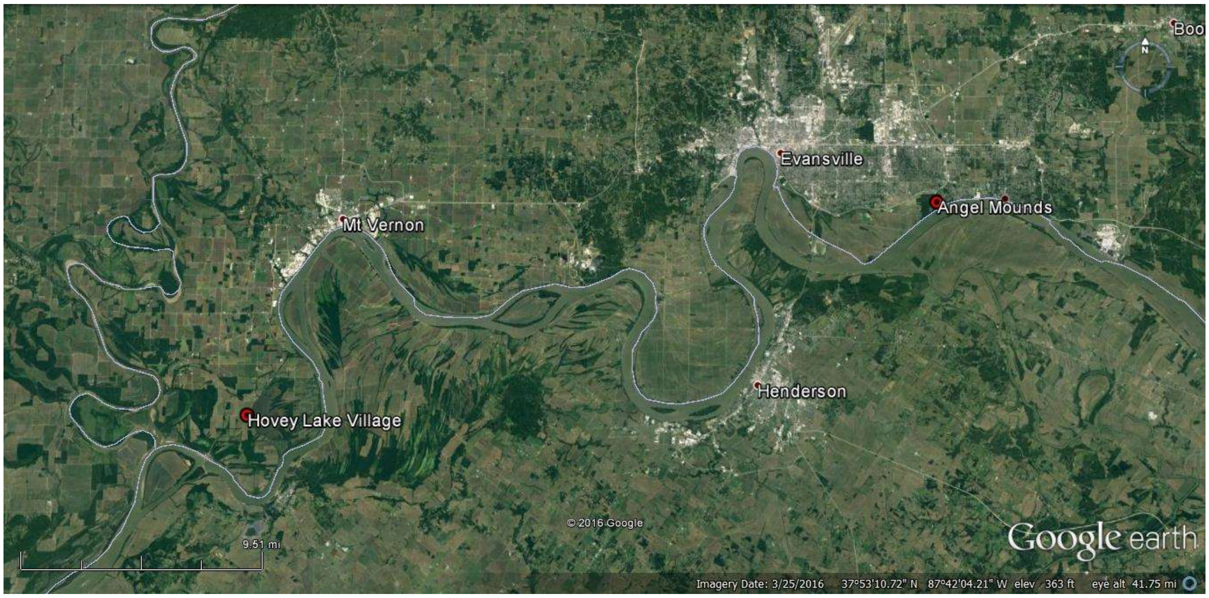

Figure 6.5 Location of Hovey Lake Village and Angel Mounds, Indiana (Google Earth, 2015).

(Monaghan et al., 2010). The anthropogenic-paleoenvironmental proxy data and potential radiocarbon datable materials from early excavations were collected either from poor sample contexts or were inappropriate samples for dating the occupation of Angel Mounds, such as charred macrobotanicals from undisturbed contexts collected in the early/mid-20th Century that yielded dates 300—500 years older than establishment of the settlement (Counts et al., 2014). Only more recently has there been a solid understanding of when and how Angel Mounds were constructed based on further evaluation of the site and the obtaining of reliable radiocarbon dates (Monaghan et al., 2010; Counts et al., 2014).

So far, no pollen studies have been conducted at Angel Mounds or immediately nearby. Therefore, the paleovegetation during the Angel Phase occupation is difficult to compare to Hovey Lake Village's paleovegetation. However, the close proximity of the sites, Angel Mounds is ~46 km to the east of the Hovey Lake Village, and that both sites have similar soil series that reflect their location on the low-relief and generally poorly drained floodplain of the Ohio River (Kelly, 1976; McWilliams, 1979), the pollen record of Hovey Lake can be applied to the archaeology of Angel Mounds. The age range of this mound site are comparable to the timing of pollen Subzone HL1b (990—860 cal yrs BP; AD 960—1090) and Zone

HL2 (860—650 cal yrs BP; AD 1090—1300) described in this thesis, as well as the zones of more distant pollen studies in the Midwest (e.g. McLauchlin, 2003; Munoz et al., 2014). *Quercus* and *Carya* possibly dominated the upland forests at Angel, and *Populus* and *Fraxinus* were likely the main taxa in the lowlands. These two pollen zones at Hovey Lake include the entire estimated time range of both the Medieval Warm Anomaly, which lasted from ~1000 to 700 cal yrs BP (AD 950 to 1250), and the time Angel Mounds was occupied between ~950 to 450 cal yrs BP (AD 1000 to 1400). As discussed in the Results (Chapter 5) and earlier in this Discussion (Sections 6.1.2 and 6.1.3), the MWA likely did not have a significant impact on the vegetation makeup overall (likely only minor shifts of the areal extent of particular species) in the Lower Ohio River Valley, and any changes were thus more likely due to anthropogenic disturbance.

The main difference between the Hovey Lake Village and Angel Mounds is that the latter had a significantly larger population and hence probably had a greater impact on the surrounding vegetation. About 1,000 to 7,000 people lived within or immediately outside the Angel Mounds palisade and at farther distances (up to 120 km) from Angel Mounds there were dozens of satellite communities, which ranged from villages of several hundred to individual homesteads with only a few residents (Muller, 2004; Jenkins, 2013). The Hovey Lake Village, on the other hand, only had several hundred residences at most. Angel Mounds and associated satellite communities of smaller villages, hamlets, and individual homesteads spanned across the southern Wabash Lowlands and relied on maize agriculture, EAC domesticates, and wild resources (Counts et al., 2014). Given the large human population and cultigens in the macrobotanical record, undoubtedly the Angel Mounds inhabitant removed a significant number of trees with stone axes and/or by girdling (Jenkins, 2013). There is also evidence for greater intensification of *Z. mays* agriculture, suggesting that large areas of forests around Angel were cleared at increasing distances from the palisade as the population grew and established fields were fallowed for some time (Monaghan, conference keynote presentation, June 1, 2014). Also a larger human population would require more wood for building construction and for fires, furthering the local deforestation.

The amount of time that it took the forest to reclaim the Angel Mounds site proper and surrounding fields after the site was depopulated was likely a longer duration than what occurred at the Hovey Lake Village (Jenkins and Parker, 2000; Guyette et al., 2003). Comparison of the pollen record and archaeology at Hovey Lake indicates that the significant decline of *Ambrosia* (ragweed) and notable increase in trees and shrubs during Zone HL4 occur around the same time as when the village was abandoned. If pollen data were available for Angel Mounds they would indicate the same trends after the site was abandoned, but possibly the forest recovery was slower given the larger area of human disturbance at this site along the Ohio River than at Hovey Lake. Possibly the increased precipitation and cooler temperatures of the Little Ice Age (~550—250 cal yrs BP; AD 1400—1700) may have aided the forests around Angel and other sites to reclaim the landscape more quickly. Of course, more research at the Angel Mounds Site is required to fully compare the amount of human disturbance on vegetation between that site and the Hovey Lake Village.

6.2.3 Cahokia Mounds (11MS2), Illinois

Cahokia Mounds, located >200 km west of Hovey Lake, is considered the nucleus and apex of the Mississippian culture in the Midwest. Located in the central Mississippi River Valley, Cahokia was the political and social center of the region, with a population of several thousand inhabitants during its heyday between ~900 to 700 cal yrs BP (AD 1050 to 1250) (Ollendorf, 1997; Benson et al., 2007). The Cahokia Mounds State Historic Site today is an UNESCO world heritage site, known for its large size (16 km^2) and impressive earthen mound structures in addition to its dominant political influence over the greater Middle Mississippian cultures (Yerkes, 1988; Fortier and McElrath, 2002; Pauketat, 2004). Cahokia is situated immediately south of the confluence of the Mississippi, Missouri and Ohio rivers, which made it a very strategic location for trade by watercraft during its heyday (Figure 6.6). Given Cahokia's ideal

Figure 6.6 Location of Hovey Lake Village, Indiana and Cahokia Mounds, Illinois (Google Earth, 2015).

geographic location and being the largest Middle Mississippian city in the Midcontinent, it is no surprise that this large city had the greatest impact on its surrounding vegetation during its occupancy, as compared to other coeval settlements.

The area that would later become Cahokia Mounds was first inhabited by Late Woodland/Emergent Mississippian populations, from ~1,200 to 1,000 cal yrs BP (AD 800—1000) (Pauketat, 2003; Pauketat, 2004). The site transformed from a simple nucleated village to the largest Mississippian city after the central plaza was constructed around 950—900 cal yrs BP (AD 1000—1050) at the transition from Emergent Mississippian to Middle Mississippian (Pauketat, 2003, 2004; Benson et al., 2007). Pauketat (2003) suggested that the construction of the central plaza at Cahokia indicated a more centralized political power structure which changed where and how people interacted with one another, and shifted the relationship inhabitants had with their landscape. With the establishment of a centralized political regime in Cahokia, the small upland villages and hamlets in the vicinity were abandoned in favor of a central city and the more fluid bands that inhabited the lowland floodplain in the area either moved away or settled in Cahokia (Pauketat, 2003). The population size of Cahokia grew considerably in size from an initial approximate population size of 1,400—2,800 to 10,200—15,300 at the time the central plaza was built at ~900 cal yrs BP (~AD 1050) (Benson et al., 2007; Alt, 2010). To accommodate this great population increase, the surrounding upland and lowland forests were cleared for space to construct residential structures as well as to supply wood for building materials and fuel. The paleoenvironmental record around Cahokia (both pollen and macrobotanical) indicate that the surrounding deciduous upland forests were not as dense as those located farther south or east (Table 6.3) (Lopinot at Woods, 1993, Munoz et al., 2014, 2015).

Wooden beams and charred woody material recovered from postholes and leveled mounds were the basis of Lopinot and Woods' (1993) research on the wood used by Cahokia's residents. These researchers calculated that over 800,000 individual trees were required to build and maintain the wall posts of the residential, public, and religious buildings and palisades of Cahokia. Most buildings were used for several generations before being repaired or entirely rebuilt. Centralized residential buildings were slowly repurposed as public buildings for ceremonial purposes, which probably required new wood for the renovations (Fowler, 1978). Therefore, with all of the wood resources required for building and re-building, as well as needed as fuel for cooking and warmth, local deforestation was certainly extensive. First there would have been population declines of the tree species providing preferred wood for construction, such as *Quercus* and *Carya* and, to a lesser extent, softwoods such as *Taxodium* (bald cypress), and when these were depleted less desired trees (e.g. *Populus*) were harvested from the lowlands and adjacent slopes. Local wood was depleted as Cahokia expanded over the centuries, as evidenced by the increased amount of nonlocal wood over time, verified by wood radiocarbon dated to later periods of Cahokia (Lopinot and Woods, 1993). This interpretation is supported by a decline in the quality of timber, particularly a decrease in log diameter indicative of the depletion of large trees and resorting to cutting younger trees for building construction (Lopinot and Woods, 1993).

Pollen and tree ring reconstructions from Horseshoe Lake and the surrounding area indicate that the uplands and bluff edges surrounding the Central Mississippian River Valley were mainly vegetated by nut-bearing trees, mainly *Quercus*, *Carya* and some *Juglans*, during Late Woodland and Mississippian times (Table 6.3) (King, 1981; Munoz et al., 2015). The lowlands contained highly diverse vegetation with plants of prairie and Midwestern affiliations that included wild and early cultivated EAC taxa (Ollendorf, 1993; Munoz et al., 2004), similar to that reconstructed for Hovey Lake. The pollen record conducted by Ollendorf (1993) was collected from a series of oxbow and sinkhole lakes near Cahokia. Horseshoe, McDonough, and Gilmore lakes provided a macroscale paleoenvironment study, which showed that the most abundant AP and NAP taxa were *Quercus* and Poaceae, respectively (Table 6.3). However, the amount of *Quercus* pollen is significantly lower during the expected time Cahokia was inhabited rather than later during historic times. Pollen analysis was also conducted on borrow pits excavated within the Cahokia palisade (Ollendorf, 1993). The borrow pits show the pollen assemblage from exactly when Cahokia was occupied within the palisade, though there is a higher possibility of bioturbation and inconsistencies between pits (due to water collecting in some pits and not others). The borrow pits pollen assemblage is dominated by *Quercus*, with lesser amounts of *Carya*, *Ulmus*, *Salix*, and indeterminate *Pinus*, the latter attributed to pollen rain. NAP taxa from the borrow pits are overwhelmingly dominated by Cheno-Ams (~69—90% of the total pollen sum) with lesser amounts of Poaceae, *Ambrosia*, *Iva*, *Polygonum*, and Cyperaceae. The NAP, particularly the Cheno-Am, is indicative of Cahokia's position on the edge of the Great Plains, and hence having a drier climate (Ollendorf, 1993). The high percentage of Cheno-Ams is also evident in the Horseshoe Lake pollen record conducted by Schoenwetter (1971), who argued that the percentage values of these weedy taxa were a result of human occupation.

The most recent pollen record from Cahokia is also from Horseshoe Lake, was conducted by Munoz et al. (2014). Munoz et al. (2014) concluded that the peak land use occurred from AD 900 to AD 1200, based on the high amounts of *Ambrosia* pollen and low AP taxa identified. The pollen data, indicates that *Z. mays*-based agriculture began "abruptly" in the Cahokia region at ~1500 cal yrs BP (AD 450) and continued to intensify over the next few centuries until it seems to have stopped at 600 cal yrs BP (AD 1350) (Munoz et al., 2014). Sediments from Horseshoe Lake were also cored to identify the intensity of flooding. Munoz et al. (2015) cored sediments and looked at particle sizes to determine the intensity of flooding, which appears to have subsided at the start of the MWA at ~1350 cal yrs BP (AD 600) and large floods were fairly uncommon over the course of Cahokia's occupation, intense floods. At approximately 750 cal yrs BP (AD 1200) the sediment particle size increased which is indicative of increased flooding, given that a greater stream discharge is required to move sediments of larger particle size) (Munoz et al. 2015).

The primary difference between the vegetation of the Hovey Lake Village and Cahokia is the significantly higher values of prairie-type taxa at the latter site, even prior to the heyday of Cahokia at ~1050 cal yrs BP (AD 900). The greater abundance of warm-to-temperate herbaceous prairie taxa, including Poaceae and Amarthanaceae, at Cahokia is not only due to the larger area of deforestation and agriculture there, as compared to Hovey Lake Village, but can also be attributed to Cahokia's location farther west of Hovey Lake, closer to the grasslands of the Central Plains (Ollendorf, 1993; Munoz et al., 2014). Cahokia is situated ~200 km eastward of the eastern border of the Central Plains (Ollendorf, 1993; Munoz et al., 2014), so the local climate of the Central Mississippi River Valley (Cahokia) would notably drier than that of the Lower Ohio River Valley (Hovey Lake) in the past, as it is today (Sceeringa, 2002; Angel, 2009). This interpretation of an east-west precipitation gradient (decrease) is supported by pollen data for the Early and Mid-Holocene, which clearly document the "Prairie Peninsula," an eastward extension of tall-grass prairie that certainly extended well over the area that would later become Cahokia (Bartlein et al., 1986), but so far as the Hovey Lake area.

Similarly, the warmer and drier MWA certainly affected the western Illinois landscape in a greater manner than in the more humid southwestern Indiana. During this climatic episode, the disparity in the local environments between Cahokia (more prairie taxa) and the Hovey Lake Village (more deciduous tree taxa than at Cahokia, but still a decline in AP at this time compared to before) is probably due mainly to the geographical location of each site, with a drier climate farther west in Cahokia. Another factor, perhaps secondary in importance, is socio-political and human population differences between the two sites, with greater agricultural intensity (and hence higher NAP pollen values) by the inhabitants of Cahokia versus those of the Hovey Lake Village. However, similar trends indicative of anthropogenic disturbance are still apparent in the pollen records of both sites.

Specifically, the pollen record of Horseshoe Lake clearly documents the clear-cutting of local forest and associated increase in NAP pollen when the city was occupied (Munoz et al., 2014). The same trend occurs in the Hovey Lake pollen record but at a lesser magnitude. From Munoz et al.'s (2014) research, Cahokia was occupied during Zone HORM-1 through HORM-4, which is concurrent with Hokey Lake's Zone HL1 and HL2. Pollen values of the disturbance taxa *Rhus* (sumac) and *Ambrosia* increase dramatically during Zone HORM-2, the time when the archaeological record indicates that the landscape was occupied by the Cahokia Mississippians who engaged in intensified EAC cultivation. During the occupation of Cahokia, *Ambrosia* values are very high and fluctuate between ~5 and 25% of the total pollen sum and those of Poaceae are ~5 to 35% of the total pollen sum. Again, explanations of these remarkably high values for grass (which could include EAC grass species) and ragweed during the Cahokia occupation are due to climate, where precipitation was lower than at Hovey Lake, as expected for Cahokia's drier location close to the grassland biome, especially during the MWA when the drying and warming trends were accentuated. Disturbance by Cahokians was also a contributing factor for the expansion of grasses and forbs. At this time, the Hovey Lake pollen record (Zones HL1b and HL2) shows a similar trend with relatively high *Ambrosia* values which likely also indicates both a mild to warming climatic (MWA) influence as well as limited disturbance by humans, but at a smaller scale than at Cahokia. The Hovey Lake Village was not established until the middle of Zone HL2, but beforehand there would have been a low level of disturbance in the vicinity; first by mobile Late Woodland populations and later possibly by early Mississippians from other sites, including possibly the Angel Site upriver. In addition, some of the Poaceae and *Ambrosia* pollen grains in the Hovey Lake record may be of a long distance origin, from settlements dozens of kilometers of away, so there is good evidence for a low level of anthropogenic disturbance in the Lower Wabash Lowlands prior to the establishment of the Hovey Lake Village.

The deforestation around Cahokia during the time of its occupation was not just for constructing the large palisade or residential homes, but also to clear forest for farming, and here the pollen record provides an even stronger signal for Native American agriculture than at Hovey Lake (Zone HL3). Pollen grains from domesticates, particularly *Zea mays*, became increasingly abundant starting with the onset of the Middle Mississippian (950—900 cal yrs BP; AD 1000—1050) until Cahokia's abandonment at ~600 cal yrs BP (~AD 1350) (Munoz et al., 2014). This interpretation is supported by ample archaeological evidence that indicate that *Z. mays* consumption began to significantly increase among Mississippians at ~1000 cal yrs BP (AD 950), at the time of the Cahokia peak in population (Lopinot and Woods, 1993; Munoz et al., 2004). Supporting this interpretation is isotopic analysis of human skeletal remains that indicate an increase in the ratio of C_4 (grasses primarily attributed to maize) as compared to C3 plants (trees, shrubs, cool-season grasses, etc.) (Pauketat, 2004). Dental caries also are much more common in excavated Cahokian skeletal remains as compared to skeletal remains dated to pre-Cahokians in the region, further suggesting that *Z. mays* was a significant part of the diet as it is the leading cause of caries in pre-Columbian populations (Pauketat, 2004).

Zea mays was not the only food source consumed during the peak Cahokia occupation. EAC domesticates and wild taxa (nuts, berries, tubers) were still part of the Cahokian diet, although at considerably lesser amounts (Redmon and McCullough, 2000; Fortier and McElrath, 2002). Taxa of the EAC are native to the Central Mississippi River Valley, but they are not as prolific as farther east (Smith, 2007). As land was cleared to plant crops and provide wood to the growing human populations, there was an increase in hillslope erosion, causing a removal of soil from the upland prairie-forest and redeposition of the sediment in lowlands. The combination of less vegetation rooting the upland soil in place and soil drying during the MWA, made the upslope soils susceptible to erosion whenever there was occasional thunderstorms and associated flash flooding that impacted the Cahokians (Lopinot and Wood, 1993; Ollendorf, 1993).

The residents around Hovey Lake left little indication of a regular direct interaction with Cahokians when the larger Middle Mississippian settlement was at its heyday (Munson, 1997, 1998, 2000, 2003, Munson et al., 2001). Likewise when the Hovey Lake Village was populated, Cahokia was already experiencing a significant population decline (Pauketat, 2004). The Hovey Lake and Horseshoe Lake (Cahokia) pollen records both indicate similar trends of forest disturbance due to populations practicing agriculture and both show an increase in upland taxa, such as *Quercus* and *Carya*, that suggest climate forcing, specifically the warmer and drier conditions of the MWA.

Additionally both lake records also indicate a significant pollen decrease in *Ambrosia* and Poaceae and a significant increase in tree and shrub pollen (AP) after the sites were largely abandoned by their populations (King, 1981; Ollendorf, 1993; Pauketat, 2004; Munoz et al., 2014). The dramatic reforestation at both sites demonstrates the important impact Native Americans had upon their local environment during the time of site occupation. The difference between the two sites is the timing, nearly 300 hundred years apart. Cahokia was abandoned at ~600 cal yrs BP (~AD 1350), a century after the end of the MWA, whereas the Hovey Lake Village was vacated during the height of the LIA (after 300 cal yrs BP [AD 1350]). These two short but distinct climatic episodes did affect local environments, but not as much as did the prior human occupations, confirmed by the near identical pollen trends of reforestation at both sites during different climatic intervals. Similar patterns in pollen and archaeological data have been reconstructed for the core settlement at Fort Ancient, a Woodland Phase period and associated city located in central Ohio.

6.2.4 Fort Ancient Site (33WA2), Ohio

The Fort Ancient Site is a Late Woodland/Emergent Mississippian settlement covering ~0.5 km^2 that overlooks the Little Miami River, a tributary to the Ohio River, and situated over 380 km east-northeast from Hovey Lake (Figure 6.7). The Mississippian Fort Ancient was occupied from ~950 to 550 cal yrs BP (~AD 1000 to1400) and developed *in situ* from previous Late Woodland populations who inhabited the same mesophytic and mesic deciduous forests along the Middle and Upper Ohio River drainage in southern Ohio, western West Virginia, and northeastern Kentucky (Delcourt, 1979). The earthen mounds and earth walls that surround the site were constructed during the Middle Woodland (~2,000—1,500 cal yrs BP; ~50 BC—AD 950) and the region was occupied continually by these and later populations until the arrival of Euro-Americans at ~200 cal yrs BP (AD 1750) (Essenpries, 1978; McLauchlan, 2003). However, mound construction seemed to have stopped abruptly at ~1550 cal yrs BP (AD 400) at the beginning of the Late Woodland/Emergent Mississippian period (McLauchlan, 2003).

The residences of the large Fort Ancient Site and surrounding smaller Fort Ancient Aspect satellite communities likely had little political influence or social interaction with the residences of Hovey Lake Village, as the Fort Ancient heyday was centuries prior to the establishment of Hovey Lake Village or other Caborn-Welborn Mississippian settlements down river (McKern, 1939; Essenpries, 1978; Pollack et al., 2002; Pollack, 2004). This interpretation of limited social interaction between Fort Ancient and western Mississippian groups is indicated by the sparse recovery of Mississippian-style ceramics and gorgets at Fort Ancient sites (Essenpries, 1978).

The Middle Woodland residents of the Fort Ancient cultures along the Middle Ohio River Valley settled in tightly nucleated villages and relied heavily on EAC cultivars, in addition to hunting and gathering a wide range of wild species (Essenpries, 1979; Smith et al., 2007). Later the Emergent Mississippian population of the larger (Fort Ancient) and smaller (Fort Ancient Aspect) settlements shifted slightly to more dependency on *Zea mays*, similar to their western Middle Mississippian neighbors (Essenpries, 1979;

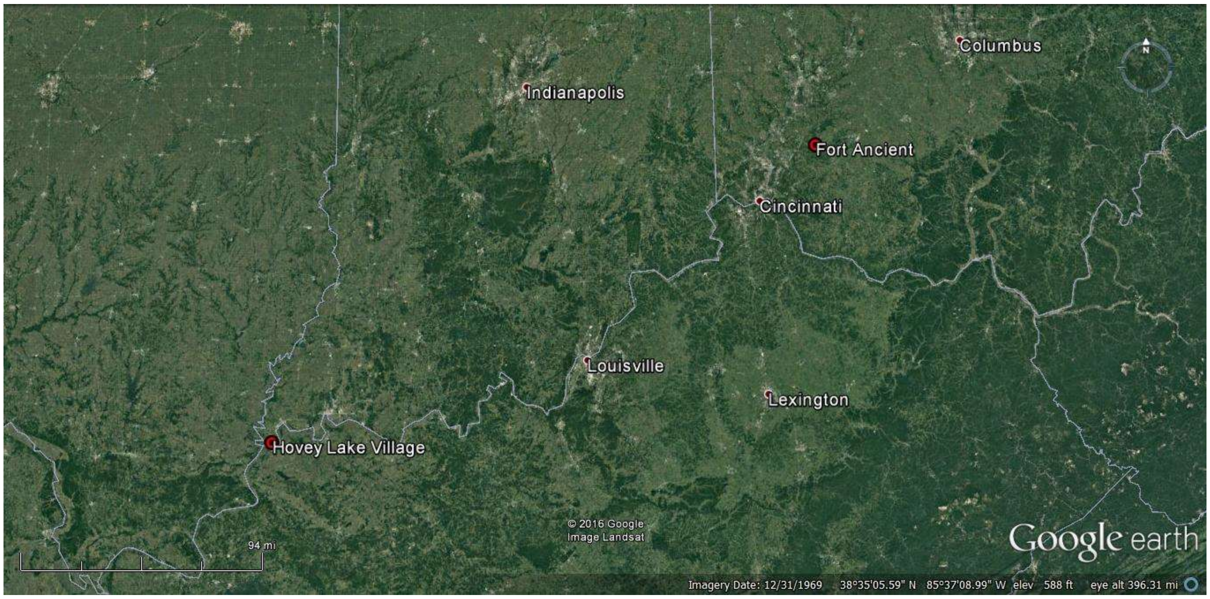

Figure 6.7 Location of Hovey Lake Village, Indiana and Fort Ancient, Ohio (Google Earth, 2015).

Wymer, 1993), and hence warrants discussion of the landscape and anthropogenic impacts of the Fort Ancient sites in this chapter.

The pollen data from the Fort Ancient area provide good evidence of forest clearance for the entire occupation of the nucleated site. McLauchlan (2003) conducted pollen analysis on the sediments of two human-excavated ponds on the north and south limits within the palisade which were dug to hold water. The pond sediment cores date from approximately the beginning of the Middle Woodland period through the Emergent Mississippian onto the present day (~2,000 to 0 cal yrs BP; 50 BC to AD 1950). Interpretations of these pollen data, along with artifacts recovered from archaeological excavations conducted in the Middle and Upper Ohio River Valley areas, suggest that the Fort Ancient community significantly altered their surrounding environment, as did the Mississippians to the west. Pollen grains from the Middle Woodland occupation in Ohio show high percents of *Iva*, *Polygonum*, and Chenopodiaceae-type, which are all native species as well as members of the EAC. Burned *Chenopodium* seed coats were also recovered from the sediment cores. The presence of these species in the pollen record is likely indicative of the EAC as oppose to merely the presence of the natural weedy vegetation.

Charred macrobotanicals also recovered from archaeological contexts show an early usage of *Cucurbita* spp. in addition to many charred nutshells from local nut-bearing trees, although both rinds and shells dwindle over the course of occupation (McLauchlan, 2003). *Plantago*, another taxon often found in disturbed environments as a wild plant with no food value, is "conspicuously absent" from the pollen record and only appears in extremely low values in the modern surface sample of the pond sediment (McLauchlan, 2003). This suggests that most of the weedy taxa identified in the pollen record were cultivated by the Middle Woodland Fort Ancient population rather than being of natural origin, although these species were also native to the region (Deam, 1940). Very few *Z. mays* pollen grains were recovered for this interval, which suggest either that the Middle Woodland population did not heavily utilize *Z. mays*, or that the fields were not close enough to the ponds to trap the heavy and large corn pollen grains except in the case of these rare grains (McLauchlan, 2003; Lane et al., 2010).

The end of McLauchlan's Zone 1 for both the North and South Ponds overlap with the pollen data from Zones HL1 and HL2 (although the Fort Ancient Site data goes back further in time) (Table 6.3). The pollen data for the Middle Woodland Fort Ancient Site and the Woodland occupation at Hovey Lake are very different, although some potential similarities are present. At both sites, the sediment cores that produced pollen records were taken from water bodies located adjacent to where the respective residents lived and the pollen from both data sets reconstruct both natural (climate) local conditions as well as anthropogenic impacts on landscapes. At Hovey Lake, the pollen record during this time indicates that the mesic deciduous forest was comprised of a mix of primarily *Quercus* and *Carya*, with lesser amounts of *Fagus*, *Acer*, *Fraxinus*, *Ulmus*, *Nyssa*, *Liquidambar*, *Juglans*, *Plantanus*, and *Pinus*. McLauchlan (2003) reconstructed an identical forest composition at her site, and earlier Wilkins (1991) proposed that the dominance of *Quercus* and *Carya* may be linked to Fort Ancient populations managing specific wild taxa for gathering nuts to supplement their diet.

The pollen records for both Fort Ancient and Hovey Lake during this time are also virtually identical for the incredibly high values of *Ambrosia*, Asteraceae (daisy family), Chenopodiaceae, and *Iva* species, however the abundance of pollen grains per taxon at each site differs. At Fort Ancient, the amount of *Ambrosia* is nearly 40—60% of the total pollen sum, whereas at Hovey Lake this taxon comprises a significant amount of the total pollen sum, but is notably lower, at only about 6—11%. This difference can be explained by the fact that Fort Ancient was heavily populated by the Late Woodland/Emergent Mississippian population, whereas the archaeology at Hovey Lake indicates that there were not any large or sedentary populations in the immediate area at this time, or at least not until approximately 200 years later. So at Hovey Lake from ~950 to 550 cal yrs BP (~AD 1000 to 1400), before the Caborn-Welborn occupation, the increase of *Ambrosia* and higher values of *Quercus* and *Carya* are interpreted as due to a gradual warming and drying trend of the MWA, given that the local area was sparsely and intermittently occupied then, prior to the establishment of the village. In contrast, the incredibly high values of *Ambrosia* and higher values of *Quercus* and *Carya* at Fort Ancient should be considered as being both climatic and anthropogenic in origin. Additionally, the rate of erosion into the ponds at Fort Ancient at this time was very high and probably some of the sediments deposited had been eroded from the earthen walls. McLauchlan (2003) concluded that EAC taxa were heavily utilized during the Middle Woodland period which is supported by the archaeology of the site; five seeds coats of *Chenopodium* spp. were identified and radiocarbon dated to the occupation of the site. Other Woodland sites in the region also have evidence of EAC taxa being utilized for subsistence (e.g. Delcourt et al., 1986; Smith, 2007).

In the Middle Ohio River Valley, high values of *Zea mays* pollen grains do not appear in the pollen record until after the arrival of Euro-Americans in the area at ~250 cal yrs BP (AD 1700) (Wilkins, 1991; McLauchlan, 2003; Liu et al., 2013). Nutritional studies on human skeletal remains indicate that the diet of Fort Ancient residents was transitioning to a maize-based agricultural economy at this time (Smith et al., 2007). *Z. mays* was added to an already diverse diet, and eventually became an increasingly important component of the diet over the duration of the Fort Ancient occupation (Simon, 2000). The assemblage of nutshells recovered from macrobotanical analysis of the Fort Ancient Site gradually decreased over time as did the amount of *Curcurbita* rinds and seeds, which are indicators that maize became more important in the diet over time (Wymer, 1993). The pollen record does confirm that *Z. mays* was planted locally during the Fort Ancient occupation (McLaughlan, 2003), but the amount of which cannot be determined based on the palynological data alone.

McLauchlan's (2003) second pollen zone (Zone 2) spans after the Hopewell-Woodland period and after the heyday of Fort Ancient and during the Late Woodland/Emergent Mississippian period up to modern (Table 6.3). Over the centuries in the Middle Ohio River Valley, the Fort Ancient populations shifted from highly nucleated settlements in the Middle Woodland period, to more dispersed settlements during the early Late Woodland, and back to a highly nucleated fortress during the terminal Late Woodland/Emergent Mississippian period (Wymer, 1993). Archaeological data indicate that after the peak of Fort Ancient occupation at the site, the city was slowly depopulated, with abandonment some point after ~550 cal yrs BP (AD 1400) (Pollack et al., 2002). These data also suggest that the population dispersed to occupy a larger area where they established smaller towns and villages, but not completely abandon the landscape (McLauchlan, 2003); similar to what occurred with the Middle Mississippians in the Vacant Quarter. McLauchlan's (2003) Zone 2 from indicates that the surrounding landscape was reforested, and presumably was largely undisturbed by humans. Tree and shrub pollen dominate (>90%) this portion of the record, with the highest percentages (~20—40%) comprised of *Quercus* and *Carya*, along with other smaller (though increased) values of AP taxa, while pollen grains of *Ambrosia* and other NAP taxa drop to less than 10% of the total pollen sum (McLauchlan, 2003). The Fort Ancient Zone 2 is contemporaneous with Hovey Lake Zones HL3—5. Zone 2 at Fort Ancient begins at the start of the LIA, which can explain the increase of AP as potentially a response to the cooler and wetter conditions, allowing hydric species to expand upslope, but given the archaeological record this vegetation shift is more likely a result of abandonment of the site and subsequent reforestation, and is contemporaneous with Zone HL4 at Hovey Lake. The archaeology of both sites suggests that the Fort Ancient City and Hovey Lake Village were slowly abandoned, though the former was abandoned nearly 200 years earlier.

The argument for human disturbance as oppose to vegetation responses to climatic events, such as the MWA or LIA, is based on these pollen indicators: a greater abundance and taxonomic diversity of weedy NAP taxa; overall lowered abundance of AP taxa; and the archaeological evidence. Together, this information reveals that the occupants of Fort Ancient were not merely utilizing the natural wild resources immediately surrounding the site, but cleared large amounts of the forests for EAC cultivation and domesticated *Z. mays*; an identical trend is seen at Hovey Lake. There is little to no evidence that Fort Ancient had direct contact with the Late Woodland populations that in habituated the area around Hovey Lake to the west; no Fort Ancient-stylized artifacts or ceramics linking the two sites have been recovered at this time (Pollack et al., 2002). Both Hovey Lake and Fort Ancient show similar trends in disturbance due to both the short-term climatic anomalies MWA and LIA, and also comparable signals indicative of anthropogenic disturbance. During the MWA at both sites, *Quercus* and *Carya* increase along with *Ambrosia*. Fort Ancient was abandoned after the end of the MWA, yet the values of pollen grains from species that could be credited to the warmer and drier climate do not decrease when the MWA ended. Only after the site is abandoned and the LIA begins is there evidence of increased pollen grains from AP taxa and more hydric and mesic species. At both sites, the surrounding forests reclaimed the landscape very quickly, with dramatic increases in AP pollen and declines in NAP pollen (*Ambrosia*, *Iva*, and *Polygonum*) in the upper part of Zone 2 (Fort Ancient) and Zone HL4 (Hovey Lake), and existed until Euro-American settlement and agriculture

6.2.5 Archaeological Comparison Summary

All of the Late Woodland/Emergent Mississippian populations of the Midcontinent USA, described above, occupied sites with similar vegetation, topography and soils and experienced comparable climatic conditions (Munson, 1997, 1998, 2000; Munson and Cook, 2001; McLauchlan, 2003, Munson et al., 2004; Munoz et al., 2014, 2015). Specifically, these archaeological sites are situated on a first- or second-order terrace above a river, and had a vegetation with great species diversity due to the moist, temperate climate (Braun, 1950; Kelly, 1976; McWilliams, 1979). Naturally, there would have been minor differences in the abundance of specific individual plant species between individual settlements based on site-specific differences in slope, soils, hydrology and microclimate, but given the uniformity of the regional climate, any significant differences in the pollen data (from lakes/ponds adjacent to archaeological sites) must be largely due to local anthropogenic disturbance. The size of Native American settlements and the timing of their occupation are the greatest determinants of vegetation change at these sites over time and space.

The Caborn-Welborn sites, such as Bone Bank, Murphy, and Slack Farm, do not have associated analyses of pollen or other proxies, as of yet, to infer the intensity of anthropogenic disturbance of the vegetation occurred at these sites. The macrobotanicals and other archaeological data recovered, however, are very similar to Hovey Lake, with similar size of estimated population, ceramic style and usage, and subsistence reconstructed for these other Caborn-Welborn sites (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). Therefore, we can assume that the amount of anthropogenic disturbance at these other sites was similar to that of the Hovey Lake Village, and so the pollen data from Hovey Lake can be extrapolated, with caution, to these other sites. The amount of vegetation change attributed to climate change, particularly the regional expressions of the MWA (warmer and drier) and LIA (cooler and moister), should be considered to have effected the entire Lower Ohio River Valley, as indicated by paleoclimatic models that simulate the trends in pollen and other proxy data sets (e.g. Wilkins, 1991; Benson et al., 2007; Cronin et al., 2013).

The Caborn-Welborn communities were large and small villages, hamlets, and individual residences scattered on the fertile floodplain nestled between the confluence of Lower Ohio and Wabash rivers (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004; Pollack, 2004). The geography of the floodplains is low relief, and frequent floods can improve soil fertility in this area. The floodplains occupied by Caborn-Welborn populations were covered by a deciduous forest with high species diversity, which may have been able to flourish despite anthropogenic disturbance because of the humid climate.

During the MWA, prior to the Caborn-Welborn Phase, the landscape was potentially occupied by smaller Woodland bands (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004 Pollack, 2004). The pollen record of Hovey Lake provides good, although not conclusive, evidence for local EAC cultivation (Zone HL 3, possibly HL2), suggesting the growing of these crops at Caborn-Welborn communities. This interpretation is not unreasonable given that the pollen records and recovered macrobotanicals throughout the Midwest report even higher EAC pollen values and macrobotanicals for this time (Delcourt et al., 1986; McLauchlan, 2003; Smith, 2006; Smith and Yarnell, 2009; Munoz et al., 2014). Additionally, an occasional *Zea mays* pollen grain was found in three levels of the Hovey Lake core, two of which (Zones HL 2 and 3), suggesting the local planting at Caborn-Welborn settlements to supplement their diet. However, without pollen studies of wetlands located next to the other Caborn-Welborn sites (Slack Farm Site, Murphy Site, Bone Bank Site, and others) we cannot fully understand the impact that these communities had on their surrounding environment.

Similarly, the Angel Mounds Site (Mississippian), upstream on the Lower Ohio River near present day Evansville, Indiana, does not have any paleoenvironmental study based on pollen or other proxy, so similarly the extent of anthropogenic disturbance occurring at the site during its occupation can only be roughly inferred by the pollen record of Hovey Lake. Given that the distance between Hovey Lake and Angel Mounds is only 48 km, the application of the pollen record of the former site to the latter is reasonably feasible. Regional climate reconstructions can be applied to Angel, which experienced an interval of higher temperatures and reduced precipitation during the MWA, which was when the site was occupied, and the site was abandoned during the early part of the LIA, which was when the Hovey Lake Village was established. There are many cultural similarities between the Angel Phase and the Caborn-Welborn, and some archaeologists suggest that the Caborn-Welborn developed directly from people who left Angel to migrate down river to create new and smaller settlements (i.e. Clay, 1997; Pollack, 2004).

Geoarchaeological and geomorphological studies have proven very helpful in determining when and how the mounds at Angel were constructed which provides an excellent timeline for the heyday of occupation (Monaghan et al., 2010; Counts et al., 2014). Angel was likely only mildly influenced by the drying and warming effects of the MWA, given the minor vegetation response reconstructed for this time at Hovey Lake (Zone HL1b and HL2). The close proximity of Angel to the Lower Ohio River and the site's low relief would have resulted in frequent flooding and deposition of sediment and organics, thereby creating a moist and the fertile landscape. Based on the size of the site and amount of the charred macrobotanicals recovered from within the palisade, the population of Angel was likely much larger than the population later living at the Hovey Lake Village (Counts et al., 2014). Therefore, the Angel Mound residents likely had a greater impact on the surrounding forests by cutting down more trees and shrubs for both building materials and fuel as well as clearing larger tracts of land to plant domesticated crops such as *Z. mays* and the EAC species than did the Hovey Lake Villagers. Again, it is difficult to fully expound upon the anthropogenic disturbance that occurred in the vicinity of the Angel Site given the lack of associated pollen research.

In contrast to the Caborn-Welborn and Angel Mounds Upper Mississippian sites, Cahokia Mounds (Middle Mississippian) does have companion studies of the local paleoenvironment, that of the pollen record of Horseshoe Lake that documents changes to the local landscape as it's a small oxbow lake located just outside the palisade (Ollendorf, 1993; Munoz et al., 2014). Cahokia was the largest Middle

Mississippian city in the Midwest and had the greatest impact on the local vegetation compared to other Middle Mississippian settlements and so has attracted the greatest amount of attention by archaeologists and paleoecologists. Pollen data and the macrobotanical analysis of archaeological deposits indicate that prior to the establishment of Cahokia the vegetation of this area along the Middle Mississippi River Valley was a species-rich deciduous forest with many pockets of *Quercus*-savannas (primarily *Quercus* with an understory of Poaceae, *Ambrosia*, *Artemisia* (wormwood/sagebrush), and other prairie-type species) (Ollendorf, 1993; Munoz et al., 2014).

The Cahokia population rose to over ~10,000 inhabitants by ~900 cal yrs BP (AD 1050) and the population was even higher when considering the affiliated satellite communities under Cahokia's political and cultural dominance (Pauketat, 2004; Munoz et al., 2014, 2015). The pollen record of Horseshoe Lake, suggests that the Late Woodland/Emergent Mississippian populations that lived in the region prior to the proper establishment of Cahokia likely had little impact on the surrounding forest (Munoz et al., 2014). Towards the end of the Late Woodland/Emergent Mississippian cultural time period at ~900 cal yrs BP (~AD 1050), earthen mounds were constructed (Pauketat, 2003; Alt et al., 2010). The presence of earthen mounds and the dedicated increase of reliance upon the domesticated *Z. mays* likely stemmed from a shift in social and political hierarchies (Lopinot and Woods, 1993; Pauketat, 2004). With a more centralized political regime in the Middle Mississippian, the majority of the smaller populations that existed on the periphery of the centralized region relocated to the lowland floodplains closer to the central plaza by ~900 cal yrs BP (~AD 1050) (Pauketat, 2003, 2004). In time, the population increase at Cahokia, within the city proper and its hinterland, would have exceeded the resources needed to support these people, causing distress and impacts on local vegetation (Lopinot and Woods, 1993; Pauketat, 2003, 2004).

The archaeological record clearly indicates that Middle Mississippian human population increased to peak between ~900—700 cal yrs BP (~AD 1050—1250), and during this time a significant extraction of local resources occurred, which led to local depletion of wood and other resources (Lopinot and Woods, 1993). The pollen record of Horseshoe Lake confirms this local deforestation by the decline in AP values (Munoz et al., 2014). Dated charred macrobotanicals from earthen mounds, postholes, and hearths indicate that the amount of locally sourced timber decreased over Cahokia's occupation; likewise the average diameter of beams from structures decreased (Lopinot and Woods, 1993). Certain taxa like *Quercus*, *Carya* and *Taxodium* were clearly favored as building materials over other species, and as the population grew more buildings were constructed or rebuilt, more fuel was needed for cook fires, and more cleared land was required for planting crops (Lopinot and Woods, 1993). This deforestation trend dating to the Middle Mississippian is clearly documented in the pollen record of Horseshoe Lake, as it was for Hovey Lake (Munoz et al., 2014, 2015). There is a notable difference in the pollen assemblages of these two lakes in that the Horseshoe Lake record contains much higher percentages of prairie-type species like Poaceae, *Artemisia*, *Iva*, and *Polygonum*, which is likely due to Cahokia's location farther west, on the border of the Great Plains. The lower values of certain EAC taxa, such as *Iva* or *Polygonum*, in the Horseshoe Lake record is a puzzle, but may be due to the residents of Cahokia clearing land to plant *Z. mays* as oppose to EAC taxa (Fowler, 1978; Smith, 2007).

The Middle Mississippian population at Cahokia greatly affected their surrounding environment, more so than during the previous Late Woodland/Emergent Mississippian periods. Although the MWA climate likely contributed to the decrease of upland and lowland AP taxa, a greater impact was induced by the large number of humans living in a relatively small area and over-utilizing local resources. Cahokia boasted of upwards of 10,000 individuals during its heyday and covered an area over 20 times greater than the land occupied by the Hovey Lake Village (nearly 100 years later), which had at most several hundred houses (Lopinot and Woods, 1993; Munson, 1997, 1998, 2000; Benson et al., 2007; Munoz et al., 2014). Although the Late Woodland population at Hovey Lake (before the formation of the village) likely had limited interactions with their western neighbors at Cahokia, similar trends in the pollen record are apparent for the intervals when the sites were occupied and later abandoned (Munson and Cook, 2001; Pollack, 2004). There is a stronger signal for deforestation at Cahokia, which isn't surprising given that it was a larger settlement than the later Hovey Lake Village ever was, and also Cahokia would have naturally had less trees given its close proximity to the Great Plains boundary to the west (reflectivity of the east-to-west decreasing precipitation gradient). After Cahokia was abandoned, Hovey Lake and other Caborn-Welborn settlements were established, possibly by these migrants, although there is no definitive evidence for this at the moment. The similar trend of *Ambrosia* increase and decrease in overall AP at Hovey Lake, even after the MWA ended and the LIA took effect; it is a clear sign that human forces effected local vegetation, as indicated by the pollen records of this lake as well as other water bodies adjacent to the cities Cahokia and Fort Ancient.

Fort Ancient is a Hopewell-Late Woodland settlement situated in south-central Ohio inhabited prior to the occupation of the Hovey Lake Village that similarly caused a significant impact on its surrounding environment. The site was first inhabited by Middle and then Hopewell-Late Woodland populations who cleared the land to construct large earthen mounds, starting at ~950 cal yrs BP (~AD 1000), and which were no longer maintained by ~1550 cal yrs BP (AD 400) when there was a cultural shift to what is now considered "Emergent Mississippian" (Yerkes, 1988; Pauketat, 2003). Pollen analysis of the sediments of two ponds excavated outside the palisade at Fort Ancient (McLauchlan, 2003) reconstructs a similar paleoenvironment to that of later Mississippian settlements along the Lower Ohio River. Correlation of the archaeological and pollen records from Fort Ancient clearly documents a decline of tree pollen and the increase of weedy EAC taxa and *Ambrosia* pollen grains in McLauchlan's (2003) Zone 1. This trend could be due strictly to the MWA climate, but given that the site was occupied long before the MWA (during the Middle and Late Woodland period), it is likely due to human influence rather than climate. Again, this same signal of land clearance was reconstructed for Hovey Lake, but here it occurred centuries later. Both pollen studies report reforestation after the decline of the main occupation, which at Fort Ancient occurred after the main Terminal Woodland/Emergent Mississippian occupation period ended (beginning of Zone 2 in the Fort Ancient pollen record), when the vegetation became a *Quercus*-dominated forest (McLauchlan, 2003). At Hovey Lake, reforestation occurred after the village was abandoned, where a *Quercus-Carya* forest became established on the uplands like before, and several tree species comprised the lowland forest (Zone HL5).

These patterns of higher amounts of *Ambrosia* and Poaceae, the presence of weedy EAC taxa, and rare *Zea mays* grains during prehistoric human occupations are almost identical in the pollen records associated with Fort Ancient, Cahokia, and the Hovey Lake Village, albeit at different intensities and times. Prior to expanding settlement area resulting from population increase, and the onset of agriculture the vegetation at all of these site was a temperate deciduous forest. The pollen records associated with Fort Ancient and Cahokia have much higher values of *Ambrosia* and Poaceae than reported for Hovey Lake. The high Poaceae values in the Cahokia pollen record is attributed not just to land clearance by also results from its location close to the eastern boundary of the Great Plains, whereas at Fort Ancient the high grass percentage is more likely due just to deforestation for agriculture and building purposes. In the Hovey Lake pollen record, *Ambrosia* and Poaceae pollen grain values peak, but at much lower percentages, indicating largely changes in the natural vegetation with slight additions attributed to agriculture when the village was occupied. The best clue as to some human disturbance in the Hovey Lake area is not so much during the time the village was occupied, but afterwards, during Zone HL4 when the site was abandoned and the percentage of *Ambrosia* pollen grains dropped significantly, suggesting that other taxa (trees) were able to reclaim the landscape. The size of the archaeological communities was the primary factor that determined how much disturbance occurred over time and space. Consequently, the landscape impacts were less at Hovey Lake as it was a small village occupied for only a few centuries, as compared to the long-inhabited cities of Cahokia and Fort Ancient.

CHAPTER 7: CONCLUSION

7.1 Summary of the Hovey Lake Pollen Record

The pollen record of Hovey Lake is a relatively short period compared to other palynology studies conducted in the Midwest region. It was hypothesized that the vegetation at Hovey Lake would change over time due to both microscale climatic anomalies as well as anthropogenic influences. Hovey Lake was of particular interest for a pollen vegetation reconstruction as no such study associated with an adjacent archaeological site had been conducted in the Lower Ohio River Valley. The Hovey Lake Village was a perfect example of a small archaeological site situated next to a body of water. In order to obtain the lake sediments for pollen analysis, Hovey Lake was cored using a modified Livingstone Corer. The lake sediments were then subsampled at Indiana University-Purdue University and processed at the Pollen Laboratory, Department of Geography at Michigan State University. Pollen samples were prepared using standard procedures, which involved physical and chemical removal of carbonates, clay particles, silicates, peat, and other organics. The samples were viewed under a high power microscope and counted for a minimum of 300 pollen grains of upland taxa per sample. The pollen grains were identified by comparing those from Hovey Lake samples to photos and drawings (McAndrews et al., 1973; Kapp et al., 2000), as well as reference pollen grain slides from the MSU Department of Geography's reference collection. The results of the Hovey Lake pollen analysis were plotted in a pollen diagram and broken into zones.

Hovey Lake Zone 1, subdivided into HL1a and HL1b (1,260—860 cal yrs BP; AD 690—1090), identified the dominate tree species as being *Quercus* (oak), *Acer* (maple), and *Carya* (hickory or pecan) arboreal pollen (AP) at this time. Other AP taxa were identified in this zone (i.e. *Fraxinus* [ash], *Populus* [cottonwood], and Roscaeae [rose family]), but at lesser pollen grain values than compared to *Quercus* and *Acer.* Together, the AP pollen grains identified during Zone HL1a likely represent a deciduous forest characteristic of the Midwest today. A notable taxon identified in this zone is *Taxodium* (bald cypress), which indicates the relatively warm and wet climate in the Hovey Lake at this time. *Taxodium* is considered a southern taxon with its northern limits today in southern Illinois-southern Indiana (Burns and Honkala, 1990b). The majority of nonarboreal pollen grains (NAP) identified in Zone HL1 belongs to *Ambrosia* (ragweed) and Poaceae (grass family). Other NAP pollen grains were identified at percentages <2% per taxa of the total pollen sum. Taxa such as Chenopodiaceae/Amaranthaceae (goosefoot/amaranth families), *Stachys* (hedgenettle), *Iva* (marsh elder), *Galium* (bedstraw), and *Polygonum* (knotweed). It is assumed that the region around Hovey Lake was comprised of a deciduous forest dominated by *Quercus*, *Acer*, and *Carya.*

The Medieval Warm Anomaly (MWA; ~1000—700 cal yrs BP; AD 950—1250) begins during this subzone (HL1b) and is a time which precipitation decreased and temperatures slightly increased (Mann et al., 2009; Cronin et al., 2010). As the regional temperature increased, the hydric tree and shrub taxa may have been restricted to the river banks and the lowest topography of the floodplain, allowing both mesic AP taxa and weedy disturbance species to expand. It is known in other regions of the United States, the MWA had a much greater impact, causing severe droughts and wild fires (Delcourt et al., 1998; Benson et al., 2007; Munoz et al., 2015), and it certainly is possible that the MWA had a significant effect on the Lower Ohio River Valley than what has been detected in the pollen record.

Besides climate, another possible explanation for these trends in the pollen data is anthropogenic, caused by the Woodland populations existing in the area at this time. The domestication of wild plants, including *Chenopodium berlandieri* (goosefoot), *Iva annua* (marsh elder), *Helianthus annuus* (sunflower), and *Cucurbita* spp. (squash), to form the Eastern Agricultural Complex (EAC) would have disturbed the natural vegetation to some degree (Smith and Yerkes, 2006; Smith, 2007; Smith, 2009). *Phalaris carolinana* (maygrass) and *Hordeum pusillum* (little barely) are also identified as EAC crops from archaeological contexts, and may be present at this time at Hovey Lake. However, pollen analysis is unable to make the important distinction between EAC crops and wild populations of the same species. Given this, EAC cultivation in the Hovey Lake area is unlikely, these taxa likely represent disturbance by Woodland populations.

Zone HL2 (860—650 cal yrs BP; AD 1090—1300) has similar taxa represented. The AP species are dominated by *Quercus*, *Acer*, and *Carya*, with lesser pollen grain percentages of *Populus*, *Fraxinus*, *Salix* (willow), Rosaceae, and some *Pinus* (pine). The *Pinus* pollen is a very low percentage of the total pollen sum and likely blew from great distances as *Pinus* species produce a high-volume of pollen, which may account for the presence of this species at Hovey Lake—almost no *Pinus* naturally occurs in the region today and none in the study area (Honkala and Burns, 1990a; Hupy and Yansa, 2009). The NAP assemblage is also similar to the previous zone. The majority of NAP identified was *Ambrosia* and Poaeceae, and lesser values of Cheno-Am, *Stachys*, *Iva*, *Galium*, *Polygonum*, and *Vitis* (grape). The MWA was at its full strength at the beginning of this zone, but ends about halfway through Zone HL2. During this time, the MWA may still be influencing the vegetation, as indicated by the pollen data. A single *Zea mays* (maize) pollen grain was identified in Zone HL2, and is clearly that of maize which is significantly larger than that of other Poaceae pollen grains (McAndrews et al., 1973; Kapp et al., 2000; Lane et al., 2010). Due to the size and good condition of the grain, maize pollen was most likely transported only a short distance by wind. The presence of the *Z. mays* pollen grain gives strong support to some kind of Late Woodland/Emergent Mississippian occupation and influence on the landscape during this zone. The earliest that the Hovey Lake Village is thought to have been established is coeval with the end of Zone HL2, so it is possible that humans utilized the area before the village was constructed.

Pollen Zone HL3 (650—340 cal yrs BP; AD 1300—1610) differs from the previous zones in that *Salix* pollen grains become the most dominate AP species followed by *Quercus*, *Acer*, and *Carya*. Lesser values of *Populus*, *Fraxinus*, and Roasaceae were also identified in this zone. The high amount of *Salix* is attributed to the beginning of the Little Ice Age (LIA) that begins at approximately the start of Zone HL3 at 550 cal yrs BP (AD 1400). The LIA is characterized as a brief climatic period of cooler temperatures and increased precipitation (Cronin et al., 2003; Mann et al., 2009). With more water available, more hydric species were likely able to expand further from the riverbanks, though it should be noted that mesic and more xeric taxa were also likely expanding. *Ambrosia* and Poaceae continued to remain the dominant NAP taxa, with lesser pollen values of *Iva*, Cheno-Ams, and *Polygonum*. Of the Poaceae pollen grains identified, two were determined to belong to *Z. mays*. The Hovey Lake Village was likely settled in the previous zone, but it is not until Zone HL3 that solid archaeological evidence documents a growing population at the village site (Munson 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004). It is highly probable that the residents of Hovey Lake Village were practicing *Z. mays* agriculture.

The LIA continued into Zone HL4 (340—250 cal yrs BP; AD 1610—1700), but this pollen zone differs from the previous zone. Overall, the total AP increases considerably. The most numerous arboreal taxa included primarily *Salix*, *Quercus*, and *Acer*, followed by lesser amounts of *Carya*, *Populus*, *Fraxinus*, Cupressaceae (cypress family), Rosaceae, and very small values of *Nyssa* (gum). *Salix* is still the dominant taxa which may be a result of the continued effect of the LIA, as higher precipitation and a cooler climate allowed this hydric and mesic taxon (which could have involved more than one species) to potentially expand their coverage within lake basins and stream beds. The trend of high AP may be exclusively a climatic response. However, this zone correlates with the abandonment of the Hovey Lake Village. Radiocarbon dates from the village predate this pollen zone and the archaeological evidence suggests the site slowly was abandoned at a time equivalent to Zone HL3. The abandonment of the site would explain the high AP values and the low *Ambrosia*, Poaceae, and other NAP values during Zone HL4. The total pollen grain percentages of all NAP taxa are at their lowest during this time, suggesting the influence of the Hovey Lake Village occupation was greater during this time than before.

The final zone, Zone HL5 (250—200 cal yrs BP; AD 1700—1750), is the shortest pollen zone for the Hovey Lake record. This zone is characterized by the arrival and influence of Euro-Americans in the Lower Ohio River Valley as exhibited by the lowest AP values and the highest values of weedy taxa like

Ambrosia and *Iva*. Paleoenvironmental and archaeological records clearly document that with the landscape drastically changed with the arrival of Euro-Americans to North America and their settlement. Forests were cleared and the landscape plowed to plant domesticated row crops and to other areas were cleared of trees for livestock grazing (Bigham, 1998). With trees cut down, weedy taxa such as *Ambrosia* and *Iva* readily colonized the edges of actively tended or fallow fields (Guyette et al., 2003), which explains the increase of the NAP taxa in the pollen record of Hovey Lake and other lake records throughout the continent.

The Hovey Lake pollen record clearly shows a response to both climatic influences as well as human disturbances. Overall, the forest makeup did not change drastically, the main AP species were *Quercus*, *Acer*, *Carya*, and later *Salix*, and the NAP species identified as mainly *Ambrosia* and Poaceae with a sprinkling of potential EAC taxa. However, the microscale changes in the paleovegetation over time are perceptible in the pollen record of Hovey Lake, which is the first for the Lower Ohio River Valley.

7.2 Synthesis of Paleoenvironmental and Archaeological Studies of Native American Land Use

There have been few paleoenvironmental studies involving analysis of pollen or other proxies from lake sediments which have directly targeted improving our understanding of prehistoric Native American impacts on landscapes in the Midwest, USA. Instead, most pollen studies have been mainly focused on reconstructing past climate changes. Furthermore, the assumption of many paleoecologists is that Native American populations had little to no impact on their natural environment prior to the arrival of Euro-Americans, i.e. the “pristine wilderness” concept (e.g. King, 1981; Jackson et al., 1997; Liu et al., 2013). In defense of these paleoecologists, the Midwest at the time of Euro-American settlement was recently vacated by Native Americans due to displacement and/or disease. Prior disturbance of land by these Native American settlements were spotty in spatial coverage and appeared less intense than the widespread land clearance by Euro-Americans. However, to ignore the impacts of aboriginal people prior to Contact is erroneous. Even though these anthropogenic impacts were limited in geographic area, isolated to the vicinity of settlements, they were profound, as documented by archaeology, primarily, and secondarily through pollen analysis of lakes or wetlands adjacent to archaeological sites.

Archaeologists have long contended that prehistoric people significantly disturbed their local environments, in terms of cutting forest to build structures and to clear land for agriculture, but their literature has been often overlooked by most paleoecologists, until recently (e.g. McLauchlan, 2003; Munoz et al., 2014). It also doesn't help that paleoenvironmental studies are often published in different journals than are most archaeological data (with the exception of *Quaternary Research* and a few others) so there is limited sharing between the two disciplines than can be overcome by reading a wide range of materials, which was done in this thesis.

The advantage of studying pollen from lake adjacent to archaeological sites is that it provides a broader landscape context to interpret past anthropogenic disturbance to local environments. Pollen analysis documents change in the species composition of upland and lowland forests and can identify the amount of non-arboreal vegetation, including weeds and cultigens. Archaeology itself cannot directly assess the composition and structure (open vs closed) of vegetation, just the species of wood used in structures and those consumed based on charred macrobotanicals. Companion pollen analysis of adjacent lakes or wetland sediments can. Unfortunately, not all archaeological sites are situated close to such a waterbody, such as at Angel Mounds where there is no such lake or pond site to core (W. Monaghan, personal communication, 2014). Fortunately, the Hovey Lake Village was established on the shoreline of Hovey Lake, permitting a close correlation of the archaeology (Munson, 1997, 1998, 2000; Munson and Cook, 2001; Munson et al., 2004) with the results of this pollen study. This is the only such paleoenvironmental study affiliated with a Caborn-Welborn Phase settlement. There were such studies conducted with regards to Cahokia and Fort Ancient which produced important details on prehistoric deforestation and agriculture followed by reforestation after the sites were abandoned. Despite such sparse data, there are other challenges in discerning the anthropogenic signals from the impacts of climate change upon vegetation, but they can be isolated, with caution, to some success.

The extent of prehistoric Native American impact on the local environment, as reconstructed from companion archaeology-paleoenvironment studies, varied temporally, culturally, and geographically. Due to the size of Cahokia, it has been a studied from multiple facets. The amount of deforestation is well documented by archaeological studies (e.g. Pauketat, 2003) including macrobotanical (e.g. Lopinot and Woods, 1993) and pollen (e.g. Ollendorf, 1993; Munoz et al., 2014). Cahokia and Fort Ancient were significantly larger settlements than Hovey Lake Village, which spanned a longer duration and had a greater cultural and political influence of their respective regions than did the Hovey Lake Village. Therefore, Cahokia and Fort Ancient had greater impacts on the local landscapes surrounding these cities.

The purpose of this thesis research was to examine the anthropogenic influences of a smaller settlement only occupied for ~200—400 years upon the local vegetation, compared to the greater impacts associated with two prehistoric cities (Ollendorf, 1993; McLauchlan, 2003; Munoz et al., 2014). Not surprisingly, the pollen results for Hovey Lake produce more subtle signals of Mississippian land use than at Cahokia and Fort Ancient, but they were still distinguishable to some extent from the natural changes in vegetation attributed to the prevailing climate. My pollen study was the first to be conducted in the vicinity of a small settlement in the Midcontinent USA and the only one associated with a Caborn-Welborn site, and hence makes a significant contribution to Mississippian archaeology. My research also distinguished general changes in the vegetation that can indicate the response of plants to the climate changes of the MWA and LIA, but identified that for the duration of the Hovey Lake Village occupation that humans were a more important stressor on vegetation than was the LIA climate. Another finding is that the deforestation induced by Native American settlement and agriculture can be assessed not just during the time of site occupation (Zone HL3), but also afterwards (Zone HL4) when the people vacated the village and forest succession resumed until the onset of extensive forest clearance by Euro-Americans

(Zone HL5). The same patterns are also evident in the pollen records associated with Cahokia and Fort Ancient.

Reconstructing the exact nature of prehistoric agriculture based on pollen analysis does have some limitations. Unfortunately, the presence of *Zea mays* is rare at all three sites, resulting from this species producing the largest of all pollen grains, which are poorly dispersed beyond tens of meters (Lane et al., 2010). However, these grains are reliable indicators of local agricultural production as *Z. mays* can be acquired by trade, a question always raised in archaeological investigations. When *Z. mays* pollen grains are found they can confirm fields adjacent to settlements.

EAC taxa in the pollen record pose a different problem. EAC taxa (*Iva annua*, *Cucurbita* spp., *Helianthus annuus*, and *Chenopodium berlandieri*) are species native to the Midwest that have been actively or passively selected for specific traits, such as larger seeds and fruits, and, in the case of *Cucurbita*, thicker rinds (Fritz, 1990, 1993; Smith, 2006, 2007, 2009). However, EAC pollen grains are indistinguishable from their wild counterparts. The presence of EAC taxa in the pollen record (of a lake or wetland adjacent to an archaeological site with evidence for agriculture) is not conclusive that EAC cultivation was taking place. The higher pollen values of these taxa likely indicate disturbance and occupied the fringe spaces between agricultural fields. Another valuable weedy pollen indicator is *Ambrosia*, a natural weed that requires open-light conditions produced by disturbances, both natural (such as windthrow and lightning-ignited fires) and anthropogenic (cutting and girdling trees and human-caused fires). Notably, the *Ambrosia* values are quite high, well above background (natural, prior to site occupation) levels, in all three pollen records, but greatest at Cahokia and Fort Ancient where there was more extensive land use than at the Hovey Lake Village. *Ambrosia* percentages are highest in the final zone of each pollen record during the Euro-American period, indicating that deforestation by Native Americans was significantly less, probably confined to the immediate vicinity of their settlements, than the Euro-American's widespread land clearance using steel axes. Still, my pollen research and the three others associated with other archaeological sites do document that prehistoric Native Americans did have a profound impact on Pre-Columbian landscapes (Table 6.3). Thus these environments were not untouched by humans at the time of Euro-American settlement and not “pristine,” but in selected areas along rivers were anthropogenic landscapes. This thesis research thus demonstrates that there is a great need for additional pollen studies of the sediments of lakes and ponds adjacent to archaeological sites to better assess the spatial and temporal patterns prehistoric or human impacts upon vegetation in the Midcontinent USA and beyond.

7.3 Future Research Directions

The species composition and the dominance of key taxa can change in response to shifts in regional temperature and precipitation patterns in addition to local human activities, such as logging and agriculture. It is always challenging to differentiate between these two causal mechanisms when interpreting abundance changes of fossil pollen recovered from lakes or wetlands adjacent to studied archaeological sites. Both mechanisms can operate at the same time and sometimes produce similar signals in the interpreted data. However, with a good understanding of plant ecology, physical geography and archaeology some important insights can be made about past climate and anthropogenic impacts on local vegetation based on such pollen research. My research at Hovey Lake has demonstrated that even small settlements occupied for a few centuries still had a detectable impact on the local flora. These findings should encourage other paleoecologists to conduct similar fine temporal studies, rather than the traditional emphasis on reconstructing solely paleoclimate records. Such pollen research, as presented in this thesis, requires biogeographers and ecologists to have a working knowledge of archaeology and to preferably collaborate with archaeologists, an area of interdisciplinary research that should yield valuable new insights into the landscape impacts of prehistoric people and their diet, data that cannot be provided by archaeology alone.

APPENDICES

APPENDIX A

Plant Scientific and Common Names

Table A.1: Plant Taxa Scientific Names and Common Names

Latin name	Common Name(s)
Abies	fir
Acer: ***A. saccharum*** ***A. negundo*** ***A. rubrum***	maple silver maple box-elder red maple/swamp maple
Aesculus ***A. flava***	buckeye/horse chestnut sweet buckeye
Alnus	alder
Amaranthaceae (family)	amaranth family
Ambrosia	ragweed
Amorphia canescens	leadplant
Artemisia	wormwood/sagebrush
Arundinaria ***A. gigantean***	cane giant cane
Asclepias perennis	milkweed
Asimina	pawpaw
Asteraceae (family) ***Iva annua*** ***Helianthus annuus* var. *marcarpus*** ***Tripolium* (invasive)**	daisy family marsh elder/sumpweed sunflower Euro-African aster
Betula ***B. papyrifera***	birch paper birch
Carpinus	hornbeam
Carya ***C. illinoinensis*** ***C. laciniosa***	pecan and hickory pecan shellback hickory
Castenea	chestnut
Catalpa speciosa	catalpa
Celtis ***C. laevigata***	hackberry sugarberry
Cephalanthus	buttonbush
Chenopodiaceae (family) ***Chenopodium. berlandireri***	goosefoot/lambsquarter family goosefoot/lambsquarter
Cornus	dogwood
Corylus	hazel
Cucurbitaceae ***Cucurbita pepo* spp. *ovifera*** ***Lagenaria siceraria***	gourd family ornamental gourds (acorn, nut) bottle gourd
Diospryous	persimmon
Fagus	beech

Table A.1 (cont'd)

Latin Name (continued)	Common Name(s) (continued)
Fraxinus ***F. nigra*** ***F. pennsylvanica*** ***F. tomentosa***	ash black ash green ash pumpkin ash
Galium	bedstraw
Gleditsia ***G. aquatic*** ***G. triacanthos***	locust water locust honey locust
Hottonia inflate	American featherfoil
Hymenocallis occidentalis	spiderlily
Hypericum	St. John's wart
Ilex vomitoria	yaupon holly
Juglans ***J. cinerea*** ***J. nigra***	walnut butternut black walnut
Larix	larch
Liquidambar ***L. stryacflua***	sweetgum sweetgum
Liriodendron ***L. tulipifera***	tulip tulip tree
Lycopus americanus	horehound
Magnolia	magnolia
Mollugo verticiullata	carpetweed
Nicotiana	tobacco
Nyssa ***N. syvatic***	gum black gum/tupelo
Osytra	hophornbeam
Petalostemum	prairie clover
Phaseolus ***P. vulgaris***	bean common bean
Picea ***P. glauca;***	spruce white spruce
Pinus ***P. banksiana*** ***P. echinata*** ***P. virginiana***	pine jack pine shortleaf pine scrub pine
Planera ***P. aquatica***	water elm: water elm

Table A.1 (cont'd)

Latin Name (continued)	Common Name(s) (continued)
Plantago	plantain
Platanus occidentalis	sycamore
Poaceae (family): ***Echinochloa* spp.** ***Hordeum pusillum*** ***Pancium* spp.** ***Phalaris canariensis*** ***Phalaris caroliniana*** ***Zea mays*** ***Zizania palustris***	grass family: barnyard grass little barley panic grass canary grass maygrass maize (corn) wild rice
Polygonum ***P. erectum***	knotweed erect knotweed
Populus ***P. deltoides*** ***P. tremuloides*** ***P. heterophylla***	cottonwood/aspen eastern cottonwood quaking aspen swamp cottonwood
Portulaca oleracea	purslane
Potenilla	cinquefoils
Pteridium aquilinum	bracken fern
Quercus ***Q. bicolor*** ***Q. falcata*** ***Q. virginiana*** ***Q. macrocarpa*** ***Q. marilandica*** ***Q. mixhauxii*** ***Q. palustris*** ***Q. phello*** ***Q. prinus*** ***Q. stellata***	oak swamp white oak southern red oak southern oak bur oak blackjack oak swamp chestnut oak pin oak willow oak chestnut oak post oak
Ranunculaceae (family)	buttercup family
Rhus	sumac
Rosaceae (family) ***Prunus americana***	rose family wild plum
Rubus	blackberry
Rumex	dockweed
Salix: ***S. nigra***	willow: black willow
Stachys	hedgenettle

Table A.1 (cont'd)

Latin Name (continued)	Common Name(s) (continued)
Taxodium: ***T. distichum***	cypress: bald cypress
Tilia	basswood
Trifolium	clover
Tripolium	sea aster
Tsuga	hemlock
Ulmus	elm
Uritca	nettles
Vaccinium	blueberry/huckleberry/bilberry
Verbascum	mullein
Verbena	verbena
Viola	violet
Vitis ***V. palmate***	grape catbird grape

APPENDIX B

Final Pollen Data

Table B.1: Final Pollen Data of Key Taxa Used to Product the Hovey Lake Pollen Diagram

Key Taxa \ cal yrs BP	206	235	265	297	324	350	376	397	403	431	456	472	485	512	539	557	567	596
Acer	11	11	10	18	24	13	12	18	23	13	19	14	17	19	8	22	14	18
Betula	9	6	3	4	9	2	4	1	3	2	2	4	8	2	5	5	3	7
Carya	21	13	18	21	16	22	17	25	25	12	21	11	21	4	14	12	26	17
Castenea	1	4	9	6	3	5	4	10	6	8	9	16	8	9	4	10	9	5
Celtis	1	3	2	4	0	3	2	1	2	2	3	3	1	2	2	9	2	6
Cornus	0	6	6	8	0	3	3	3	1	4	3	2	3	2	3	2	7	6
Corylus	3	4	12	6	4	5	1	4	2	4	2	1	4	1	4	5	1	3
Cupressaceae	12	23	17	23	9	9	9	11	13	16	8	2	10	13	9	8	10	16
Fagus	1	1	0	3	6	2	1	18	6	2	3	14	1	0	2	6	3	2
Fraxinus	18	14	13	18	30	19	19	14	15	18	16	18	12	21	17	19	12	16
Juglans	2	0	4	3	4	1	2	3	1	1	2	3	2	0	3	3	2	1
Liquidambar	1	4	5	8	5	4	3	1	5	1	0	2	1	1	0	0	1	3
Nyssa	3	4	7	12	7	1	6	0	8	5	2	4	3	2	5	6	2	2
Ostrya/Carpinus	6	4	4	9	6	4	3	3	1	2	5	4	3	3	4	10	5	8
Pinus	5	4	5	7	4	3	4	8	3	5	9	1	6	4	3	10	10	9
Populus	13	25	30	21	12	20	17	11	20	14	12	14	14	18	11	17	67	16
Quercus	31	26	33	36	55	29	30	29	38	31	39	38	40	35	36	30	43	39
Rosaceae	10	9	18	12	20	33	24	18	18	12	11	17	20	25	25	11	14	15
Salix	11	7	31	19	29	38	36	58	45	30	45	59	63	57	63	24	28	11
Taxodium	14	10	9	8	0	3	1	4	4	3	1	2	2	3	3	1	6	3
Ulmus	14	5	9	4	12	11	3	6	2	1	3	7	7	6	7	7	3	5
Other AP	6	9	14	7	12	15	11	11	10	17	9	10	11	14	9	25	18	11
Ambrosia	55	58	7	7	9	10	34	24	25	45	42	27	28	40	36	38	28	35
Cheno/Am	1	6	3	4	5	6	8	2	6	5	7	4	6	2	4	3	3	2
Galium	1	4	2	1	0	3	1	0	0	1	3	1	0	0	0	0	2	3
Iva	17	9	0	2	0	6	11	3	3	8	6	1	2	4	0	2	5	0
Poaceae (*Zea mays)	13*	16	18	29	15	25	18	14	14	22	14	14	12	16	14*	13	24*	26
Polygonum	2	6	0	0	2	1	1	7	1	2	1	6	1	0	0	0	0	0
Stachys	2	3	6	3	1	9	4	0	4	7	6	3	4	3	8	3	3	3
Vitis	1	1	2	3	0	0	1	0	1	2	0	0	0	0	0	0	0	2
Other NAP	15	7	5	1	4	7	17	7	4	13	1	5	3	5	3	5	4	11
Cyperaceae	25	22	22	30	18	15	13	10	8	11	3	10	16	8	8	32	31	18

Table B.1 (cont'd)

Key Taxa / cal yrs BP	621	647	670	697	716	744	772	797	821	847	872	898	929	955	1014	1074	1127	1195
Acer	15	17	27	16	26	17	23	15	19	24	18	18	16	35	22	38	20	23
Betula	4	1	4	2	3	2	5	10	4	1	4	5	2	1	6	6	3	2
Carya	24	20	14	16	26	9	26	13	16	14	16	13	22	16	12	25	15	29
Castenea	6	4	1	6	5	14	8	7	6	0	3	8	6	3	7	3	9	2
Celtis	9	2	1	1	5	4	6	2	3	0	4	3	3	0	4	3	7	9
Cornus	8	4	4	1	5	5	6	2	4	0	3	1	5	1	16	4	7	1
Corylus	6	4	8	2	4	5	4	4	1	10	4	6	4	11	3	4	6	9
Cupressaceae	7	10	15	11	13	9	20	14	17	11	14	10	18	10	16	12	19	13
Fagus	5	11	1	8	3	12	1	14	5	6	6	16	4	6	9	5	9	1
Fraxinus	20	23	16	24	14	21	16	15	19	18	29	15	19	10	21	13	16	16
Juglans	5	1	8	2	4	2	6	6	6	6	9	10	5	0	4	9	6	1
Liquidambar	0	0	0	2	1	1	1	0	1	0	0	1	0	0	0	0	2	0
Nyssa	10	6	5	4	5	5	2	4	5	9	3	6	7	7	10	6	2	1
Ostrya/Carpinus	8	2	3	4	5	5	4	3	7	6	2	5	5	7	2	4	5	5
Pinus	15	18	16	13	7	9	8	5	10	18	6	5	10	2	6	6	11	15
Populus	16	20	15	12	22	15	22	11	24	15	16	21	19	13	16	24	12	34
Quercus	21	32	38	29	37	23	30	29	38	17	35	27	32	45	31	35	14	29
Rosaceae	19	11	16	18	17	12	8	14	25	7	17	17	20	5	11	6	21	7
Salix	15	16	10	36	15	23	9	39	12	24	16	22	12	20	14	17	15	16
Taxodium	3	8	4	5	3	12	4	3	5	6	10	7	10	1	5	6	6	2
Ulmus	2	6	2	8	4	7	2	4	6	2	3	8	1	3	5	0	14	1
Other AP	26	21	18	15	16	15	19	14	22	21	18	13	13	20	23	21	25	24
Ambrosia	24	17	29	25	25	41	44	34	18	49	33	21	25	37	20	13	10	20
Cheno/Am	3	9	3	14	5	4	5	7	5	3	2	8	2	14	6	0	13	3
Galium	2	2	1	0	0	0	1	2	1	0	0	0	1	3	1	1	3	0
Iva	2	2	4	2	2	0	3	1	1	0	2	5	5	3	2	0	1	2
Poaceae ***(*Zea mays)***	14	21	24	15	15	21*	13	16	18	30	15	20	24	19	12	18	8	21
Polygonum	2	7	0	7	2	2	1	10	4	3	2	4	6	2	1	0	2	1
Stachys	8	4	7	0	10	0	22	5	2	0	10	2	3	1	10	1	0	3
Vitis	1	2	1	0	1	1	1	0	0	0	2	2	0	1	1	0	0	0
Other NAP	2	4	5	10	9	13	7	11	6	9	7	11	7	9	7	14	9	12
Cyperaceae	19	30	22	29	28	37	29	20	16	42	31	19	33	24	23	28	42	55

Table B.1 (cont'd)

Key Taxa / cal yrs BP	1127	1195	1256	1419	2008	2876	3459	3750	4041	4333	4790
Acer	20	23	20	29	18	34	15	17	17	27	45
Betula	3	2	8	7	3	8	6	4	5	5	3
Carya	15	29	21	23	17	31	7	16	25	18	9
Castenea	9	2	11	5	4	11	7	9	8	10	1
Celtis	7	9	2	10	8	9	5	3	9	4	2
Cornus	7	1	4	0	9	1	3	6	9	6	9
Corylus	6	9	2	12	6	10	13	5	5	6	2
Cupressaceae	19	13	10	13	14	13	23	22	16	29	13
Fagus	9	1	3	5	18	4	3	8	8	4	24
Fraxinus	16	16	16	8	17	12	12	13	6	6	23
Juglans	6	1	1	6	3	6	4	4	7	8	7
Liquidambar	2	0	1	0	0	1	0	0	0	0	0
Nyssa	2	1	7	2	7	2	0	3	3	2	0
Ostrya/Carpinus	5	5	6	7	9	6	9	5	9	2	2
Pinus	11	15	4	19	9	5	11	14	16	17	2
Populus	12	34	20	15	18	25	19	18	20	28	29
Quercus	14	29	33	22	36	19	19	33	27	30	27
Rosaceae	21	7	16	7	8	7	11	12	7	14	21
Salix	15	16	26	19	12	11	11	17	7	12	19
Taxodium	6	2	2	1	2	2	8	3	3	5	0
Ulmus	14	1	5	5	8	4	30	18	11	4	1
Other AP	25	24	18	20	25	33	32	17	31	19	14
Ambrosia	10	20	24	9	18	22	21	19	22	27	2
Cheno/Am	13	3	11	7	12	3	5	4	4	0	0
Galium	3	0	0	1	1	2	1	0	2	0	3
Iva	1	2	1	0	0	1	2	5	1	0	0
Poaceae (*Zea mays)	8	21	15	38	11	9	14	16	11	19	20
Polygonum	2	1	0	0	4	0	2	2	4	0	6
Stachys	0	3	8	0	0	3	0	4	3	0	0
Vitis	0	0	0	0	0	0	0	0	1	0	0
Other NAP	9	12	10	15	13	14	7	11	10	11	21
Cyperaceae	42	55	27	56	18	37	49	39	37	49	6

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