A Palynological Study of Two Upland Bogs in the Gulf Coastal Plain, Alabama and Mississippi

Linda C. Pace

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A PALYNOLOGICAL STUDY OF TWO UPLAND BOGS
IN THE GULF COASTAL PLAIN,
ALABAMA AND MISSISSIPPI

A Thesis
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Natural Sciences

in
The Interdepartmental Program in
Natural Sciences

by
Linda C. Pace
B.S., Louisiana State University, May 1992
May 1998
MANUSCRIPT THESES

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ACKNOWLEDGMENTS

I would like to thank my major professor Dr. Kam-biu Liu for his advice, support, kindness, encouragement, and understanding during the writing of this thesis, especially during the final months. I would also like to thank Dr. Liu for supplying the Minamac Bog core, the funding for the C-14 dating, and the processing lab and supplies.

Dr. Miriam Fearn has been important to me as a mentor, fellow-pollen counter, encourager, and friend. She has also been my compatriot in discussions of the Tilia computer software.

I would like to thank those people who helped extrude the Sweetbay Bog sediment cores, i.e., Dr. Kam-biu Liu, Miriam Fearn, Andy Maxwell, and Youngmin Lee, and also Barry McPhail and Chester Hunt for providing assistance and advice. I would also thank Don Watson, Jeff O'Connell, and Marilyn Forbes for accompanying me on a survey of Sweetbay Bog in 1994.

I would like to thank The Mississippi Nature Conservancy for permission to acquire the Sweetbay Bog sediment cores, for unlimited visits to Sweetbay Bog, and for access to information acquired during their acquisition of the land. I would also thank Mr. and Mrs. McCartee for allowing the sediment core to be taken from Minamac Bog and for providing information produced by the USDA Natural Resources Conservation Service, formerly the USDA Soil Conservation Service, Alabama.

My friends have been invaluable for their encouragement and willingness to listen to my many exclamations of distress that have been expressed during the time involved in this study. I especially want to thank Marilyn Forbes, Sharon Forbes, Ann Fugler, Judy Wright, and Vernon Wright.

I also thank my mother for her understanding.

Praise God it's over.
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ABSTRACT

Fewer Quaternary palynological studies have been conducted in the Gulf Coastal Plain of the southeastern United States than in the northern United States and Canada, resulting in major gaps in the pollen record of this region. The existing studies display discrepancies in the chronology of the pine rise, appearance of the modern climatic regime and vegetation, and timing of the Hypsithermal.

In order to fill a gap in the paleoecological data network of the Gulf Coastal Plain, pollen analysis, charcoal analysis, and sediment stratigraphic techniques were used to reconstruct the last 6500 years of Sweetbay Bog, Mississippi, and Minamac Bog, Alabama, and to document the appearance of the modern climatic regime and vegetation, the pine rise, the timing of the Hypsithermal, and natural and human disturbance.

Synchronous peat initiation occurred at Minamac Bog and Sweetbay Bog at 6000 B.P., indicating a regional rise in the water table caused by the postglacial sea level rise, which stabilized at the modern level about 6000 B.P. The bogs developed in low upland areas by paludification.

*Pinus* was the dominant upland vegetation as early as 7000 B.P. and possibly earlier. The data are inconclusive regarding the presence of the Hypsithermal. However, the paleoecological records suggest the presence of a warm and dry period from 6000 B.P. to 2800 B.P. The modern vegetation and climate became established at ca. 2800 B.P., with the establishment of a *Sphagnum* bog at Minamac Bog and a sedge-dominated fen at Sweetbay Bog. This synchronous wetland development suggests a regional climatic change to a cooler and more humid environment at 2800 B.P.

European settlement was evidenced by an increase in *Ambrosia* pollen after 500 B.P. During the same time, fire suppression was shown by a decrease in charcoal, and the logging industry was reflected by a decrease in *Pinus.*
CHAPTER 1
INTRODUCTION

Paleoecological studies have documented the effects of human disturbance and climate on vegetation (McAndrews 1988). Palynology, a branch of paleoecology, is used to reconstruct the vegetational history of the late Pleistocene and Holocene (Roberts 1989) in conjunction with analysis of peat stratigraphy and C-14 dating. Palynology is based on the analysis of pollen grains and spores that have been deposited into sediments of lakes, bogs, or other depositional environments. Charcoal analysis is used in paleoecological studies to reconstruct past fire regimes (Roberts 1989).

There have been numerous paleoecological studies in the southeastern United States, a region that is diverse in landform and vegetation and is characterized by ten distinct physiographic regions of varied vegetation communities (Delcourt and Delcourt 1985) (Fig 1). The Gulf Coastal Plain, the southernmost region, is the focus of this study. Fewer Quaternary palynological studies have been conducted in the Gulf Coastal Plain than in the northern United States and Canada, resulting in major gaps in the pollen record of this region. No studies exist for southern Mississippi.

Interspersed throughout the Gulf Coastal Plain are fire-dependent vegetation communities such as bogs and savannas that are located in areas of poor drainage and are often found in conjunction with longleaf pines, *Pinus palustris*. Existing palynological studies in the Gulf Coastal Plain display discrepancies in the chronology of the appearance of the modern climatic regime and vegetation, the corresponding pine rise, and the timing of the Hypsithermal (see Chapter 2).

This study will reconstruct the history of two upland bogs that are unaffected directly by sea level changes, using palynological and sediment stratigraphic techniques. The purpose of this study is to fill a gap in the paleoecological data network of the Gulf Coastal Plain, to provide additional information needed for a clearer understanding of the
Figure 1. The Gulf Coastal Plain of the Southeastern United States (from: Delcourt and Delcourt 1985)
climatic and vegetational history of the Gulf Coastal Plain, and to provide long-term data on southern bog communities.

The two study sites are Sweetbay Bog, Stone County, Mississippi, and Minamac Bog, Baldwin County, Alabama. The goal is to analyze these sites for pollen and sediment-stratigraphic changes spanning the last 6500 years. If changes, abrupt or gradual, occur, the two sites will be compared to determine if the changes are regional or local. Regional changes will be inferred if they are roughly synchronous between the two sites and interpreted as climatic changes. Local changes will be independent of the other site.

The main objectives of the study are to establish the age of the two Gulf Coastal Plain bogs; to document their history of development; to determine if vegetation changes relate to climatic or local environmental changes; to analyze bog initiation and maintenance; and to record the effects of disturbance, especially human disturbance and fire disturbance. This study will look for evidence of the Little Ice Age, the Hypsithermal, and an abrupt climatic change at 3200 B.P. The timing of the pine rise and appearance of the modern vegetation will be recorded.

The data from this study will fill a gap in the paleoecological data network of the Gulf Coastal Plain. It will provide long-term data on southern bog communities and document succession in stable non-climax communities. It will contribute a prehistoric view of the importance of naturally occurring fires in maintaining this environment and a historic record of the effects of human disturbance.
According to the Köppen climatic classification, the Gulf Coastal Plain lies in the humid subtropical climatic type Cfa, warm and moist with hot summers. The Maritime Tropical (mT) air mass originating in the Gulf of Mexico dominates during the summer season. The Maritime Tropical and the Continental Polar (cP) air mass from the north co-dominate during the winter season.

Previous palynological studies in the Gulf Coastal Plain disagree in the chronology and pattern of major climatic changes. Post-glacial records from peat bogs in Central Texas reveal a climatic change from cool and wet to warm and dry conditions at ca. 10,000 B.P., followed by relative stability to the present (Bryant and Holloway 1985). The pollen record of Hershop Bog of Central Texas reveals a change at 10,000 B.P. from a more mesic oak parkland to the present less mesic oak savanna (Bryant and Holloway 1985; Larson et al 1972). The pollen record from South Soefje Bog indicates that the oak-hickory association has existed since 8000 B.P. (Graham and Heimsch 1960; Bryant and Holloway 1985).

In the southeastern Gulf Coastal Plain, the appearance of the modern vegetation and climate corresponds with the timing of the pine rise. The pollen records suggest times for the onset of the modern climatic regime and vegetation in the southeastern Gulf Coastal Plain ranging from 3500 B.P. to 8400 B.P. The discrepancies may result from different local topographic site factors, such as uplands, floodplains, and coastal wetlands; or different land use and settlement histories.

The pollen record from the Nyssa-Taxodium swamp near Columbus, Mississippi, suggests that the vegetation became more modern between 3500 B.P and 2400 B.P., with increases in Nyssa, Liquidambar, Quercus, and Carya (Whitehead and Sheehan 1985). Around 2400 B.P., pine and herbaceous vegetation began to increase while Nyssa and
Quercus decreased. Whitehead and Sheehan (1985) attribute this pine rise to increased fire frequency and land use by indigenous people, which is supported by the presence of maize pollen. A more recent increase in Nyssa was due to European land clearance resulting in an increase in river discharge and the duration of inundation in swamps (Whitehead and Sheehan 1985).

The pollen record from Goshen Springs, Alabama, shows that oak-hickory forests were replaced by the modern vegetation of southern pines, swamps, and marshes at about 5000 B.P. (Delcourt 1980). This vegetation change is interpreted to result from the onset of the present humid subtropical climatic conditions characterized by abundant summer precipitation and frequent widespread fires that favored pine over hardwood communities (Delcourt 1980; Delcourt and Delcourt 1985).

Paleoecological studies in Florida indicate that the modern vegetation, dominated by Pinus and tree and shrub species common in swamp environments, was established by 5000 B.P. as a result of rising sea levels and water tables, but became more modern at 2500 B.P. (Watts and Hansen 1988). The pollen records also suggest that during the early Holocene to 5000 B.P., a drier and warmer climate was present, as evidenced by the dominance of oak and prairie vegetation. Pollen records from Lake Louise and Lake Annie, Florida, indicate that wetlands expanded at approximately 2500 B.P., indicated by an increase in Taxodium, as a result of increased precipitation and a subsequent rise in the water table (Watts and Hansen 1988).

The pollen and diatom records from Pearl River Marsh, southeastern Louisiana, show that swamp changed to brackish marsh around 5900 B.P., followed by intermittent conversions to fresh marsh from 3400 B.P. to 2200 B.P. and 1400 B.P. to 1100 B.P. as a result of marine regression and late Holocene sea level changes (Li 1994). Feam (1995) finds no evidence to support marine regression from 3400 B.P. to 2200 B.P. from her paleoecological studies in southwestern Louisiana. Li also infers that the period of 6000 B.P. to 4500 B.P. was a time of higher river discharge than the present, implying a wetter
climate, although this contradicts the model developed by Penland (1990) to reflect sea level change and coastal development.

The pollen record from Camel Lake, Florida, reveals that the modern vegetation became established by approximately 7760 B.P. with increases in *Pinus*, *Taxodium*, *Liquidambar*, *Myrica*, Ericales, and *Cyrilla*, concomitant with decreases in oak and mesic arboreal species (Watts et al. 1992). The first occurrence of pollen of a floating aquatic community and the deposition of gyttja (an organic lake sediment) suggests a trend toward a wetter climate and a rise in the water table (Watts et al. 1992).

The paleoecological record from Cahaba Pond, Alabama, shows higher water levels in the pond and the development of the modern vegetation, reflected by increases in *Nyssa sylvatica*, *Acer rubrum*, *Liquidambar styraciflua*, *Cephalanthus occidentalis*, and southern pines after 8400 B.P. (Delcourt et al. 1983). Rising water levels in the pond are inferred from a decrease in the sedimentation rate, a change from fibrous peat to gyttja sediment, a decrease in abundance and change in the composition of the macrofossils of emergent aquatics, and an increase in the macrofossils of floating and submergent aquatics. The increase in water levels is attributed to an increase in precipitation resulting from the increasing dominance of the Maritime air mass, characteristic of the modern circulation pattern, in the Gulf of Mexico; it is suggested that hurricane frequency also increased during this time (Delcourt et al. 1983).

**Hypsithermal**

This study also covers the time period of the Hypsithermal, a warm and summer-dry period during the mid-Holocene, 8500 B.P. to 4000 B.P. (Delcourt and Delcourt 1985). In the midwestern United States, the Hypsithermal was represented by a transition from forest to prairie communities (Delcourt 1980).

The record of the Hypsithermal in previous studies in the Gulf Coastal Plain is not consistent. There is no evidence of a period warmer and drier than the present during the mid-Holocene according to the pollen diagram of Camel Lake, Florida; a rising water table
is suggested at approximately 7600 B.P. (Watts et al. 1992). Delcourt et al. (1983) infer a rising water table at 8400 B.P. at Cahaba Pond, Alabama, but suggest a drier period from 10,000 B.P. to 8400 B.P. based on the dominance of oaks and hickories. However, several studies do indicate a warm and dry period during the mid-Holocene. Whitehead and Sheehan (1985) note a drier period from 7300 B.P. to 3500 B.P. near Columbus, Mississippi, as suggested by a decrease in mesic taxa, dominance by oaks and hickories, and lower water levels in the oxbow. The latter is evidenced by a decrease in floating aquatics, an increase in emergent aquatics, and an increase in wetland shrubs. At Goshen Springs, Alabama, Delcourt (1980) notes a warm and dry period dominated by oaks and hickories from 12,500 B.P. to 5000 B.P. This period may not represent the Hypsithermal but may have been a time of gradual transition from a warm and dry climate to the present climatic regime, as suggested by an increase in aquatic pollen and the implied presence of a permanent pond at approximately 8500 B.P. The timing of this warm and dry episode also does not fit the classical Hypsithermal scheme. Watts and Hansen (1988) suggest a drier period, dominated by oaks and prairie plants, from 8500 B.P. to approximately 5000 B.P. at Lake Louise and Lake Annie, Florida.

**Possible Abrupt Climatic Change at 3200 B.P.**

Recent paleoecological studies in the Gulf Coastal Plain have suggested a possible abrupt climatic change at approximately 3200 B.P. In a study to determine prehistoric hurricane activities along the northern Gulf of Mexico coast, Liu and Feam (1993) note an absence of sand layers in sediments deposited prior to 3200 B.P. in cores taken from Lake Shelby and Middle Lake, Alabama, and Western Lake in the Florida panhandle. They attribute this to a possible "regional climatic shift or sea-level change" that may have affected hurricane frequencies and storm tracks along the Gulf of Mexico coast.

A wetter climate over the past 3000 years is suggested by Tanner's (1992) study of oversized oxbows, channel remnants greater than the modern channel, in the Rio Grande
Delta of Southwest Texas. Tanner infers that they were created during the past 3000 years and that they indicate frequent, but not continuous, high river discharge. Carlson (1964, 1965) states that six times the present precipitation would be required to form a larger oversized oxbow. Tanner infers that a northward shift of the present boundary of the dry westerly and wet easterly winds occurred, resulting in increased precipitation over the southern states due to increased east-west flow from the Atlantic. Lawrence's (1974) C-14 data from drowned pine stumps on the northeast coast of the Gulf of Mexico indicate a cooler and most likely drier climate at 5000 B.P. to 4500 B.P. (Tanner 1992). Alternatively, the drowned tree stumps may be a result of sea level rise.

The Little Ice Age

The Little Ice Age is a period of global climatic cooling from approximately 1430 A.D. to 1850 A.D. (520 B.P. to 100 B.P.), consisting of a series of temperature fluctuations (Grove 1988; Critchfield 1983). When investigating vegetation changes as a result of a century-scale climatic change, the sensitivity of the study site and the resolution of the time intervals are critical factors. According to Webb (1980), it is possible to determine changes in the vegetation of a large region as a result of a 1°C summer temperature change. To determine a vegetative response for a time span of 50 to 100 years, the plant community studied must be in a region highly sensitive to small climatic changes, pollen must be sampled at intervals of 20 to 50 years, and dating must be more precise than the radiocarbon technique allows. These criteria would be met by lakes with high sedimentation rates or with varved (annually laminated) sediments in an area close to a vegetational boundary or by communities with high species richness in which a small climatic change could result in a change in the competitive balance from one species to another (Grove 1988).

Outside the Gulf Coastal Plain, the pollen record from Femdale Bog, Oklahoma, shows an increase in arboreal taxa, especially pine and oak, and a decrease in
nonarboreal taxa. This may be attributed to the moister, cooler climate of the Little Ice Age of the 1600s (Albert and Wyckoff 1981).

There is no definitive evidence for the Little Ice Age in the Gulf Coastal Plain. A palaeoecological study of impacts from prehistoric and historic hurricanes on Horn Island, Mississippi, suggests a decrease in the frequency of hurricanes during the early part of the Little Ice Age, based on an absence of hurricane-induced sand layers in lake sediments dating between 600±60 and 240±50 B.P. (Gathen 1994).

**Human Impact**

The effect of human disturbance on vegetation has been well documented from the fossil pollen and stratigraphic records. Many studies discuss the alteration of the natural vegetation and hydrology by man-made fires and forest clearance for agriculture and lumber (van Zant et al 1979; McAndrews 1968, 1988; Edwards and MacDonald 1991). Whitehead and Sheehan (1985) attribute a late-Holocene pine rise to increased fire frequency and land use by indigenous people. A result of human disturbance is that the natural vegetation is often replaced by ruderal or weedy species. Clark and Royall (1995) note the transition from a northern hardwood forest to a *Pinus-Quercus* successional forest during Iroquois settlement.

Certain species of vegetation have become specific indicators of human disturbance, both prehistoric and historic. A decrease in certain arboreal species favored for logging also reflects human disturbance. As early as the 1930s, van Zant et al (1979) detailed such studies.

*Zea* serves as an indicator of prehistoric native American agriculture and generally implies small-scale disturbance, as a result of low population levels and the absence of grazing animals (McAndrews 1988). A recent paper by Fearn and Liu (1995) documents the presence of *Zea mays* pollen in coastal Alabama at 3500 B.P.; a single grain of maize pollen was found in the sediments of Lake Shelby, approximately 32 km south of Minamac Bog. The 3500 B.P. date coincides with the Gulf Formational Stage
along the Gulf Coastal Plain. Feam and Liu (1995) propose that prehistoric agriculture, with corn as a minor crop, was taking place in the Alabama coastal plain around 3500 B.P. Whitehead and Sheehan (1985) found maize pollen at 2400 B.P. at B. L. Bigbee near Columbus, Mississippi. The finds at Lake Shelby and B. L. Bigbee suggest a possible travel route from the Alabama coastal region to northeastern Mississippi. The pollen record from the Dismal Swamp in southeast Virginia reveals Zea pollen dating to 200 B.C. (Whitehead 1965). Because the Zea pollen was found in conjunction with Gramineae, Myrica, Ilex, and Corylus pollen, Whitehead (1965) infers secondary succession following disuse of the area for agriculture.

A rise in Ambrosia pollen is the main indicator of European settlement, generally reflecting large-scale human disturbance from the clearing of land for settlements and farming, logging, and stock grazing (McAndrews 1988). It is expected that European land clearance will be reflected by a decrease in tree taxa and an increase in herbaceous taxa. Because Ambrosia is a prolific pollen producer and can be carried great distances by the wind, it may represent regional pollen (McAndrews 1988).

The Ambrosia rise, or settlement horizon, has been observed in pollen diagrams from locations in southern Ontario, the northeast United States, Washington State (McAndrews 1988), and the Gulf Coastal Plain (Whitehead and Sheehan 1985, Delcourt 1980). It is usually found in conjunction with other weedy species, i.e., Umbelliferae, Gramineae, Compositae, Rumex, and Chenopodiaceae (McAndrews 1988). Warner et al (1991) infer that European land clearance was responsible for the decrease in forest species at 200 B.P. and the increase in Alnus, Ambrosia, Gramineae, Pteridium, and other herbs in pollen diagram of bogs in New Brunswick, Canada. Davis et al (1977) infer grazing disturbance from the presence of the Ambrosia rise and other disturbance weedy herbs at Wildcat Lake, Washington State.

Land clearance may affect sedimentation rates by altering the hydrology and increasing erosion. Increased erosion may increase the rate of sedimentation. Based on
radiocarbon dates, McAndrews (1988) documents an increased historic rate of sedimentation of "10 to 20 times the prehistoric rate."

The effects of the commercial lumber industry should be reflected near the top of the pollen diagram by a decrease of certain tree taxa and an increase in disturbance plants. This could explain the abrupt decrease in pine pollen and increase in Umbelliferae and Chenopodiaceae/Amaranthaceae near the top of the pollen diagram of Femdale Bog, which coincides with a dramatic decrease in charcoal (Albert and Wyckoff 1981). Fire suppression after settlement is thought to be the cause for the decrease in charcoal.

Pollen analysis has other implications for deciphering human impacts. Delcourt et al (1986) note that Ralska-Jasiewiczowa (1977) and Behre (1981) propose that the area of human impact can be estimated by a change in the percentage of arboreal to non-arboreal pollen species. Delcourt (1980) attributes an abrupt increase in pollen influx to erosion from logging and agriculture. Edwards and McDonald (1991) record an increase in the pollen influx of woody species and a relative decrease in the pollen influx of herbaceous species at the initial clearing of forest land; tree pollen subsequently decreased, however.

Fire

Environmental impacts of fire depend on its intensity, duration, and frequency. Intensity is based on the fuel source, which is directly affected by the frequency of fire (Landers 1991). For example, grass fires burn at lower temperatures and for shorter durations than forest fires. If the fire is intense and there is little standing water on the soil surface, subsurface organic matter can be charred. A low frequency of surface fires in Sphagnum peat causes short-term, or decade-scale, changes in the vegetation, as opposed to a high fire frequency, during which the peat is repeatedly burned, causing changes in the vegetation composition (Kuhry 1994). In northern Sphagnum-dominated peatlands, an increase in fire frequency will reduce the peat accumulation rate (Kuhry 1994).
Fire can affect soil in several ways: 1) increase erosion from loss of vegetative cover, 2) decrease soil moisture, 3) increase soil temperature, 4) change the accumulation of decomposed organic matter, 5) change soil pH, and 6) increase the ability of the soil to absorb heat by the addition of charcoal (Albert and Wyckoff 1981).

Fire has played a major role in establishing pine communities in the Gulf Coastal Plain during presettlement times. Naturally occurring fires were started by lightning, with longleaf pine (*Pinus palustris*) often providing the catalyst (Natural Heritage Program, *The Longleaf Pine Flatwood Savannas of Southeastern Louisiana*, 1990). Rain may not extinguish a fire that occurs at the leading edge of the storm in which the fuel source is still capable of burning, or a fire that smolders until conditions are more conducive to burning and then erupts (Natural Heritage Program, *The Longleaf Pine Flatwood Savannas of Southeastern Louisiana*, 1990). Landers (1991) suggests that during presettlement time in the southeastern United States, there was an increase in fire frequency and a decrease in fire intensity in pine communities.

Pines and oaks generally prefer similar dry and infertile habitats, but disturbance will favor pine communities over oak communities (Landers 1991). Delcourt (1980) notes that hardwood trees are outcompeted by longleaf pine on dry uplands as a result of a thick understory of grasses preventing hardwood seed germination and frequent fires damaging or killing the seedlings. Frequent but low-intensity fires prevent the competition and establishment of woody species that are not fire dependent, enabling pine communities to persist. The longleaf pine community has a mild-intensity fire regime but the highest fire frequency of any pine community (35 per century or one every three years) (Landers 1991). The season in which a fire occurs may also influence the species composition. Longleaf pine is a savanna pine that is favored by frequently occurring fires during the early growing season; this fire regime also favors many grasses and composites (Natural Heritage Program, *Proposed Management for Hillside Seepage Bogs of Kisatchie National Forest*, 1990). Miller and Futyma (1987) infer that the increase in Cyperaceae at the core
top of Gates Bog was a result of anthropogenic fires. Late growing season fires promote shrub oaks and other woody species (Natural Heritage Program, Proposed Management for Hillside Seepage Bogs of Kisatchie National Forest, 1990).

The presence of macroscopic charcoal layers in peat indicates a fire that burned the surface layer (Kuhry 1994). Many factors can contribute to variations in charcoal abundance and type, i.e., fire intensity, type and amount of material burned, dispersal mechanism, dispersal time, depositional environment, and distance from the fire (Patterson et al 1987). Small charcoal fragments are considered to be indicators of high intensity fires and fires farther from the deposition site. In analyses of charcoal type, it is generally assumed that linear charcoal fragments indicate herbaceous vegetation and that chunk fragments indicate woody material. Charcoal fragments are dispersed by the same mechanisms as pollen, i.e., air, water, and gravity fallout. In an investigation of charcoal in bog sediments, Mehringer et al (1977) propose that charcoal abundance corresponds to pollen abundance (concentration) and therefore reflects the same dispersal and deposition mechanisms as pollen. Patterson et al (1987) suggest that charcoal present in small bogs reflects extra-local fires (occurring between 20-200 meters from source).

**Peat Development**

A peatland is any wetland that accumulates peat, an organic sediment derived from partially decomposed plant tissue in a waterlogged anaerobic environment (Ivanov 1981). Bogs, fens, savannas, and hillside seeps are examples of peatlands. Hillside seeps develop at the base of steep slopes as a result of groundwater intersecting with the land surface and flowing downhill as surface water (Mitsch and Gosselink 1993). Savannas form in seasonally flooded areas of little relief, whereas fens form in depressions. Fens are eutrophic (high in nutrients) and receive nutrients from an outside water source (rheotrophic or fed-by-flow) (Ivanov 1981, Moore 1986).

Peat accumulation occurs when primary productivity exceeds decomposition. The rate of peat accumulation varies with different environmental conditions. Reducing
(anoxic) conditions prevalent in waterlogged environments create slow decomposition rates and increased peat accumulation. When flooded, the water content in peat soils is approximately 80% by volume (Mitsch and Gosselink 1993). This anaerobic environment affects the soil water chemistry by reducing the pH and affecting nutrient availability. Compared to other wetland systems, fens and bogs are less productive. The factors that contribute to lower productivity, i.e., acidity, waterlogged conditions, and low temperature, also contribute to low decomposition rates (Mitsch and Gosselink 1993). Low temperatures, however, are not a factor in the Gulf Coastal Plain. The peat accumulation rate may decrease as a result of increased decomposition during drier time periods, and increased frequency of fires in the surface peat (Kuhry 1994).

Changes in hydrology can directly affect the water table and available nutrients. Vegetation, soil type, geology, topography, climate, fire, and human disturbance may affect hydrology (Swank and Douglas 1974; Miller and Futyma 1987; Moore 1986). According to Swank and Douglass (1974), conversion of a hardwood forest to a pine forest resulted in a decrease in streamflow because of greater evapotranspiration by young white pines than by mature hardwoods. Peat compression over mineral soil may create a perched water table, increasing waterlogged conditions (Mitsch and Gosselink 1993). Fire and human disturbance can destabilize the soil, resulting in increased water flow (Moore 1986).

The study of bog environments is extensive and dates back to the early 1900's. Heathwaite et al (1993) describe three theories for development: the hydrographic, biotic, and trophic-dynamic. A peatland may be influenced by all three aspects.

Paludification, the covering of terrestrial environments with bog vegetation (Mitsch and Gosselink 1993), is included in the hydrographic theory, which is based on hydrology and topography. Peat formation as a result of paludification usually occurs in low areas with a high water table (Heathwaite et al 1993). As the once-dry ground becomes wet, the vegetation changes in response. Initiation can be caused by climatic change, rising sea
level in low-lying or coastal areas, or changes in the geomorphology by natural or man-made disturbance (Mitsch and Gosselink 1993; Moore and Bellamy 1974; Heathwaite et al 1993). The peatlands in the humid Gulf Coastal Plain developed as a result of paludification in areas of low-energy water flow (Pfadenhauer et al 1992). A hillside seep can induce paludification at the base of the slope.

Paludification can occur in river flood plains, forest soils, and coastal plain environments. The stratigraphy of Gates Bog of Michigan shows that peat initiation began above a 2 cm layer of charcoal overlying sand at approximately 3800 B.P. (Miller and Futyma 1987). From core bottom to top, the peat ranged from highly humified dark reddish brown to unhumified *Sphagnum* peat at the top 5 cm. The point of peat development was 2 m above the level of the adjacent lake. Miller and Futyma (1987) infer that peat accumulation began when the sand became waterlogged by a rise in the water table as a result of the cool and moist late-Holocene climate and that peat initiation itself further impeded the water flow. There seems, however, to be one serious flaw in the proposal that a climatically induced water table rise was responsible for peat initiation. The 2 cm layer of charcoal directly overlying the sand has never been addressed as a possible factor in peat initiation. It is possible that the initial peat accumulation was a result of a change in hydrology due to fire. Ferndale Bog in southeastern Oklahoma was thought to have developed from a spring that gradually filled in with sediment, as evidenced by a basal stratigraphy with a high percentage of clay and a low percentage of organic matter which increased steadily to the top of the core (Albert and Wyckoff 1981). The Oswego Bog of the New Jersey Pine Barrens formed in a meander scar of coarse sand and gravel overlain with a clay lens and peat (Florer 1972). The core base dated to 10,485±240 B.P. at a depth of approximately 2.1 meters. The Maple Bog in the Sunken Forest of Fire Island, New York, developed in a depression in the forest floor (Sirkin 1972). The core base consisted of heavy mineral sand, grading into sand with rootlets, sandy peat, and ultimately brown fibrous peat in the top 50 cm. Hershop Bog developed in a blocked
stream meander in Central Texas and evolved into an upland domed-quaking peat bog maintained by a groundwater seep (Larson et al 1972). The stratigraphy is described as a sandy base overlain with decomposed peat mixed with sand, followed by finely decomposed peat comprising the top 5 meters. The initial peat buildup began approximately 10,574 B.P.

The concept of terrestrialization is included within the biotic theory (Heathwaite et al 1993). Terrestrialization is based on hydroserai succession, an autogenic or in-situ process, whereby a lake or pond fills with organic matter and results in a community change and ultimately a stable climax community. The factors controlling the initiation and rate of terrestrialization are lake bathymetry, catchment topography, lake water-level fluctuation, and trophic status. Miller and Futyma (1987) document development of Gleason Bog in northern Michigan by terrestrialization, wherein a shallow pond was represented in the sediment stratigraphy by sandy, highly decomposed dark brown peat, not gyttja, and by pollen and macrofossils of aquatic and wetland species. Miller and Futyma (1987) infer that a climatically-induced rise in the water table at ca. 6000 B.P. was responsible for the peat development. As the pond filled in, the sediment changed to moderately decomposed peat and then to unhumified Sphagnum peat in the top 15 cm.

The trophic-dynamic theory is based on climate as the controlling factor. Heathwaite et al (1993) give this theory less credence and state that "it may be almost impossible to isolate climatic influences on mire formation from the autogenic changes in mire hydrology, chemistry and biota as the mire develops." Godwin (1981) proposes that it is possible for a fen to develop independently of climate if the topography and drainage are conducive to waterlogging. Any climatic effects on peat accumulation may be indirect (Ovenden 1990). Temperature and precipitation influence the hydrology of an area and may produce regional or local changes such as a rise in the water table.

The classical interpretation of Holocene climatic changes in Europe is the Blytt-Semander scheme, which is based on changes in peat stratigraphy. This classification
was refined in 1908 and proposes a series of distinct climatic periods. Slightly humified peat is interpreted to be evidence of fast peat growth due to anaerobic reducing conditions of a wet bog surface and a corresponding wet climate; more decomposed peat is interpreted as evidence of a drier bog surface and a drier, warmer climate (Birks and Birks 1980; Roberts 1989). Later studies found that changes in peat stratigraphy are not always a result of a climatic change but are often due to fire and local changes in the hydrology.

Several major factors may contribute to the maintenance of seeps and fens. Succession from predominantly herbaceous vegetation to woody shrubs must be prevented. The frequency of fire and the soil conditions, i.e., a seasonally high water table and acidic, nutrient-poor soil, are the two most important factors for successful competition of bog species (Norquist 1985). In the absence of fire, bogs will be invaded by woody species that lower the water level of the soil and allow further invasion by less water-tolerant species (Folkerts 1982).

Based on the pollen records, there was apparent stability at Gates Bog, Oswego Bog, Maple Bog, and Hershop Bog since approximately 3800 B.P., 10,000 B.P, 250 B.P., and 8000 B.P., respectively. It can be argued, however, that the pollen records emphasize the regional vegetation rather than the local bog vegetation. With the exception of Hershop Bog, all function as bog communities today. The pollen record of Gates Bog shows little change in the vegetation since peat deposition at 3840 B.P. (Miller and Futyma 1987). In an analysis of Oswego Bog, a postglacial bog in the New Jersey Pine Barrens, only minor changes occurred in the pollen profile (Florer 1972). There is no evidence of succession or climatic change within the last 10,000 years. Florer (1972) infers that the Pine Barrens, an acidic and fire-susceptible community, has remained stable for the past 10,000 years. The pollen record of Maple Bog reveals that the present vegetation is similar to the initial vegetation established at 250±80 B.P. (Sarkin 1972). The pollen record of Hershop Bog shows no evidence of plant succession (Larson et al 1972). Because the bog surface was destroyed in the 1940's as a result of overgrazing, the pollen
record is not complete. In spite of this, the record reveals that the regional vegetation of a post-oak savanna has remained relatively stable since about 8000 B.P.
CHAPTER 3
STUDY AREAS

The two upland bogs chosen for the study are Minamac Bog in Alabama and Sweetbay Bog in Mississippi (Fig. 2). Both formed in the Holocene during the same time period that modern coastal zones and deltas were forming around the world, from 7500 to 4000 B.P., due to the slowing of transgression and stabilizing of sea level (Pirazzoli 1991). Minamac Bog and Sweetbay Bog share characteristics of two types of peatland; i.e., hillside seep and fen. Both sites receive drainage from the surrounding mineral soil, which brings nutrients into the system and creates a nutrient-rich environment.

The regional vegetation is classified as the deciduous forest association of Southern Mixed Hardwoods, a transitional forest between Mixed Mesophytic and tropical forests. It is named for the dominant species, such as Quercus virginiana, Q. laurifolia, Magnolia grandiflora, and Fagus grandifolia. Pine woods are included in the Southern Mixed Hardwood association and are considered to be fire dependent and successional (Vankat 1979). The vegetation of both study sites consists of trees, shrubs, Sphagnum moss, carnivorous plants, and marsh-like vegetation such as grasses and sedges. Table 1 lists the vegetation associated with coastal plain bogs and savannas.

Minamac Bog, Baldwin County, Alabama

Location

Minamac Bog (30°30'50"N, 87°45'50"W; elevation 15 m), (Section 20, T6S-R3E), is located in the southwest portion of the Silverhill District and is approximately 14.5 km southeast of Fairhope in Baldwin County, Alabama. It is approximately 32 km north of the Gulf of Mexico. The topography of this region consists of V-shaped valleys, flat uplands, or "saucer-like valleys" continually moistened from hillside seeps (Harper 1943). The origin of these saucer-like valleys may be a result of continuous slumps from soil saturation and loss of soil cohesion.
Figure 2. The location of Sweetbay Bog, Mississippi, and Minamac Bog, Alabama (from: Landforms of the United States by Erwin Raisz)
Table 1. Vegetation species associated with coastal plain bogs and savannas (adapted from O'Neal 1990; Folkerts 1982; and U. S. Army Corps of Engineers, Jacksonville District, 1988)

<table>
<thead>
<tr>
<th>Major Overstory Species</th>
<th>( \text{Pinus palustris} ) Longleaf Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Pinus elliotti} ) Slash Pine</td>
<td></td>
</tr>
<tr>
<td>( \text{Pinus taeda} ) Loblolly Pine</td>
<td></td>
</tr>
<tr>
<td>( \text{Pinus glabra} ) Spruce Pine</td>
<td></td>
</tr>
<tr>
<td>( \text{Liquidambar styraciflua} ) Sweetgum</td>
<td></td>
</tr>
<tr>
<td>( \text{Liriodendron tulipifera} ) Yellow Poplar</td>
<td></td>
</tr>
<tr>
<td>( \text{Quercus spp.} ) Red and White Oaks</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major Understory Species</th>
<th>( \text{Cornus florida} ) Dogwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Ilex opaca} ) Gallberry</td>
<td></td>
</tr>
<tr>
<td>( \text{Vaccinium arboreum} ) Sparkleberry</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Understory Species</th>
<th>( \text{Symplocos tinctoria} ) Common Sweetleaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Ilex opaca} ) American Holly</td>
<td></td>
</tr>
<tr>
<td>( \text{Smilax spp.} ) Greenbrier</td>
<td></td>
</tr>
<tr>
<td>( \text{Myrica cerifera} ) Southern Bayberry</td>
<td></td>
</tr>
<tr>
<td>( \text{Andropogon elliotti} ) Little Blue Stem</td>
<td></td>
</tr>
<tr>
<td>( \text{Aristida spp.} ) Threeawn</td>
<td></td>
</tr>
<tr>
<td>( \text{Lespedeza spp.} ) Native Lespedezas</td>
<td></td>
</tr>
<tr>
<td>( \text{Aristida stricta} ) Wiregrass</td>
<td></td>
</tr>
<tr>
<td>( \text{Calopogon tuberosus} ) Grass-pink</td>
<td></td>
</tr>
<tr>
<td>( \text{Panicum abscissum} ) Cutthroat Grass</td>
<td></td>
</tr>
<tr>
<td>( \text{Pleu tenuifolia} ) Rush Feathering</td>
<td></td>
</tr>
<tr>
<td>( \text{Sarracenia flava} ) Trumpet-leaf</td>
<td></td>
</tr>
<tr>
<td>( \text{Sarracenia minor} ) Hooded Pitcherplant</td>
<td></td>
</tr>
<tr>
<td>( \text{Amphicarpum} ) Blue Maidencane</td>
<td></td>
</tr>
<tr>
<td>( \text{Begelowia nudata} ) Rayless Goldenrod</td>
<td></td>
</tr>
</tbody>
</table>

(table con'd.)
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctenium Aromaticum</td>
<td>Toothachegrass</td>
</tr>
<tr>
<td>Dichromena colorata</td>
<td>White-top Sedge</td>
</tr>
<tr>
<td>Drosera capillaris</td>
<td>Sundew</td>
</tr>
<tr>
<td>Fuirena breviseta</td>
<td>Umbrellagrass</td>
</tr>
<tr>
<td>Hymenocallis palmeri</td>
<td>Alligator-lily</td>
</tr>
<tr>
<td>Lechnlanthes caroliniana</td>
<td>Redroot</td>
</tr>
<tr>
<td>Lachnocaulon anceps</td>
<td>Bog Buttons</td>
</tr>
<tr>
<td>Lobelia glandulosa</td>
<td>Glades Lobelia</td>
</tr>
<tr>
<td>Marshallia graminifolia</td>
<td>Barbara's-buttons</td>
</tr>
<tr>
<td>Pinguicula caerulea</td>
<td>Blue Butterwort</td>
</tr>
<tr>
<td>Pluchea foetida</td>
<td>Marsh Fleabane</td>
</tr>
<tr>
<td>Polygala spp.</td>
<td>Milkworts</td>
</tr>
<tr>
<td>Stokesia laevis</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Zigadenus glaberrimus</td>
<td>Liliaceae</td>
</tr>
<tr>
<td>Habenaria integrata</td>
<td>Yellow Fringeless-Orchid</td>
</tr>
<tr>
<td>Sabatia campanulata</td>
<td>Gentianaceae</td>
</tr>
<tr>
<td>Utricularia spp.</td>
<td>Bladderworts</td>
</tr>
<tr>
<td>Sphagnum spp.</td>
<td>Moss</td>
</tr>
<tr>
<td>Eriocaulon spp.</td>
<td>Pipewort</td>
</tr>
<tr>
<td>Rhexie mariana</td>
<td>Meadow Beauty</td>
</tr>
<tr>
<td>Stilltingia aquatica</td>
<td>Corkwood</td>
</tr>
<tr>
<td>Xyris spp.</td>
<td>Yellow-eyed Grass</td>
</tr>
<tr>
<td>Panicum spp.</td>
<td>Low Panicums</td>
</tr>
<tr>
<td>Evergreen Hardwoods at Stream Channels</td>
<td></td>
</tr>
<tr>
<td>Magnolia grandiflora</td>
<td>Southern Magnolia</td>
</tr>
<tr>
<td>Magnolia virginiana</td>
<td>Sweetbay Magnolia</td>
</tr>
<tr>
<td>Quercus virginiana</td>
<td>Live Oak</td>
</tr>
<tr>
<td>Near Stream Deltas</td>
<td></td>
</tr>
<tr>
<td>Taxodium distichum</td>
<td>Bald Cypress</td>
</tr>
<tr>
<td>Nyssa aquatica</td>
<td>Water Tupelo</td>
</tr>
</tbody>
</table>
Minamac Bog was purchased privately in 1971 and was to be developed into a lake surrounded by pastureland. Ten acres of trees were cleared for the pastureland and a five-acre pond replaced the boggy depressions. The pond was constructed by damming a small stream at the property's lowest spot, the north end. When the pond was completed in 1973, it had a north-south orientation, with the north end having a water depth of 6.7 m. The south end, being the natural contour and undisturbed, had a water depth of less than 2 m. The land is now managed as a nature sanctuary and educational site.

Physiography

Based on the U.S.G.S. 7.5 minute Silverhill Quadrangle topographic map, the tract's elevation ranges from 24 m to a low of approximately 15 m at the bog surface (Fig. 3). The local floodplain lies at 3 m. Minamac Bog is situated just south of the confluence of the Pensacola Branch, Perone Branch, Worm Branch, and Fish River, which is approximately 0.8 km to the west. Fish River flows southward into Weeks Bay on the east side of Mobile Bay. Minamac Bog is characterized by low depressions and hillside seeps with slopes ranging from 2-8%.

Soil

At the request of the landowners, the USDA Natural Resources Conservation Service, formerly the USDA Soil Conservation Service, Alabama, produced a Soil and Capability Map, dated June 1971, categorizing the area in and around what would become Minamac Bog. One objective of the Soil and Capability Map was to determine and delineate the pond location. The SCS suggested the pond location to be the Rains fine sandy loam (RaC) with Lakeland loamy fine sand (LaC) to the east (Fig. 4). Rains fine sandy loam (RaC) and Hyde, Bayboro and Muck (Hb) are associated with hillside seeps, and all of the soil categories range from strongly acid to extremely acid. The soil categories mapped in Fig. 4 are described in Table 2.
Figure 3. Minamac Bog: location (from: U.S.G.S. 7.5 minute Silverhill Quadrangle)
Figure 4 Minamac Bog: bog and pond location (adapted from Soil and Capability Map, June 1971, USDA Natural Resources Conservation Service, Alabama)
Table 2: Minamac Bog: soil categories (adapted from Soil and Capability Map, June 1971, USDA Natural Resources Conservation Service, Alabama)

<table>
<thead>
<tr>
<th>SOIL CATEGORIES FOR SOILS IN AND AROUND MINAMC</th>
<th>NATURAL VEGETATION</th>
<th>SLOPE</th>
<th>EROSION HAZARD</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAKELAND loamy fine sand</td>
<td>Mainly longleaf pine and loblolly pine; understory of black jack oak, blue jack oak, post oak, turkey oak, water oak and dogwood</td>
<td>LaC: 5 - 8%</td>
<td>LaC: slight to moderate</td>
<td>strongly to very strongly acid</td>
</tr>
<tr>
<td>LaC and LaB</td>
<td></td>
<td>LaB: 2 - 5%</td>
<td>LaB: slight</td>
<td></td>
</tr>
<tr>
<td>Excessively drained loamy sand,  low in natural fertilizer; developed on uplands in thick sand and loamy sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KLEJ loamy fine sand</td>
<td>Longleaf pine, slash pine, loblolly pine, scrub oak, gum and sassafras</td>
<td>2 - 5%</td>
<td>little or none</td>
<td>strongly acid or very strongly acid</td>
</tr>
<tr>
<td>KIB Moderately well-drained upland soil; developed in loamy sand and loamy fine sand on uplands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYDE, BAYBORO &amp; MUCK</td>
<td>Cypress, slash pine, gum and bay trees; understory of myrtle, lili and galberry</td>
<td></td>
<td></td>
<td>extremely acid, saturated, standing water most of the time</td>
</tr>
<tr>
<td>Hb Very poorly drained muck and swamp; in low areas or depressions; receive water as result of overflow or seepage from adjacent, higher lying areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAINS fine sandy loam</td>
<td>Pitcherplants, grasses, sedges, cypress, gums, slash pines, and pond pines</td>
<td>5 - 8%</td>
<td>little or none</td>
<td>very strongly acid</td>
</tr>
<tr>
<td>RaC Poorly drained stream flood plain and low-lying uplands with a high water table; saturated with water most of the time; developed in sandy loam to sandy clay loam on uplands; occur in seep areas at the base of slopes and in slight depressions along drainageways</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Vegetation

Minamac Bog is located in the southwestern pine hill region of southern Alabama; the regional vegetation is listed in Table 3 (Harper 1943). At the time the land was purchased by the current owners, Minamac Bog consisted of hillside seeps and boggy depressions covered with shrubs, trees, weeds and *Sphagnum* moss. Subsequent to the construction of the pond, the remaining brush was burned as the final step in clearing the land. This burning allowed the regeneration of many plant species typical to bogs, such as *Sarracenia*, *Drosera*, and orchids. Table 2 lists the natural vegetation associated with the soil categories present at Minamac Bog. The Rains fine sandy loam (RaC) soil type, suggested as the pond location, is characterized by pitcherplants, grasses, sedges, cypress, gums, slash pine, and pond pines. The owners now conduct yearly burns to maintain the bog species and eliminate the invasion of woody species.

Geology

The Geologic Map of Alabama shows the Minamac Bog to be on the edge of the Miocene Series Undifferentiated and Citronelle Formation. Based on information from the Geological Survey of Alabama, both consist of sand, gravel, and clay, and are difficult to differentiate in the absence of shell fossils in the Miocene Series. Citronelle is considered terraced deposits, while Miocene is nearshore deposits. The Geologic Map of Alabama shows that the upper part of the Miocene Series is actually Pliocene in age.

Climate

This region has the highest annual precipitation in the state. The average monthly precipitation is a high of approximately 228.6 mm in July, with a low of approximately 76.2 mm in November (Harper 1943). According to Dr. Bob Klimer of the University of Alabama (pers. comm. 1997), data from the National Climatic Data Center show that the average summer temperature is 75.2°F (April to September), and average winter temperature is 54.5°F (October to March), calculated on a 30 year average from 1951-1980.
Table 3  Vegetation of Southwestern Pine Hills Region of Alabama  
(adapted from Harper 1943)

<table>
<thead>
<tr>
<th>SPECIES LIST OF SOUTHWESTERN PINE HILLS REGION OF ALABAMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td><em>Pinus palustris</em></td>
</tr>
<tr>
<td><em>Pinus elliottii</em></td>
</tr>
<tr>
<td><em>Nyssa biflora</em></td>
</tr>
<tr>
<td><em>Taxodium ascendens</em></td>
</tr>
<tr>
<td><em>Pinus taeda</em></td>
</tr>
<tr>
<td><em>Quercus falcata</em></td>
</tr>
<tr>
<td><em>Liriodendron tulipifera</em></td>
</tr>
<tr>
<td><em>Acer rubrum</em></td>
</tr>
<tr>
<td><em>Magnolia grandiflora</em></td>
</tr>
<tr>
<td><em>Chamaecyparis thyoides</em></td>
</tr>
<tr>
<td><em>Liquidambar styraciflua</em></td>
</tr>
<tr>
<td><em>Pinus echinata</em></td>
</tr>
<tr>
<td><em>Quercus nigra</em></td>
</tr>
<tr>
<td><em>Pinus glabra</em></td>
</tr>
<tr>
<td><em>Pinus serotina</em></td>
</tr>
<tr>
<td><em>Quercus laurifolia</em></td>
</tr>
<tr>
<td><em>Taxodium distichum</em></td>
</tr>
<tr>
<td><em>Fagus grandifolia</em></td>
</tr>
<tr>
<td><em>Quercus stellata</em></td>
</tr>
<tr>
<td><em>Magnolia glauca</em></td>
</tr>
<tr>
<td><em>Quercus marylandica</em></td>
</tr>
<tr>
<td><em>Quercus cinerea</em></td>
</tr>
<tr>
<td><em>Quercus catesbaei</em></td>
</tr>
<tr>
<td><em>Cornus florida</em></td>
</tr>
<tr>
<td><em>Ilex myrtifolia</em></td>
</tr>
<tr>
<td><em>Ilex opaca</em></td>
</tr>
<tr>
<td><em>Clifonia monophylla</em></td>
</tr>
<tr>
<td><em>Quercus margaretta</em></td>
</tr>
<tr>
<td><em>Persea pubescens</em></td>
</tr>
<tr>
<td><em>Osmanthus americanas</em></td>
</tr>
</tbody>
</table>
History

The first major prehistoric occupation of Mobile Bay occurred during the late Archaic period (4000-1000 B.C.) Shell middens of brackish-water clams were found in Baldwin County at Tensas Lake, north of Minamac Bog (Walthall 1980). Walthall points out that this coincides with the establishment of the modern climatic regime. There is also evidence of occupation at Tensas Lake during the middle Gulf Formational period (1200-500 B.C.). Shell middens and mounds of the Woodland and Mississippian stages have been located in other parts of Baldwin County. A 1928 historical document refers to an unexcavated knoll in Fairhope and an excavated mound at Fish River that contained a "vessel with a carved human head of perfect design and workmanship" (Comings and Albers 1928).

The Spanish first entered Mobile Bay in 1519 and again in 1528; the French arrived in the early 1700s. The 1928 document references Fish River again by stating that Indians on Fish River entertained French settlers from Mobile (Comings and Albers 1928).

The name Silverhill appeared in the historical records as early as 1861. At that time it included the area from Fish River to Black Water. In 1897, the Silverhill colony was established by Scandinavian farmers. In order to supplement their meager incomes, the farmers later established dairy farms. The first railroad, the Bay Minette and Fort Morgan, was built in 1905. Silverhill was incorporated in 1926, with a village population of approximately 300 people and a district population of approximately 400 families (Comings and Albers 1928).

In 1909 a Bohemian farming settlement was established in the southwest part of the Silverhill District. Two community halls were built for social activities; Minamac Bog is slightly less than a mile to the west of the one built in the Silverhill District.

Harper (1943) states that in the early 1900's there was extensive logging of longleaf pine in the southwestern pine hill region and that this region was the main logging
area in Alabama for over a century. There is no indication, however, that there were
logging activities in the area around Minamac Bog.

**Sweetbay Bog, Stone County, Mississippi**

**Location**

Sweetbay Bog (30°49'30"N, 89°17'05"W; elevation 76.2 m), (Section 34, T2S-
R13W), is located on a 194-acre tract approximately 12.9 km west of Wiggins in Stone
County, Mississippi, and 61 km north of the Gulf of Mexico. It lies within the Piney
Woods ecological zone, a fire-influenced vegetation complex, in southern Mississippi.
McDaniel (1988) describes this zone as part of the longleaf pine forest that extends, with
some interruptions, from Georgia to central Louisiana. Stone County has no river systems,
but numerous creeks occur throughout. Marshes and bayous are also absent, and the
only bottomlands are those along creek beds.

The Mississippi Nature Conservancy bought Sweetbay Bog in 1989 to protect the
bog and six rare plant species. *Parnassia grandifolia*, or the Grass of Parnassus, is known
to exist in less than a dozen locations in the world. The other rare species are
*Rhynchospora macra, Xyris scabrifolia, Carex exilis, Lindera subcoriacea* and *Pinguicula
primuliflora*. Thick *Sphagnum* mats also contribute to Sweetbay's uniqueness because
this is uncommon in southern bogs (Folkerts 1982).

**Physiography**

Sweetbay Bog is composed of several boggy areas separated by an old logging
trail. According to the 7.5 minute Browns Lake Quadrangle, the bogs are situated on the
eastern side of a 100.6 m hill, which is the source of a minimum of 8 intermittent springs
(Fig. 5). At least one of these streams flows to the lower elevation of 57.9 m at Kirby
Creek, a tributary of Red Creek. The tract's elevation ranges from approximately 70 m to
91.4 m. The local floodplain occurs at 57.9 m, and the bog occurs at 76.2 m. According
to W. J. Autin of the Louisiana Geological Survey (pers. comm. 1992), if the feature is 20
feet (6.1 m) or more above the local flood plain, it is likely of Pleistocene age. The site
Figure 5 Sweetbay Bog: location (from: U.S.G.S. 7.5 minute Browns Lake Quadrangle)
records of Sweetbay Bog prepared by the Mississippi Nature Conservancy show it to be a hillside and branch-bottom quaking bog with a high frequency of Magnolia virginiana, particularly in the middle of the bog. The bog contains partially decomposed organic muck typically measuring up to 2.2 m thick and large mats of Sphagnum moss.

**Soil**

The USDA Natural Resources Conservation Service (NRCS), formerly the USDA Soil Conservation Service, mapped the soil categories of Stone County, Mississippi. The soil categories in the vicinity of Sweetbay Bog, as determined by the NRCS, are shown in Fig. 6 and further described in Table 4. All of the categories are described as very strongly acid to extremely acid, and Saucier and Smithton soils are characterized by perched water tables.

**Vegetation**

Sweetbay Bog is a pitcher plant bog and is currently being invaded by woody species because of an absence of fire. According to Clifton Eakes of the Mississippi Natural Heritage Program (1992 pers. comm.), no prescribed burn of the bog occurred in the 7 years that he was involved in the program (approximately 1984 to 1991). Chester Hunt said that a wildfire burned to the edge of the bog in October 1991 but did not burn the bog surface. The woody species invading Sweetbay Bog include Magnolia virginiana, Myrica cerifera, Itea virginica, Myrica heterophylla, Viburnum spp., Liquidambar, and Liriodendron. A partial inventory of the species present at Sweetbay Bog is listed in Table 5.

**Geology**

The Geologic Map of Mississippi shows Stone County to be both Citronelle formation (Pc) and Pascagoula and Hattiesburg formation (Mph). Citronelle (or Upland Complex) is defined as "red sand and gravel and white clay, possibly of Pliocene age." Autin (1993) describes it as Quaternary and occurring as "erosional remnants on hilltops and interfluves." Pascagoula and Hattiesburg formation is "green and bluish-green clay,
Figure 6. Sweetbay Bog: soils (from: Detailed Soils map, July 24, 1992, USDA Natural Resources Conservation Service, Mississippi)
Table 4  Sweetbay Bog: soil categories (from: Detailed Soils map, July 24, 1992, USDA Natural Resources Conservation Service, Mississippi)

<table>
<thead>
<tr>
<th>SOIL CATEGORY</th>
<th>SLOPE</th>
<th>DEPTH TO WATER TABLE</th>
<th>EROSION HAZARD</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAUCIER (#31)</td>
<td>Fine sandy loam, undulating</td>
<td>slightly convex at 2 - 8%</td>
<td>perched at 2.5 to 4.0 feet</td>
<td>moderate to severe</td>
</tr>
<tr>
<td>SMITHDALE (#33)</td>
<td>Fine sandy loam</td>
<td>convex at 8 - 15%</td>
<td>more than 6 feet below soil surface</td>
<td>severe to very severe</td>
</tr>
<tr>
<td>SMITHDALE (#34)</td>
<td>Fine sandy loam</td>
<td>convex at 15 - 25%</td>
<td>more than 6 feet below soil surface</td>
<td>very severe</td>
</tr>
<tr>
<td>SMITHTON (#35)</td>
<td>Fine sandy loam, frequently flooded</td>
<td>planar to slightly concave at 0 - 2%</td>
<td>perched at 0 to 1 foot below soil surface December - May</td>
<td>none to slight</td>
</tr>
<tr>
<td>SUSQUEHANNA (#38)</td>
<td>Silt loam</td>
<td>upland hill at 5 - 15%</td>
<td>more than 6 feet below soil surface</td>
<td>severe</td>
</tr>
</tbody>
</table>
Table 5. Partial inventory of vegetation at Sweetbay Bog (adapted from species list, Mississippi Nature Conservancy)

<table>
<thead>
<tr>
<th>Partial Inventory of Sweetbay Bog</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lindera subcoriacea</em></td>
</tr>
<tr>
<td><em>Pamassia grandifolia</em></td>
</tr>
<tr>
<td><em>Rhynchospora macra</em></td>
</tr>
<tr>
<td><em>Xyris scabifolia</em></td>
</tr>
<tr>
<td><em>Carex exilis</em></td>
</tr>
<tr>
<td><em>Pinguicula primuliflora</em></td>
</tr>
<tr>
<td><em>Sarracenia spp.</em></td>
</tr>
<tr>
<td><em>Eriocaulon spp.</em></td>
</tr>
<tr>
<td><em>Solidago spp.</em></td>
</tr>
<tr>
<td><em>Lobelia spp.</em></td>
</tr>
<tr>
<td><em>Smilax spp.</em></td>
</tr>
<tr>
<td><em>Andropogon spp.</em></td>
</tr>
<tr>
<td><em>Osmunda regalis</em></td>
</tr>
<tr>
<td><em>Pteridium spp.</em></td>
</tr>
<tr>
<td><em>Osmunda cinnamomea</em></td>
</tr>
<tr>
<td><em>Helianthus spp.</em></td>
</tr>
<tr>
<td><em>Magnolia virginiana</em></td>
</tr>
<tr>
<td><em>Myrica heterophylla</em></td>
</tr>
<tr>
<td><em>Myrica cerifera</em></td>
</tr>
<tr>
<td><em>Itea virginica</em></td>
</tr>
<tr>
<td><em>Platanthera clavellata</em></td>
</tr>
<tr>
<td><em>Pinguicual spp.</em></td>
</tr>
<tr>
<td><em>Liquidambar styraciflua</em></td>
</tr>
<tr>
<td><em>Liriodendron tulipifera</em></td>
</tr>
<tr>
<td><em>Viburnum spp.</em></td>
</tr>
</tbody>
</table>
sandy clay, and sand; gray siltstone and sand; locally fossiliferous." Gravel pits are shown as interspersed throughout the topographic map, but this does not necessarily indicate Citronelle formation. According to Autin (pers. comm. 1992), Citronelle is the source of the gravel, but it could be deposited on other complexes such as the Prairie or Deweyville.

Climate

The rainfall in southern Mississippi is highest in the summer, ranging from 1210 mm to 1625 mm, and an average runoff of 762 mm. The climate is warm temperate to subtropical (The National Atlas of the United States 1970). According to Dr. Charles Wax of Mississippi State University (pers. comm. 1997), data from the National Climatic Data Center show the average summer temperature is 79.9° F, and the average winter temperature is 49.4° F, based on a 30-year average from 1951-1980.

History

The Works Progress Administration (WPA) historical research project of 1936-37 for Stone County, Mississippi, states that only a few native American arrowheads have been found and there is no history of occupation in the immediate vicinity. It is thought that this area was a temporary camping area for prehistoric peoples when traveling north or south.

The WPA research project describes the area during Reconstruction after the Civil War as a virgin pine forest with few people. These early settlers were poor and made their living by small farms, with sheep, cattle, and products from the pine forests. Cotton was grown as early as 1860 and for commercial purposes by 1890. Smithtown, the closest town to Sweetbay Bog, was settled around 1876. Red Creek Church, approximately 2.4 km northeast of Sweetbay Bog, was established in 1826. Wiggins, originally called Niles City, was established around 1894 and incorporated in 1903. The original growth was due to the establishment of the G&SI Railroad in the 1890's and the Finkbine Lumber Co. in 1902. Finkbine Lumber Co. closed in 1930 after exhausting the native timber; only small timber and sawmill operations continued thereafter. The DeSoto National Forest in the
northern part of Stone County was reforested by the Civilian Conservation Corps (CCC) during 1936-37.

A portion of the tract of land containing Sweetbay Bog has been used for stock grazing and timber production in the past. A few roads were placed in the tract to allow timber harvesting.
CHAPTER 4
METHODOLOGY

Theoretical Background

Reconstruction of the vegetational history of the study sites was based on pollen and charcoal analyses of sediment cores retrieved at both sites. The sediment stratigraphy was described, and an index of microscopic charcoal abundance in the sediments was used to reconstruct the fire history. The pollen stratigraphies of the two bogs were compared to detect any regional trends. Sedimentation rates were calculated by the Tilia software based on radiocarbon dating of the organic sediments from both sites.

Pollen is dispersed mainly by air and water. The three components of aerial dispersal are through the trunk space of the forest, above the forest canopy, and by precipitation (Birks and Birks 1980). Pollen dispersed through the forest trunk space is considered the more local pollen assemblage. Local pollen is generally defined as originating from plants within 20 meters of the site (Delcourt et al 1983). The basin size is the dominant factor in determining the pollen source. A small basin, such as the sites in this study, receives pollen mostly from the surrounding vegetation, i.e., local pollen. The dispersal mechanism for extra-local pollen would generally be aerial, above the tree canopy (Delcourt et al 1983). *Pinus* is often overrepresented in a pollen record; it is an abundant pollen producer and can travel great distances, and is generally considered to be regional pollen. Thick forest cover may decrease the distance pine pollen can travel; therefore its origin may not always be regional (Delcourt and Delcourt 1985). Pollen dispersal is also via streams. Pollen deposition into a stream occurs as a result of the proximity of plants growing along the bank, bank erosion, and surface runoff from flooding (Birks and Birks 1980).

Entomophilous, insect pollinated, species produce less pollen than anemophilous, wind pollinated, species, and have a more restricted range of dispersal. Because of this,
Entomophilous species may be underrepresented and anemophilous species overrepresented in the fossil record (Lowe and Walker 1984). This may also be complicated by the fact that some wind-pollinated species are low pollen producers.

Pollen analysis of moss polsters is a good source of information about the modern pollen assemblages for comparison to the fossil pollen assemblages. If the surface samples are from a small bog of about 20 to 40 meters in diameter, the local anemophilous pollen are most abundant (Birks and Birks 1980).

**Field Work**

In May 1991, a 114 cm core was taken from Minamac Bog by Dr. Kam-biu Liu and Miriam Feam. The core was taken at the south end of the five-acre pond at a water depth of less than 2 meters; the south end was undisturbed during pond construction. Miriam Feam and I visited Minimac Bog in May 1994 and photographed the coring location, which is shown in Figs. 7 and 8.

A field trip was taken to Sweetbay Bog on March 6, 1993, by Dr. Kam-biu Liu, Miriam Feam, Andy Maxwell, Youngmin Lee, Barry McPhail, Chester Hunt, and myself. During that trip, two sediment cores (SBA and SBB) were taken in the middle and deepest part of the larger boggy area, which is an irregularly shaped section measuring approximately 4 hectares, within Sweetbay Bog. The locations of the cores are marked in Fig. 9 and are approximately 63 meters apart. Core SBA measured 218 cm in length and consisted of two sections; core SBB measured 229 cm and also consisted of two sections. Some compaction occurred in the upper portion of SBA, between 1 cm and 106 cm, due to the high organic content. A photograph of the location of core SBA is shown by Fig. 10. The top portion of core SBB is shown by Fig. 11, and the surrounding pine uplands are shown by Fig. 12.

Five surface samples of *Sphagnum* moss polsters were collected near the two core sites on March 6, 1993. Fig. 13 shows the approximate location of these samples.
Figure 7. Minamac Bog: showing southerly end of pond, the coring location

Figure 8. Minamac Bog: showing southerly end of pond
Figure 9. Sweetbay Bog: SBA and SBB coring locations (adapted from Mississippi Nature Conservancy)
Figure 10. Sweetbay Bog: SBA core location

Figure 11. Sweetbay Bog: upper portion of SBA core
Figure 12. Sweetbay Bog: surrounding pine uplands
A  SBA core location
B  SBB core location
a  sba1
b  sba2
c  sba4
d  sb1
e  sb2

Figure 13. Sweetbay Bog: moss polster surface sample locations
There were other trips to Sweetbay Bog prior to and subsequent to the March 6, 1993, trip. Miriam Fearn and I conducted a reconnaissance trip to Sweetbay Bog on October 4, 1992, during which we recorded vegetation species and probed for the deepest location for coring. On February 8, 1993, I met with Chester Hunt, a local person who knows the bog well and periodically gives on-site talks about the vegetation and history. We walked the area and recorded vegetation species. On February 20, 1994, Don Watson, Jeff O’Connell, Marilyn Forbes, and I walked the perimeter of the bog.

All core samples were taken with a piston sampler consisting of a clear plastic tube fitted with a sharp cutting shoe and a piston. The cores were extruded in the field and wrapped first in plastic wrap and then aluminum foil before returning to the Biogeography Lab at Louisiana State University.

**Sediment Stratigraphy**

Each core was measured, visually inspected for macrofossils and sediment type, and color coded according to the Munsell Color Chart, 1988 Edition, at the Biogeography Lab at Louisiana State University. Radiocarbon dating was performed by Beta Analytic, Inc., on two bulk organic sediment samples taken from the Sweetbay Bog SBB core and one sediment sample from the Minamac core (Table 6). Because this was an unfunded study, only three C-14 dates were obtained. These C-14 dates were used to calculate sedimentation rate and pollen influx.

From the time the Minamac Bog core was extruded and initially described in 1991 until the core was processed in 1993, it had shrunk from 114 cm to 111 cm in total length. Sweetbay Bog core SBA consisted of two sections, i.e., 1 cm to 106 cm, plus 5 cm of core-bottom sediment removed from the cutting shoe of the corer and packed in a whirlpack bag in the field; 112 cm to 213 cm, plus 5 cm of shoe contents. Sweetbay Bog core SBB consisted of two segments, i.e., 1 cm to 120 cm, plus 5 cm of shoe contents; 126 cm to 229 cm.
Table 6. Sweetbay Bog: SBB and Minamac Bog C-14 dates

<table>
<thead>
<tr>
<th>CORE</th>
<th>DEPTH LEVEL</th>
<th>C-14 DATE (BP)</th>
<th>BETA ANALYTIC INC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweetbay Bog</td>
<td>84-90 cm</td>
<td>4480±60 BP</td>
<td>#72238 5/20/94</td>
</tr>
<tr>
<td>SBB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweetbay Bog</td>
<td>156-162 cm</td>
<td>6570±100 BP</td>
<td>#72239 5/20/94</td>
</tr>
<tr>
<td>SBB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minamac Bog</td>
<td>80-90 cm</td>
<td>5710±70 BP</td>
<td>#46891 9/16/91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Loss-on-ignition analysis was performed on each core to determine the contents of water, organics, and carbonates. The Minamac Bog core was sampled at 1 cm intervals except for the top 5 cm, which consisted of unconsolidated sediments and from which the top sample was taken. Sweetbay Bog core SBB was sampled at 1 cm intervals, with one exception between 120 cm and 126 cm: one sample was taken from the shoe of the top core at approximately the 123 cm level. Sweetbay Bog core SBA was sampled at 1 cm intervals.

The sediment samples were heated at 105° C., 550° C., and 1000° C. to determine the contents of water, organics, and carbonates, respectively (Dean 1974). Prior to placing the sediment in a porcelain crucible, each crucible was weighed. The filled crucibles were weighed and recorded as wet weight and then heated in a drying oven at 105° C. for approximately 24 hours. The crucibles were removed and placed in a dessicator to cool. Following this, the samples were weighed and recorded as dry weight. The samples were then heated at 550° C. for approximately one hour. The crucibles were removed and placed in the dessicator to cool prior to weighing. A final heating at 1000° C. was conducted for about one hour. Subsequent to this, the final cooling and weighing was performed. The data were entered into the Tilia computer program for calculation of the contents of water, organics, and carbonates. Water contents were calculated as percent wet weight; organic and carbonate content were calculated as percent dry weight.

**Pollen Extraction and Counting**

Pollen extraction of the sediment cores followed the procedure described by Faegri and Iversen (1975). Each core was split down the center, and .9 cc of sediment was taken from inside the core, where contamination was least likely, and packed into a .9 ml porcelain spoon before transferring to a test tube. Two tablets of exotic Lycopodium, each containing 13,911 grains, were dropped into each test tube containing the sediment sample and approximately 10 ml of 10% HCL. The Lycopodium spores facilitate calculation of pollen concentration; the 10% HCL dissolves the Lycopodium marker and carbonates in the
sediment sample. Each tube was heated in a boiling water bath, washed with distilled water, centrifuged, and decanted. Approximately 10 ml of 10% KOH was then added to each tube to deflocculate the sample and break down organic molecules, followed by the same centrifuging and decanting procedure described above. Approximately 10 ml of HF was added to each test tube to dissolve silicates (clay minerals and diatom) and heated, centrifuged and decanted. Prior to and after adding acetolysis solution into each tube to dissolve cellulose, the samples were washed with glacial acetic acid to acidify the sediments and eliminate water. Following the final wash with glacial acetic acid, the samples were washed with distilled water, centrifuged, and decanted. The final steps involved adding safranin stain, washing with tertiary butano-alcohol, and adding silicon oil to prepare the slides.

The Minamac Bog core was sampled to a depth of 107 cm. The top sample was taken from the unconsolidated sediments and approximates the 2 cm level; the first sample from the consolidated sediments equalled the 7 cm level. Ten (10) cm intervals were sampled thereafter, i.e., 17 cm, 27 cm, 37 cm, 47 cm, 57 cm, 67 cm, 77 cm, 87 cm, 97 cm, and 107 cm.

Sweetbay Bog Core SBB was sampled to a depth of 175 cm at 10 cm intervals, with two exceptions: one sample was taken from the cutting shoe contents of the upper core and approximates the 123 cm level, and a 15 cm difference occurs between samples at 145 cm and 130 cm because of wood material at the 135 cm sampling level. The levels sampled were 1 cm, 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm, 80 cm, 90 cm, 100 cm, 110 cm, 123 cm, 130 cm, 145 cm, 155 cm, 165 cm, and 175 cm.

Sweetbay Bog core SBA was sampled for pollen analysis to a depth of 140 cm at 10 cm intervals. The levels sampled were 1 cm, 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm, 80 cm, 90 cm, 100 cm, 109 cm, 120 cm, 130 cm, and 140 cm.

Pollen extraction of the moss polsters collected from Sweetbay Bog was performed by soaking approximately 100 ml of Sphagnum moss from each sample in 10% KOH;
heating on a hot plate for approximately two minutes, while stirring vigorously, and pouring through a 300-micrometer sieve. The samples were then centrifuged and decanted and processed according to the same procedure as the pollen extraction from sediment cores, with the exception that no Lycopodium marker tablets were added.

At least three hundred (300) pollen grains were counted at 10 cm intervals. The samples were calculated and graphed for relative frequencies, or percentages. The addition of Lycopodium tablets enabled the calculation of the pollen concentration, the number of grains per cm$^3$ of sediment. Pollen influx, net number of grains deposited on a cm$^2$ surface each year, was calculated by dividing the pollen concentration by deposition time, the reciprocal of the sedimentation rate (Birks and Birks 1980). In order to ensure the accuracy of the concentration and influx, analysis was also done for naturally occurring Lycopodium spores by processing several levels without adding the exotic Lycopodium; none was found.

At least three hundred (300) pollen grains were counted for each moss polster surface sample. These samples were also analyzed for naturally occurring Lycopodium, and none was found.

**Charcoal Analysis**

Microscopic charcoal was counted based on a count of 25 Lycopodium spores per sample interval, using the pollen analysis samples. This was an arbitrary number chosen to arrive at an index of charcoal abundance. The shape of the charcoal was recorded as linear or chunk; and the size, based on the length of the longest axis, was recorded in ranges of 25-50, 50-100, 100-150, and >150 microns. These size classes are similar to the classes used by Mehringer et al (1977) in their investigation of charcoal from cores extruded from a bog in Montana (Patterson et al 1987). Charcoal data were totaled and graphed by shape and size categories.
Pollen Diagrams

The taxa categories used in the analyses were trees and herbs. Included within the tree category were shrubs and vines. Upland trees were represented by Pinus, Quercus, Ulmus, Carya, Fagus, Ostrya/Carpinus, Platanus, Juniperus, Corylus, Juglans, Tilia, Symlocos, Rhus, Rosaceae, Vitis, Gleditsia, Rubiaceae, Rhamnus, Saxifragaceae, and Ericaceae. Quercus is primarily an upland tree but may also consist of wetland taxa. Liquidambar can be found in environments ranging from mesic to wet, such as mixed hardwood forests, bottomland forests, and swamps. Myrica is common in moist to wet environments, i.e., wet savannas to moist riverine sites. Wetland trees were represented by Nyssa, Alnus, Fraxinus, Magnolia (cf. M. virginiana), Salix, Alnus, Acer, Taxodium, Ilex, Betula, Celtis, Cephalanthus, Cyrilla, Itea, Sambucus, Persea, and Viburnum. Nyssa may also represent upland environments. The study region supports both Nyssa aquatica, an obligate wetland species, and Nyssa sylvatica, a species that is only occasionally found in wetlands. Fraxinus may represent upland taxa also. Upland herbs were represented by Ambrosia, Equisetum, Tradescantia, Verbenaceae, and Cruciferae (Brassicaceae). Wetland herbs were represented by Compositae (Asteraceae), Gramineae (Poaceae), Cyperaceae, Sphagnum, Umbelliferae (Apiaceae), Chenopodiaceae/Amaranthaceae (Cheno/Ams), Typha, Pteridophytes (representing mainly spore producing ferns), Eriocaulon, Potamogeton, Rhixia, Sagittaria, Sarracenia, Ultricularia, Parnassia, and Polygonaceae. The families of Compositae, Gramineae, Cyperaceae, Umbelliferae, and Chenopodiaceae/Amaranthaceae consist of upland species as well as wetland species.

Pollen percentages and concentrations of the major taxa were calculated and graphed to aid in the interpretation of data. Pollen influx of the major taxa was calculated and graphed when radiocarbon dating was available. The major taxa are those with frequencies totalling 2% or more for the portion of the core sampled. Pollen percentages of the minor taxa were calculated and graphed. The minor taxa are those totalling less than
2% for the portion of the core sampled. Pollen percentages for each moss surface sample were calculated and graphed using a single diagram. Indeterminable pollen may result from deterioration or being broken or crumpled, or from the presence of charcoal or organic detritus obstructing the view of the pollen (Delcourt and Delcourt 1980).

Pollen zonation is based on both visual observation and a dendrogram produced within the Tilia software program, CONISS (constrained incremental sum of squares cluster analysis), on the percentage data.
CHAPTER 5
RESULTS

Minamac Bog

Sediment Stratigraphy

When the Minamac Bog core was extruded and initially described, it measured 114 cm in length, as shown in the sediment stratigraphic diagram (Fig. 14). The upper 70 cm is a uniform black peat overlying increasingly sandy peat from 70 cm to the core bottom. Stems and fine roots occur throughout the core.

The loss-on-ignition data reveal parallel trends for the water and organic contents except for the top 6 cm of the core, where organic matter decreases and water content increases (Fig. 14). The overall pattern is an increase in organic matter content and water content from the core bottom to the top. At the core bottom, water content is 25% (of wet weight), and the organic matter content is 7% (of dry weight). Peat accumulation begins at about 87 cm (ca. 5800 B.P). Organic matter content increases steadily from the core bottom to 37 cm (2486 B.P). From 37 cm to the core top a series of increases and decreases in organic matter content occur. At the core top the organic matter content is 31% and water content is 80%. The maximum organic matter and water contents occur at 13 cm, 74% and 83%, respectively. The carbonate content is low (less than 3%). The presence of a reddish residue between 17-7 cm after ignition at 550° C indicates the presence of iron oxide and the oxidation process.

Radiocarbon dating was performed on a section of the core between 80-90 cm with a result of 5710± 70 B.P. The 80-90 cm section of the core was chosen for radiocarbon dating because it marks the beginning of peat accumulation.

Pollen Stratigraphy

The Minamac Bog pollen diagram is divided into 3 pollen assemblage zones (see p. 51). The pollen percentage diagram for major taxa is shown in Fig. 15, and minor taxa
Figure 14. Minamac Bog: stratigraphy and loss-on-ignition
Whole pine is represented by the solid black curve, broken pine fragments are represented by the hatched curve.

Figure 15 Minamac Bog: stratigraphy, loss-on-ignition, and pollen percentage diagram of major taxa.
are shown in Fig. 16. In the pollen diagram of major taxa, whole pine is represented by the solid black curve, and broken pine fragments are represented by the hatched curve.

Zone 1 (*Pinus* pollen zone): 107-83 cm; ca. 7200 B.P. to 5500 B.P. This zone is dominated by trees with remarkably stable high percentages. *Pinus* dominates all taxa with consistently high percentages of at least 60%, with peak percentage of 65% at 87 cm. *Myrica*, *Quercus*, and *Liquidambar* are present at low percentages. Herbs are at their lowest percentages of the core, but Gramineae increases steadily from core bottom toward zone 2. Compositae is stable, with lower percentages than Gramineae. Total pollen concentration and influx is relatively low at 107 cm, the lowest sampling level, with ca. 275,000 grains/cc and 4,000 pollen grains/cm²/yr, respectively (Fig. 17). When comparing influx and concentration to percentage data, it appears that *Pinus* is not as noteworthy as indicated by the percentage diagram. One explanation is that when local pollen production is low, the regional taxa may be overrepresented in the percentage diagram (Birks and Birks 1980). This low local pollen production is further evidenced by relatively low influx rates. Total pollen influx ranges between 3,300 - 4,400 pollen grains/cm²/yr (Fig. 18). Total pollen concentration ranges between 222,000 - 298,000 pollen grains/cc, as shown by Fig. 19.

Zone 2 (*Pinus*-Gramineae pollen assemblage zone): 83-43 cm; ca. 5500-2800 B.P. This zone is characterized by an increase in herbs and the continued dominance by trees, despite lower percentages. *Myrica* and *Quercus* are stable, with percentages slightly lower than in zone 1. *Pinus* continues to dominate all taxa, although percentages decrease steadily as a result of the increase in herbs, especially Gramineae. The steady increase of Gramineae that begins in zone 1 peaks at 57 cm. This peak percentage (20%) and peak influx of Gramineae at 57 cm overshadow a simultaneous increase in *Pinus*. Compositae is relatively unchanged from zone 1; it is present with low percentages. Cyperaceae increases slightly in zone 2. *Sphagnum* begins to increase at 47 cm. Total pollen concentration and influx are approximately the same as in zone 1.
MINAMAC BOG
Pollen Percentage Diagram of Minor Taxa

Figure 16 Minamac Bog pollen percentage diagram of minor taxa
Figure 17 Minamac Bog total pollen concentration and accumulation rate (influx) diagram
Figure 18  Minamac Bog  pollen influx diagram
Figure 19. Minamac Bog: pollen concentration diagram
Zone 3 (*Pinus-Myrica-Sphagnum* pollen assemblage zone): 43-1 cm; ca. 2800-0 B.P. This zone is characterized by an increase in herbaceous pollen and a decrease in trees. Cyperaceae and *Sphagnum* are responsible for the increase in herbs. Cyperaceae peaks with 16% at 7 cm (ca. 470 B.P.); *Sphagnum* peaks with 12.7% at 37 cm (ca. 2500 B.P.). Compositae increases slightly and is relatively stable with a peak percentage of 8.7% at 17 cm. *Ambrosia* rise is evident at the core top. Although herbaceous taxa have greater percentages, trees continue to dominate as a result of *Pinus*, which has minimum percentages and influx values in zone 3. Also noteworthy is that zone 3 has both the peak and minimum in total pollen concentration and influx. Peak total pollen influx and concentration occur at 17 cm; minimum values occur at the 2 cm depth. This results in a broad range in total pollen influx and concentration; between 8,900 - 1,100 pollen grains/cm²/yr, and between 600,900 - 76,200 pollen grains/cc, respectively. The pattern for pollen concentration and influx are identical as a result of a single radiocarbon date (Fig 17 and Table 7). In the absence of multiple radiocarbon dates, a constant sedimentation rate is assumed. An age/depth graph is shown in Fig. 20.

**Charcoal**

Zone 1 has a low charcoal count but shows an increasing trend into zone 2 (Fig. 21). Linear charcoal is present only at 87 cm. Except for the 87 cm level, the charcoal is chunky in shape and ranges in size between 25-50 microns, suggesting that most of the charcoal was derived from forest fires. This charcoal count occurs in a zone of low total pollen concentration and influx and dominance by upland trees and shrubs. One observation is that zone 1 has the lowest pollen influx of herbaceous taxa and lowest linear charcoal count.

The charcoal count increases steadily in zone 2. Linear and chunk shaped charcoal is present at every level and in every size category. The most abundant charcoal is chunk shaped and 25-50 microns in size. A comparison of charcoal and total pollen
Table 7. Minamac Bog: inferred age, sedimentation rate, and deposition time

<table>
<thead>
<tr>
<th>cm level</th>
<th>Inferred Age (BP)</th>
<th>Sedimentation Rate (cm/100 yrs)</th>
<th>Deposition Time (yrs/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>135 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>7</td>
<td>470 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>17</td>
<td>1142 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>27</td>
<td>1814 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>37</td>
<td>2486 BP</td>
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<td>67.2 yrs</td>
</tr>
<tr>
<td>47</td>
<td>3157 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>57</td>
<td>3829 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>67</td>
<td>4501 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>77</td>
<td>5173 BP</td>
<td>1.5 cm</td>
<td>67.2 yrs</td>
</tr>
<tr>
<td>87</td>
<td>(5844 BP)</td>
<td>(1.5 cm)</td>
<td>(67.2 yrs)</td>
</tr>
<tr>
<td>97</td>
<td>(6516 BP)</td>
<td>(1.5 cm)</td>
<td>(67.2 yrs)</td>
</tr>
<tr>
<td>107</td>
<td>(7188 BP)</td>
<td>(1.5 cm)</td>
<td>(67.2 yrs)</td>
</tr>
</tbody>
</table>

80-90 cm C-14 dated to 5710± 70 BP
2-77 cm interpolation
(87-107 cm extrapolation)
Sedimentation rate is not constant.
Sweetbay Bog Core SBB
Minamac Bog

Figure 20. Sweetbay Bog SBB and Minamac Bog age/depth graph
MINAMAC BOG
Charcoal Abundance Index (size in microns)

Figure 21 Minamac Bog charcoal abundance index and total pollen concentration
concentration shows that, although charcoal increases, the total pollen concentration remains steady (Fig. 21).

Charcoal abundance decreases overall in zone 3. The peak count at 17 cm (1100 B.P.) may reflect a single local fire event. The 17 cm level is also the maximum for total pollen concentration and influx, which may be a result of increased erosion from this large fire event. Charcoal is dominated by chunk shaped in the size range of 25-50 microns. The overall decreasing abundance pattern in charcoal corresponds with a decrease in the influx and concentration of Pinus, the total pollen concentration, and total pollen influx. At the 7 cm depth, the charcoal count is equally represented by linear and chunk and all size ranges. The 2 cm level shows a continued decrease in charcoal, which is only slightly greater than the lowest count at 107 cm.

Sweetbay Bog: Core SBB

Sediment Stratigraphy

Core SBB measured 229 cm in length, as shown by the sediment stratigraphic diagram in Fig. 22. The overall trend is organic fibrous peat overlying a mineral soil consisting of sandy, silty clay loam and a sandy core bottom. The sandy base grades into sandy, silty clay at approximately 215 cm and continues to 165 cm, where a single wood macrofossil occurs. Peat deposition begins gradually at approximately 170 cm in the clay loam sediment. Macrofossil wood fragments are interspersed throughout the lower part of the core, most noticeably at approximately 130 cm and 100 cm. Macroscopic charcoal fragments are present at 185 cm and 205 cm. A single gravel is present near 220 cm. From 140 cm to the core top, the core consists of black organic fibrous peat.

Two sections of the core at 162-156 cm and 90-84 cm were radiocarbon dated to 6570± 100 B.P. and 4480±60 B.P., respectively. The sedimentation rate, from core bottom to top, ranges from 3.4 -1.9 cm/100 years (Table 8). An age/depth graph is shown by Fig. 20.
Figure 22. Sweetbay Bog: SBB stratigraphy and loss-on-ignition
Table 8  Sweetbay Bog  SBB inferred age, sedimentation rate, and deposition time

<table>
<thead>
<tr>
<th>cm level</th>
<th>Inferred age (BP)</th>
<th>Sedimentation Rate (cm/100 yrs)</th>
<th>Deposition Time (yrs/cm)</th>
</tr>
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<td>52 yrs</td>
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<td>10</td>
<td>515 BP</td>
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<td>52 yrs</td>
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<td>1030 BP</td>
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<td>52 yrs</td>
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<td>30</td>
<td>1545 BP</td>
<td>1.9 cm</td>
<td>52 yrs</td>
</tr>
<tr>
<td>40</td>
<td>2060 BP</td>
<td>1.9 cm</td>
<td>52 yrs</td>
</tr>
<tr>
<td>50</td>
<td>2575 BP</td>
<td>1.9 cm</td>
<td>52 yrs</td>
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<tr>
<td>60</td>
<td>3090 BP</td>
<td>1.9 cm</td>
<td>52 yrs</td>
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<td>70</td>
<td>3605 BP</td>
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<td>29 yrs</td>
</tr>
<tr>
<td>110</td>
<td>5148 BP</td>
<td>3.4 cm</td>
<td>29 yrs</td>
</tr>
<tr>
<td>123</td>
<td>5525 BP</td>
<td>3.4 cm</td>
<td>29 yrs</td>
</tr>
<tr>
<td>130</td>
<td>5728 BP</td>
<td>3.4 cm</td>
<td>29 yrs</td>
</tr>
<tr>
<td>145</td>
<td>6164 BP</td>
<td>3.4 cm</td>
<td>29 yrs</td>
</tr>
<tr>
<td>155</td>
<td>6454 BP</td>
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<td>29 yrs</td>
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<td>165</td>
<td>(6744 BP)</td>
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<td>(29 yrs)</td>
</tr>
<tr>
<td>175</td>
<td>(7034 BP)</td>
<td>(3.4 cm)</td>
<td>(29 yrs)</td>
</tr>
</tbody>
</table>

84-90 cm C-14 dated to 4480±60 BP
156-162 cm C-14 dated to 6570±100 BP
1-155 cm interpolation
(165-175 cm extrapolation)
Sedimentation rate is not constant.
Overall, both water and organic matter contents increase from the core bottom to core top. Water and organic matter contents are generally parallel throughout the core. There are low percentages for water and organic matter contents from the core bottom until both abruptly increase at approximately 140 cm (approximately 6000 B.P.). The percentages remain high, but fluctuate, to the core top. The maximum water content of 89% occurs at 2 cm, although it is not visible in the diagram because of the resolution. The maximum organic matter content of 65.7% occurs at 1 cm. Occasional spikes occur in the percentages as a result of wood macrofossils in the core. The carbonate content is low (2.4%).

**Pollen Stratigraphy**

Core SBB is divided into 3 pollen assemblage zones based on percentages. The zones range from 175 cm to 1 cm. The pollen percentage diagram for major taxa is shown by Fig. 23. The percentage diagram for minor taxa is shown by Fig. 24.

**Zone 1 (Pinus-Quercus-Nyssa pollen assemblage zone):** 175-95 cm, ca. 7000-4700 B.P. This zone is dominated by trees, which are relatively stable with percentages always greater than 64%. The important trees are *Pinus, Quercus,* and *Myrica* and *Nyssa.* *Pinus* is the dominant taxon. Although *Pinus* percentages are greater than 50%, pollen concentration (Fig. 25) and influx (Fig. 26) are low, reflecting low pollen production from local vegetation communities and overrepresentation of regional pollen (Birks and Birks 1980). *Gramineae* is the significant herb, with minor fluctuations throughout this zone. This zone is characterized by variable total pollen concentration and influx. At 175 cm, total pollen influx is approximately 2,800 grains/cm²/yr, and total pollen concentration is 81,000 grains/cc (Fig. 27). This low abundance of pollen occurs in a mineral soil with very low organic matter. The 130 cm level marks the lowest total concentration and influx of the core with ca. 47,100 grains/cc and ca.1,600 grains/cm²/yr, respectively. The low pollen concentration may be in part due to a high sedimentation rate caused by rapid accumulation of inorganic material washed into the depression, as well as the dominance of
Figure 23  Sweetbay Bog  SBB stratigraphy, loss-on-ignition, and pollen percentage diagram of major taxa

Whole pine is represented by the solid black curve; broken pine fragments are represented by the hatched curve.
Figure 24  Sweetbay Bog  SBB pollen percentage diagram of minor taxa

intervals of 5%. all at exaggeration of 5
Figure 25. Sweetbay Bog: SBB pollen concentration diagram
Figure 26  Sweetbay Bog  SBB pollen influx diagram
Figure 27. Sweetbay Bog SBB total pollen concentration and accumulation rate (influx) diagram
the regional pollen rain. A series of simultaneous increases and decreases in influx for a majority of the taxa result in only small percentage changes in zone 1. An increase such as this occurs at 123 cm. Again, these fluctuations may be a reflection of a variable sedimentation rate.

Zone 2 (Pinus-Compositae-Myrica-Gramineae pollen assemblage zone): 95-55 cm, ca. 4700-2800 B.P. Herbaceous taxa increase, represented by Compositae, but trees continue to dominate in spite of decreasing percentages. Pinus continues to be the most abundant taxa. Myrica peaks at 90 cm with 21%. Nyssa decreases to insignificant percentages. Compositae and Gramineae are the dominant herbs. Compositae peaks in zone 2 at 80 cm with 19%. This peak percentage for Compositae at 80 cm is supported by a simultaneous peak in influx. Total pollen concentration ranges from the maximum of ca. 510,100 to 272,800 grains/cc. The range for total pollen influx is less with ca. 7,400 to 10,600 grains/cm²/yr.

Zone 3 (Pinus-Cyperaceae-Compositae-Gramineae pollen assemblage zone): 55-1 cm, ca. 2800-0 B.P. This zone is characterized by an increase in herbs, dominated by Cyperaceae, and a decrease in trees, especially Pinus. Cyperaceae, Compositae, and Gramineae are the significant herbaceous taxa. Pinus continues to be the dominant taxon until 1 cm, where it decreases to its minimum percentage (17%), which is supported by the influx diagram. Quercus and Myrica continue to be present in zone 3 but with low percentages. Sphagnum makes a brief appearance at the transition between zones 2 and 3. The Ambrosia rise is evident at the core top (1 cm). The sample at 1 cm depth is important in several respects. Cyperaceae reaches peak percentages at 1 cm but actually decreases in influx. The influx diagram reveals a decrease in most taxa; small increases occur in Ulmus, Fraxinus, Ambrosia, and Brassicaceae. The percentage diagram shows that the increase in herbaceous pollen at 1 cm corresponds with the minimum influx and minimum percentage of Pinus. From 50 cm to the core top, the total pollen influx is low and decreases to the second lowest rate with 1,200 pollen grains/cm²/yr. Total pollen
concentration shows this decreasing pattern also. The low pollen concentration and influx at the 1 cm depth most likely reflect human disturbance, as indicated by the increase in *Ambrosia*.

**Charcoal**

Microscopic charcoal is present at all levels sampled in zone 1 (Fig. 28). The lithology diagram shows that macroscopic charcoal was found at 205 cm and 185 cm. Neither pollen nor microscopic charcoal was sampled at these levels because of the high sand concentration. A comparison of charcoal to total pollen concentration shows a positive relationship, with total pollen concentration at 130 cm, 123 cm, and 110 cm. The lowest total charcoal, pollen influx, and pollen concentration occur at 130 cm. Charcoal increases at 123 cm, the location of peak pollen influx and concentration. Charcoal, pollen influx, and pollen concentration decrease at 110 cm. There is no apparent relationship with the organic matter content. This supports the contention that charcoal is dispersed by the same mechanisms as is pollen (Mehringer et al 1997).

Charcoal is most abundant in zone 2. The greatest count occurs at 70 cm (ca. 3600 B.P.) and consists of both linear and chunk charcoal. The increase in charcoal for zone 2 corresponds with an increase in total pollen concentration and influx. Although chunk-shaped charcoal dominates, linear increases, as does herbaceous pollen. Charcoal is present in all size categories, but the smaller sizes dominate.

Charcoal decreases in zone 3, as does total pollen influx and concentration, reaching minimum values. This low charcoal count corresponds with the minimum influx and concentration for *Pinus*. The linear charcoal count does not reflect the increase in herbaceous vegetation for zone 3.

**Sweetbay Bog: Core SBA**

**Sediment Stratigraphy**

Core SBA measured 218 cm in length. The sediment stratigraphic diagram is shown in Fig. 29. The overall trend is organic fibrous peat from the core top to
Figure 28  Sweetbay Bog: SBB charcoal abundance index and total pollen concentration.
Figure 29. Sweetbay Bog: SBA stratigraphy and loss-on-ignition
approximately 125 cm, followed by a mineral sandy loam and clay loam at the core bottom. The upper 125 cm is black peat consisting of many roots, some stems and occasional wood macrofossils. Below 125 cm the peat becomes silty. At approximately 130 cm, the peat becomes sandy, and the color changes from black to dark grayish-brown. The organic peat ends with a sand layer at 133-138 cm followed by sand with roots and stems. Another sand layer occurs at 155-157 cm. The sand content increases toward the core bottom. From approximately 193 cm to the core bottom, mottled clay is mixed with the sand and stem macrofossils, indicating alternating reducing and oxidizing conditions. A small piece of gravel was found at 205 cm.

The loss-on-ignition diagram is shown in Fig. 29. The overall trend is an increase in water and organic matter contents from core bottom to top. An abrupt increase occurs in both water and organic matter contents at 125 cm; water content doubles to 59%, and organic matter content increases from 3% to 16%. The water content continues to increase and reaches maximum percentages of 91% near the core top (2 cm). The maximum organic matter content is 73% at 83 cm and 5 cm. The carbonate content is low (2%).

**Pollen Stratigraphy**

Core SBA is divided into two pollen assemblage zones based on percentages. The pollen percentage diagram for major taxa is shown in Fig. 30. Minor taxa are shown in Fig. 31. Because SBA was not radiocarbon dated, no dates are available and pollen influx rates could not be calculated.

**Zone 1** (*Pinus-Quercus-Myrica-Nyssa* pollen assemblage zone): 140-75 cm. Trees dominate with high percentages. The most important trees are *Pinus*, *Quercus*, *Myrica* and *Nyssa*, with *Pinus* as the most frequent taxon. A comparison between the percentage diagram and the concentration diagram (Fig. 32) reveals that, for *Pinus*, highest percentages and lowest concentrations occur in zone 1, but lowest percentages and highest concentrations occur in zone 2. This inverse relationship between pollen percentages and concentrations also exists for *Myrica* and, to a lesser degree, for *Quercus*. Gramineae is
Whole pine is represented by the solid black curve; broken pine fragments are represented by the hatched curve.

Figure 30  Sweetbay Bog  SBA stratigraphy, loss-on-ignition, and pollen percentage diagram of major taxa.
Figure 31  Sweetbay Bog  SBA pollen percentage diagram of minor taxa
Figure 32. Sweetbay Bog SBA pollen concentration diagram
the only herbaceous taxon present with noteworthy percentages. The 140 cm level marks the lowest total pollen concentration of the core with ca. 85,100 grains/cc. This low pollen concentration may reflect a high sedimentation rate or the dominance of regional pollen rain.

Zone 2 (Pinus-Cyperaceae-Compositae-Gramineae pollen assemblage zone): 75-1 cm. This zone is characterized by an increase in herbaceous taxa, although trees continue to dominate in spite of decreasing percentages. Pinus decreases to a minimum of 38% at the 1 cm level, which is also reflected in the concentration. Myrica and Quercus are present but with slightly lower percentages than in zone 1; Nyssa is insignificant. Gramineae continues to be present but is joined by Cyperaceae and Compositae. Sphagnum is present but with low percentages. The Ambrosia rise is evident near the core top (1 cm). Total pollen concentration peaks at 50 cm and subsequently drops to the second lowest level of the core at 1 cm, approximately 753,000 and 112,400 grains/cc, respectively. The peak in total concentration most likely represents the expansion of the bog surface with a corresponding increase in wetland vegetation and the local pollen rain. Pinus, generally considered a regional component of the pollen rain, peaks dramatically at 50 cm. Pinus may also reflect a local component as a result of its presence on the hillside slopes around Sweetbay. The decrease in total pollen concentration at 1 cm may reflect human disturbance, as suggested by the Ambrosia rise.

**Sweetbay Bog: Surface Samples**

Five Sphagnum moss polster surface samples were taken from Sweetbay Bog. Two samples were taken near core SBB (sb1 and sb2), and three were taken near core SBA (sba1, sba2, sba4). The approximate location of the samples in relation to the core locations is shown by Fig. 13. At the time the samples were taken, sample sba1 was in close proximity to flowing water.

Trees are the dominant vegetation group in the surface samples. Pinus is the most frequent taxon and ranges between 50% and 60% in all surface samples. There is
generally little variability between the 5 surface samples. The variability that does occur is with Myrica, Compositae, and Cyperaceae. This variability reflects different vegetation communities among the five surface sample sites. Ambrosia is present in all surface samples as well as in the core top samples. It is interesting to note that although the surface samples are derived from Sphagnum moss polsters, there are few Sphagnum spores present. This implies that Sphagnum spores have low and probably erratic representation.

The percentage diagram of the five moss polsters (Fig. 33) reveals that the modern pollen assemblage is similar to the fossil pollen assemblage of both cores SBB and SBA. The same taxa that are important in the fossil pollen assemblage are present and significant in the surface samples. Pinus is the dominant taxon in the moss polsters, as it is for the fossil assemblages. The slightly higher percentages for Pinus in the surface samples compared to the core-top samples in SBB and SBA may reflect the replantings of pine by the Civilian Conservation Corps (CCC) in 1936-37 and the lumber industry. Myrica, Quercus, Gramineae, Compositae, and Cyperaceae are dominant in the surface samples as well as in cores SBB and SBA.

**Comparison Between SBB and SBA**

The only significant difference between SBB and SBA is that in SBA, Cyperaceae increases at the same time as Compositae; whereas in SBB, the Cyperaceae rise occurs somewhat later (Fig. 34). Therefore SBA consists of two zones and SBB of three zones. The difference may be attributed to different local vegetation communities between the two sites. These site-specific local variations in vegetation communities are even reflected in the modern pollen data today. Among the moss surface samples, Cyperaceae pollen percentages vary between 3% to 16%, and Compositae pollen percentages vary between 2% to 23%. The lower percentages of Cyperaceae in SBB zone 2 and the co-dominance of these two taxa throughout SBA zone 2 (hence the absence of two zones here) may simply
Figure 33  Sweetbay Bog  pollen percentage diagram of moss polster surface samples
<table>
<thead>
<tr>
<th>DEPTH cm</th>
<th>SWEETBAY BOG SBB</th>
<th>SWEETBAY BOG SBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>ZONE 3 (2833 BP)</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td>ZONE 2 (3606 BP)</td>
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<tr>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>peat accumulation (6000 BP)</td>
<td></td>
</tr>
<tr>
<td>175</td>
<td>ZONE 1 (7034 BP)</td>
<td></td>
</tr>
</tbody>
</table>

- *Pinus-Cyperaceae-Compositae-Gramineae*
- *Pinus-Compositae-Myrica-Gramineae*
- *Pinus-Quercus-Myrica-Nyssa* peat accumulation
- *Pinus-Quercus-Nyssa*

Figure 34. Sweetbay Bog. SBA and SBB stratigraphic and pollen comparison
reflect such local variations in wetland vegetation communities occurring in Sweetbay Bog 4700-2800 years ago.
Minamac Bog

Zone 1: 7200-5500 B.P. - *Pinus* pollen zone. Zone 1 encompasses the early and pre-peat accumulation stage of Minamac Bog, which was a time of low, but increasing, fire frequency. Minamac Bog most likely developed in a stream flood plain or abandoned stream meander with *Nyssa* and *Myrica* present along the stream bank. *Pinus* was the dominant upland vegetation at 7200 B.P., with Gramineae, Compositae, Umbelliferae and Cyperaceae present locally. This assemblage indicates the presence of the pine association of the Southern Mixed Hardwood forest.

The sedimentation rate was relatively high from the inflow of inorganic material into the low area. Local vegetation was sparse, based on the low pollen influx values. Most of the pollen were derived from regional and extra-local sources.

A change in hydrology occurred around 6000 B.P. resulting in waterlogging of the sandy sediment and initiation of peat accumulation. This hydrologic change may have resulted from a regional rise in the water table cause by the postglacial sea level rise, which stabilized at about the modern level approximately 6000 years ago (Pirazzoli 1991). Paleoecological studies in Florida suggest that the modern vegetation was established between 7000 B.P. and 5000 B.P. as a result of rising sea levels causing water tables to rise (Watts and Hansen 1988, Watts et al 1992). The absence of aquatic pollen indicates that it is likely that Minamac Bog developed gradually by paludification in a low area with a high water table (Heathwaite et al 1993). Minamac Bog and Hershop Bog of Central Texas are similar in that both developed by paludification in a stream meander; however, the mechanism initiating paludification is different at both sites. Minamac Bog developed as a result of climatic change affecting sea level rise and water table levels, whereas Hershop Bog developed as a result of a geomorphic change due to natural disturbance.
Zone 2: 5500-2800 B.P. - *Pinus*-Gramineae pollen assemblage zone. The cycle of peat accumulation and increased wetness continued at a steady pace. Cyperaceae increased slightly as sedges gradually moved into the site as it increased in wetness and size. Gramineae and Umbelliferae increased to their greatest abundance. *Pinus* continued to dominate the upland slopes. These characteristics suggest the development of a backswamp slough dominated by grassy riverine vegetation.

A gradual but steady increase occurred in fire frequency and intensity. This is likely due to a change toward a drier, warmer climate that promoted fire occurrence. A drier and warmer climate was suggested by Whitehead and Sheehan (1985) from 7300 B.P. to 2400 B.P. and Delcourt (1980) from 12,500 B.P. to 5000 B.P. An alternative explanation is that the increase in fire frequency was a result of prehistoric anthropogenic fires. This possibility is based on the presence of maize pollen at Lake Shelby, Alabama, dating to 3500 B.P. (Feam and Liu 1995) and at B. L. Bigbee in northeast Mississippi dating to 2400 B.P. (Whitehead and Sheehan 1985).

Zone 3: 2800-0 B.P. - *Pinus*-Myrica-Sphagnum pollen assemblage assemblage zone. Zone 3 documents the formation of Minamac Bog and the effects of human disturbance. A *Sphagnum* bog formed at 2800 B.P. The site became less minerotrophic and developed into a more acidic *Sphagnum* bog. *Sphagnum*, Cyperaceae, and *Myrica* increased dramatically. This further rise in the water table may have generated hillside seeps, which have maintained the bog since 2800 B.P. This bog formation implies a change to cooler and wetter conditions and a rise in the water table. A climatic change near this time period has also been suggested by Whitehead and Sheehan (1985), Watts and Hansen (1988), and Liu and Fearn (1993). Based on the pollen concentration of *Sphagnum* and *Myrica*, this was a rather abrupt change. The increase in pollen concentration and influx at this same time period reflects the predominance of pollen input from local vegetation communities growing at the coring site.
Fire frequency also decreased, which supports the scenario of a cooler and wetter climate. The charcoal peak at 1000 B.P. most likely reflects a single large fire event.

The *Ambrosia* rise at the 2 cm depth reflects the settlement horizon and increased human disturbance during the last two centuries. This increase in *Ambrosia* is an indication of large-scale human disturbance activities of clearing land for habitation and farming, stock grazing, and logging (McAndrews 1988). *Pinus* decreases at the same time that *Ambrosia* increases, lending support to the indication of increased human disturbance of land clearance for settlements or farming and logging of forests.

The *Ambrosia* rise is seen in pollen diagrams of other sites in the southeastern Gulf Coastal Plain. Whitehead and Sheehan (1985) suggest that the *Ambrosia* rise at B. L. Bigbee Swamp, Mississippi, indicates European land clearance dating to 150 B.P. Delcourt (1980) implies that the *Ambrosia* rise reflected at Goshen Springs, Alabama, suggests land clearance beginning about 200 B.P.

**Sweetbay Bog: Core SBB**

**Zone 1: 7000-4700 B.P. - Pinus-Quercus-Nyssa pollen assemblage zone.**

Peat accumulation begins rather abruptly about mid-way in zone 1, ca. 6000 B.P., in a depression in an upland interfluv surrounded by sandy loam and silt loam hills. Small streams flowed gently through the area. A bottomland hardwood forest was present, surrounded by a *Pinus-Quercus* forest on the uplands. Water oaks and upland oaks were present. *Myrica* occurred along the stream banks, as well as in riparian marshes. Grasses occurred in disturbance areas and along the forest edge. As with Minamac, the vegetation was the pine association of the Southern Mixed Hardwoods. Fire frequency was low during this time.

Sweetbay Bog developed as the sandy, silty clay became waterlogged as a result of a change in hydrology. The timing of the peat development at Sweetbay Bog coincides with the timing of the peat accumulation at Minamac Bog, which further suggests a regional rise in the water table brought about by sea level rise (Pirazzoli 1991).
A minimal increase in organic matter occurred earlier at 6600 B.P., overlying a wood macrofossil in the sandy, silty clay sediments. This increase in organic matter content is probably a result of a regional rise in the water table. The macrofossil may represent a tree carried into the depression by a hillside slump resulting from heavy rainfall, or it may have fallen in place. Depending on the size of the tree and location, the hydrology may have been altered. Water flow from springs or nearby streams may have been blocked, causing ponding and contributing to waterlogged soil.

The sedimentation rate was relatively high, with inorganic material and minimal organic matter, evidenced by small wood macrofossils, carried into the depression. Because of the high sand content, any water flowing as a result of sheetwash or a hillside seep would have drained quickly through the sand.

**Zone 2: 4700-2800 B.P.** - *Pinus-Compositae-Myrica-Gramineae pollen assemblage zone*. Peat accumulation continued with some fluctuation. *Pinus* continued to dominate the uplands, but herbaceous vegetation increased locally, represented by Compositae and Gramineae. The increase in Compositae and Gramineae together with the increased peat accumulation confirms the presence of wetland species. *Myrica* and *Alnus* were present. All these components suggest the gradual development of a fen environment dominated by wetland forbs and grasses.

A lower organic content suggests that the fen may have dried periodically. Fire frequency was highest during this time period, also suggesting a dry climate with plenty of dry ground litter. These traits indicate a warmer and drier climate. This same trend is present at Minamac Bog and other coastal plain studies (Whitehead and Sheehan 1985, Watts and Hansen 1988, and Delcourt 1980). There is no evidence that *Pinus* increased with increased fire frequency; *Pinus* actually decreased slightly.

**Zone 3: 2800-0 B.P.** *Pinus-Cyperaceae-Compositae pollen assemblage zone*. Sweetbay Bog developed into a fen dominated by sedges at 2800 B.P. A distinct increase in Cyperaceae occurred, implying a hydrologic change and subsequent rise in the water
table. This rise in the water table may have created a spring or seep that increased the rate and areal extent of paludification in the depression. Because Minamac Bog developed into a Sphagnum bog at this same time period, these events imply a cooler and wetter environment, conditions conducive to faster peat accumulation. Watts and Hansen (1988), Whitehead and Sheehan (1985), and Liu and Feam (1993) also suggest a climatic change at this approximate time period. Sphagnum was present but less so than Cyperaceae. Intermittent streams and hillside seeps brought nutrients into the system, creating a minerotrophic fen rather than a Sphagnum bog. It is possible that Sphagnum was more abundant than indicated due to its apparent underrepresentation evidenced by the moss polster surface samples, but sedges were undoubtedly abundant. Fire frequency was low, with a decreasing trend. This decrease in fire frequency also supports a cooler and wetter climate. Except for the most recent invasion of woody vegetation as a result of fire suppression, Sweetbay Bog appeared as it does today.

Human disturbance is most evident from 500 B.P. to present. The presence of the Ambrosia rise and a decrease in Pinus imply increased disturbance by clearing. The decrease in Pinus was due to clearing for farming and settlement, but was also a result of the logging activities in the area. There was a decrease in fire frequency as a result of fire suppression.

Comparison Between Sites and Synthesis of Regional Environmental Change

A comparison between the pollen, charcoal, and sediment stratigraphic data of Minamac Bog and Sweetbay Bog strongly suggests regional environmental changes as causal factors for peat initiation and wetland development. Peat accumulation began at both Minamac Bog and Sweetbay Bog during the mid-Holocene at approximately 6000 B.P. (Fig. 35). The concurrent initiation of peat at both sites at 6000 B.P. reflects a regional event controlled by sea level rise. Synchronous wetland development occurred during the late Holocene at approximately 2800 B.P. as Minamac Bog developed into a Sphagnum bog and Sweetbay Bog developed into a sedge-dominated fen. Differences in local factors
Figure 35. Environmental reconstruction for Sweetbay Bog and Minamac Bog showing synchronous peat accumulation at 6000 B.P. and wetland development at 2800 B.P.
determined the nutrient status of the environment and the resulting wetland type. This synchronous wetland development implies a regional climatic change to a somewhat cooler, more humid environment, which altered the regional and local hydrology.

Aside from the regional influence, the differences in the local topography of the two sites contributed to variabilities in peat accumulation, deposition of inorganic matter, pollen concentration, and pollen influx rates. The data suggest that Sweetbay Bog was affected by more perturbations than Minamac Bog. Minamac Bog had small-scale gradual changes in peat accumulation, pollen concentration, and influx rates, as evidenced by smooth curves. Based on a single C-14 date for Minamac, the assumed constant sedimentation rate is 1.5 cm/100 years. Sweetbay Bog, by comparison, had a greater number of, and larger scale, fluctuations in these same variables. Based on two C-14 dates, the sedimentation rate was greater in zone 1 (3.4 cm/100 yrs) and decreased upwards to 1.9 cm/100 yrs. The most dominant factor was most likely the steep, sandy slopes surrounding Sweetbay Bog and the unstable environment they provided.
CHAPTER 7
CONCLUSION

Synchronous peat accumulation began at Minamac Bog and Sweetbay Bog at 6000 B.P. This reflects a regional rise in the water table caused by the postglacial sea level rise, which stabilized at the modern level about 6000 years ago (Pirazzoli 1991). Previous paleoecological studies in the Gulf Coastal Plain suggest that a rise in the water table as a result of sea level rise coincided with the appearance of the modern climatic regime and modern vegetation (Watts and Hansen 1988; Watts et al 1992). Both Minamac Bog and Sweetbay Bog developed by paludification of low-lying areas with high water tables. This supports the position of Heathwaite and Gottlich (1993) that peatlands in the humid Gulf Coastal Plain developed by paludification in areas of low-energy water flow. Minamac Bog most likely developed in a stream floodplain or an abandoned stream meander that became waterlogged as a result of a rise in the water table. This waterlogged environment was conducive to peat accumulation because of slow decomposition rates. Hydric vegetation colonized the site, eventually becoming incorporated into the peat. As the peat accumulation continued and the organic matter content increased, herbaceous vegetation was eventually favored over trees, enabling the water table to remain high. Sweetbay Bog developed gradually as a result of a rise in the water table inducing paludification in an upland depression.

The paleoecological records of Minamac Bog and Sweetbay Bog document that pines were the dominant upland vegetation as early as 7000 B.P. and possibly earlier. The pine rise is significant because it is normally associated with the onset of the modern climatic regime. This 7000 B.P. date, which marks the beginning of the pollen records in this study, compares to 8400 B.P. at Cahaba Pond, Alabama (Delcourt et al 1983), 7760 B.P. at Camel Lake, Florida (Watts et al 1992), and 5000 B.P. at Lake Louise and Lake Annie, Florida (Watts and Hansen 1988). Local or extra-local pollen from wetland communities are the main pollen sources at Minamac Bog and Sweetbay Bog because of...
the small size of the study sites. *Pinus* is present, however, as a regional and local component. The pollen records from Minamac Bog and Sweetbay Bog mainly document more local vegetation changes due to wetland development after 7000 B.P. *Pinus* pollen actually decreased slightly in percentages after 6000 B.P. at these two sites. This decrease is due in part to the increased dominance of local pollen at the establishment of the modern vegetation and climate.

Minamac Bog and Sweetbay Bog show a time period drier and warmer than present from approximately 6000 B.P. to 2800 B.P., after which the climate became cooler and more humid. This drier and warmer period is supported by a greater fire frequency prior to the establishment of the modern climate at 2800 B.P. A lower organic content at Sweetbay Bog during 4700-2800 B.P. suggests surface fires or periodic drying of the bog. This dry and warm period from approximately 6000-2800 B.P. coincides with the timing of the Hypsithermal, a warm and summer-dry period that occurred during the mid-Holocene (Delcourt and Delcourt 1985). The timing of this regime at Minamac Bog and Sweetbay Bog agrees with the dry period from 7300 B.P. to 2400 B.P. at Columbus, Mississippi (Whitehead and Sheehan 1985). The pollen record from Goshen Springs, Alabama, suggests a dry and warm period from 12,500 B.P. to 5000 B.P. at Goshen Springs, Alabama (Delcourt 1980). Watts and Hansen (1988) noted a drier period, dominated by oaks and prairie plants, from 8500 B.P., the core basal date, to approximately 5000 B.P. at Lake Louise and Lake Annie, Florida. The paleoecological records of Minamac Bog and Sweetbay Bog suggest the presence of the warm and dry Hypsithermal from approximately 6000 B.P. to 2800 B.P. However, because the stratigraphies for both Minamac Bog and Sweetbay Bog do not extend into the early Holocene, it is not possible to determine if an oak-dominated community, indicating a drier climate than noted from 6000 B.P. to 2800 B.P., was present at these sites prior to 6500 B.P. Therefore, the data are inconclusive regarding the presence of the Hypsithermal.
The modern vegetation and climate became established at approximately 2800 B.P., with the establishment of a *Sphagnum* bog at Minamac Bog and a sedge-dominated fen at Sweetbay Bog. Both Minamac Bog and Sweetbay Bog were maintained by hillside seeps, naturally occurring fires, a high water table, and acidic nutrient-poor soil. This study supports a regional climatic change to a cooler and more humid environment at 2800 B.P., resulting in a decrease in evapotranspiration, a rise in the water table, and the development of conditions favorable to increased peat accumulation and wetland vegetation. There was also a corresponding decrease in fire frequency, which is consistent with a cooler, more humid climate. This regional climatic change supports minor climatic cooling during the late Holocene as described by Delcourt and Delcourt (1985). This 2800 B.P. time period generally agrees with the wetland expansion at 2500 B.P. at Lake Louise and Lake Annie, Florida (Watts and Hansen 1988), and broadly coincides with the 3500 B.P. date proposed by Whitehead and Sheehan (1985) for the establishment of the modern vegetation, and the 3200 B.P. date proposed by Liu and Fearn (1993) for an abrupt environmental change for this region.

The data from this study suggest a regional climatic change at 2800 B.P. rather than 3200 B.P. This 400 year difference may simply reflect the margin of error due to the coarse sampling resolution and dating control in this study. It is also generally assumed that vegetation responds to climatic change by a time lag from change to response. Because herbaceous vegetation was favored over arboreal species by the local topography, the response would have been more immediate.

There is no evidence of the Little Ice Age in the data associated with Minamac Bog and Sweetbay Bog. This is not surprising, as the 10 cm sampling resolution is too coarse to denote a change within such a small time scale.

The presence of the *Ambrosia* rise at the top of the pollen diagrams for both Minamac Bog and Sweetbay Bog is a distinct indicator of European settlement at these sites. Fire suppression is evidenced by the decrease in charcoal. As expected, a decrease
in *Pinus* is observed at the top of the pollen diagrams reflecting logging activities and land clearance for settlement and farming.

No definitive evidence was found for prehistoric settlement at Minamac Bog or Sweetbay Bog. There is, however, evidence documenting prehistoric settlement and agriculture at 3500 B.P. near Minamac Bog. In coastal Alabama at a location approximately 32 km south of Minamac Bog, prehistoric settlement dating to 3500 B.P. has recently been documented by the presence of *Zea* pollen in lake sediments (Feam and Liu 1995). Although there are many archaeological sites in this general area, the Lake Shelby site is the only one to definitely date to 3500 B.P. (Feam and Liu 1995). The discovery of *Zea* pollen provides direct evidence of prehistoric settlement and agriculture at 3500 B.P. in the area near Minamac Bog. There is evidence of prehistoric settlement in northeast Mississippi dating to 2400 B.P. with the discovery of *Zea* pollen (Whitehead and Sheehan 1985); however, as of this time, there is no definitive evidence for prehistoric settlement in southern Mississippi in the area around Sweetbay Bog.

In summary, the paleoecological records of Minamac Bog and Sweetbay Bog document that *Pinus* was the dominant upland vegetation as early as 7000 B.P. and possibly earlier. Synchronous peat initiation occurred at both sites at 6000 B.P., indicating a regional rise in the water table caused by the postglacial sea level rise, which stabilized at the modern level at this time. The modern vegetation and climate became established at approximately 2800 B.P. with the establishment of a Sphagnum bog at Minamac Bog and a sedge-dominated fen at Sweetbay Bog. This synchronous wetland development suggests a regional climatic change to a cooler and more humid environment at 2800 B.P. Human disturbance was evidenced by the Ambrosia rise at both sites after 500 B.P., indicating European settlement, and by the decrease in *Pinus*, reflecting logging activities and land clearance for settlement and farming.

This thesis provides paleoecological data that are important in gaining a better understanding of the effects of climate and human disturbance on vegetation in the Gulf
Coastal Plain, and fills a gap in the pollen record by providing data on southern Mississippi. It contributes additional data to be considered in view of the present discrepancies in the chronology of the appearance of the modern climatic regime and vegetation, the pine rise, and the timing of the Hypsithermal. This paper provides long-term data on southern bog communities, for which little information exists.

The most important findings of this study are the synchronous peat initiation at 6000 B.P. and wetland development at 2800 B.P. at Minamac Bog and Sweetbay Bog. The chronology would be more precise, however, if more C-14 dates were available for both sites, especially at each zonation boundary, and for all three cores. Additional radiocarbon dating is especially important to strengthen the reconstruction of the appearance of the modern vegetation and climate at 2800 B.P. Another recommendation would be to sample at closer intervals for pollen analysis. Although 10 cm intervals are often used, closer intervals would provide better resolution of vegetation changes and charcoal counts to document the fire history.

Future studies should be conducted on other southern bogs in the Gulf Coastal Plain. Few data exist on these ecologically interesting environments. This study illustrates that these communities are important sources of information on climate and human disturbance in the Gulf Coastal Plain of the southeastern United States.
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VITA

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Title of Thesis: A Palynological Study of Two Upland Bogs in the Gulf Coastal Plain, Alabama and Mississippi

Date of Examination: December 11, 1997