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I am submitting herewith a thesis written by Alisa Lynn Hass entitled “Fire History of Gum Swamp and Black Pond in Eastern Tennessee, U.S.A., from Macroscopic Sedimentary Charcoal.” I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

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Fire History of Gum Swamp and Black Pond in Eastern Tennessee, U.S.A.,
from Macroscopic Sedimentary Charcoal

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ABSTRACT

Eastern Tennessee and Great Smoky Mountains National Park are biological hotspots in which settlement by Native Americans and Euro-Americans dramatically changed the landscape through land clearance and changes in fire occurrence. I present two local fire histories using macroscopic sedimentary charcoal, one from a highly managed area and one from private agricultural land. Gum Swamp (35°35' N 83°50' W) is a pond located in Cades Cove, Great Smoky Mountains National Park that experiences seasonal drying. The 0.94 m sediment profile extends to about 425 cal yr BP, based on an AMS radiocarbon date on charcoal fragments at mid-depth in the profile. Black Pond (35°37' N 84°11' W) is a spring-fed sinkhole surrounded by agricultural fields. The 2.88 m sediment profile is expected to extend to about 3000 yr BP based on comparison with a sediment core previously recovered and analyzed for pollen and microscopic charcoal by Patricia Cridlebaugh in her Ph.D. dissertation research at the University of Tennessee. AMS radiocarbon dates for the new profile are pending.

The macroscopic charcoal record of Gum Swamp shows an increase in charcoal concentrations between the early 1800s and the 1950s associated with Euro-American land clearance and settlement. A decrease in charcoal concentration from the 1950s to the present likely signals fire suppression in Great Smoky Mountains National Park. This record is correlated with an earlier microscopic charcoal record completed by Jean Davidson in her M.S. thesis research at the University of Tennessee. Both records show similar trends in charcoal concentrations, but Davidson's chronology, which is based on

radiocarbon dating of bulk sediment, differs from the chronology presented here. My results suggest that the Gum Swamp record spans less time than Davidson proposed.

The macroscopic charcoal record from Black Pond shows high charcoal concentrations during an interval tentatively correlated with indigenous occupation, based on Cridlebaugh's chronology. Moderate charcoal concentrations characterize the period of subsequent Euro-American settlement, followed by low concentrations in recent times. The similar trends in macroscopic and microscopic charcoal at Black Pond and Gum Swamp suggest that the microscopic charcoal previously investigated may largely signal local fires in these small watersheds.

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CHAPTER 1

Introduction

The fire history of a region can be reconstructed from historical records (Abrams and Nowacki 1992) and from proxy evidence including fire scars dated using dendrochronology (Abrams et al. 1995); shifts in pollen data (Delcourt et al. 1986, Whitlock and Larson 2001); and sedimentary and soil charcoal. Approaches to studying charcoal in lacustrine sediments and soils include using “thin-section” methods (Clark et al. 1996) on core samples, studying microscopic charcoal on pollen slides (Gajewski et al. 1985, Clark and Royall 1995, Delcourt and Delcourt 1997, Delcourt et al. 1998), and sieving sediments or soils to extract and quantify macroscopic charcoal (Whitlock and Millspaugh 1996, Turrill-Welch 1999, Gardner and Whitlock 2001, Millspaugh et al. 2000, Long and Whitlock 2002, Lynch and Clark 2002, Whitlock and Bartlein 2004, Hart et al. 2008). Fire history studies often use two or more methods to study the links between different proxies for past fires and to determine past fire regimes as well as influential factors (Clark 1990, Clark and Royall 1995, Kirwan and Shugart 2000, Carcaillet et al. 2001a, Gavin 2003, Asselin and Payette 2005, Higuera et al. 2005).

Each method has its merits and detriments. Dendrochronology allows for precise dating of fires but is limited by the age span of living trees and remnant wood that preserves evidence of past fires. Microscopic charcoal can be counted on slides prepared for pollen but can include a large regional signal of charcoal that can interfere with the local fire signal and cause issues with the interpretation of which fire events are local and

which are regional. Macroscopic charcoal can be easily processed and provides a more certain local signal of fire, but is not present at every site.

Sedimentary charcoal is an important proxy in fire history reconstruction, especially over longer periods and in areas that lack trees that form annual rings. Charcoal is a black, porous material, mainly carbon, that is produced when fire does not fully combust organic matter (Whitlock and Larsen 2001). During a fire event, charcoal is deposited into a lake or pond through initial fallout or slopewash. After a fire event, charcoal is deposited through secondary deposition processes, involving incoming streams, delayed settling through the water column, or bioturbation (Whitlock and Larsen 2001). Researchers analyze sediment cores from lakes or wetlands to examine the charcoal that has settled into the sediments and interpret fire events based on charcoal concentrations (fragments/cm³) or charcoal influx (fragments/cm²/year). Charcoal influx, the terminology I use in this study, is sometimes called the charcoal accumulation rate or CHAR.

Researchers who study past fire from charcoal base their interpretations of source area on the sizes of charcoal fragments. Microscopic charcoal fragments less than 125 µm in maximum dimension are common in sediment samples prepared for pollen analysis and are often counted along with pollen grains to produce a generalized fire history for a region (Gardner and Whitlock 2001). Traditionally, microscopic or “pollen slide” charcoal was considered to indicate a regional input of charcoal as the small size of microscopic charcoal allows for long distance transport (Clark and Royall 1995, Long et al. 1998, Whitlock 2001). More recent studies have shown that microscopic charcoal

records can reflect local as well as regional fires (Delcourt and Delcourt 1997, Delcourt et al. 1998, Anchukaitis and Horn 2005). However, these records can exclude much information, as pollen slides are typically prepared from sediment samples spaced at intervals along a core that are separated in time by many decades or centuries, depending on the sedimentation rate at the study site (Clark and Royall 1995, Carcaillet et al. 2001b, Whitlock 2001).

Macroscopic charcoal ($\geq 125 \mu\text{m}$) in sediment cores, in contrast, is most commonly sampled from contiguous intervals, producing a more detailed record. Sediment samples for macroscopic charcoal analysis are prepared by disaggregation and sieving of sediments and quantified using a stereomicroscope. The records provided by this type of analysis are considered to show a local input of charcoal with minor inputs from regional sources (Long et al. 1998). Different size sieves separate fragments small enough to be derived from regional sources from the larger fragments that tend to be of local origin because of their low capacity for transport (Long et al. 1998). While guidelines have not been set, macroscopic charcoal fragments over $100 \mu\text{m}$ in maximum dimension are generally thought to primarily reflect fires within the watershed of a lake (Long et al. 1998, Millspaugh et al. 2000, Whitlock and Larsen 2001).

Site selection is also an important aspect of paleoecological research and can affect the outcome of studies of sedimentary charcoal (Jackson and Bradshaw 1981). Medium-sized lakes with no incoming streams typically allow for a local input of charcoal (Whitlock and Larsen 2001). Incoming streams can carry charcoal from other areas within the watershed, possibly indicating a fire that occurred at some distance from

the lake. After a fire event, steep slopes on the lake edges can produce a secondary input of charcoal through slope wash or mass wasting. This can be problematic in paleoecological studies because it may cause a sudden input of charcoal that is not actually associated with a fire event at that time. Bioturbation in sediment is also important as mixing can result in inaccurate records. Deep lakes are often considered useful for avoiding bioturbation as deep water is calmer than shallow water and may be anoxic at depth, reducing populations of organisms that can cause sediment mixing (Jackson and Bradshaw 1981).

In many areas, including the southern Appalachians, deep natural lakes of medium size are rare or absent. Swamps, small hollows, smaller lakes, and ponds are commonly used for paleoecological and paleofire studies in this area (Delcourt and Delcourt 1998, Kneller and Peteet 1999, Lynch and Clark 2002). These smaller sites are typically considered to be accurate for pollen reconstruction because vegetation provides pollen from a small source area around the site, increasing the probability that pollen that is representative of local vegetation will be incorporated into the sediments (Jackson and Bradshaw 1981). Charcoal profiles from swamps are good indicators of fire because of a lack of incoming streams that transport charcoal from the entire watershed (Whitlock 2001). As a result of shallow water and relatively shallow basins, less redeposition of charcoal occurs in swamps and bogs than in lakes, which is important for the accuracy of dating and for recognizing fire events (Wein et al. 1987).

This study presents a fire history reconstruction from macroscopic sedimentary charcoal in eastern Tennessee based on analyses at Gum Swamp in Great Smoky

Mountains National Park and Black Pond in nearby Loudon County. Understanding how macroscopic charcoal records compare to prior microscopic charcoal and pollen studies (e.g. Davidson 1983, Delcourt et al. 1986) can help test whether these proxy signals reflect local or regional fires in eastern Tennessee. These local fire histories will help identify periods of prehistoric settlement, clearing, and burning in eastern Tennessee. Associating pollen and charcoal records allows for the identification of possible shifts in vegetation caused by fire or lack of fire. Understanding settlement and fire occurrence and regimes within eastern Tennessee and Great Smoky Mountains National Park can help inform resource managers charged with protecting forest resources and biodiversity. Studies such as mine help to reveal the factors that have shaped the vegetation that exists today. Macroscopic charcoal evidence of past fires provides resource managers with a historical perspective for deciding whether fires should be prescribed or let burn to help create and maintain the healthiest and most desired vegetation assemblages. I will answer the following questions:

- What are the general trends in fires in the Cades Cave area of Great Smoky Mountains National Park and in a small portion of the upland region of the Little Tennessee River watershed, near the Tellico Reservoir, as seen through macroscopic charcoal analysis of pond sediments?
- How do the charcoal records from two sites with similar forest composition compare?
- How do the new macroscopic charcoal, pollen, and loss on ignition data compare to the previous pollen and microscopic charcoal records produced by Davidson

(1983) and Cridlebaugh (1984) at these sites and with tree-ring and soil charcoal records of fire at other sites in Great Smoky Mountains National Park and eastern Tennessee?

- What are possible management implications of the long-term records of local fire history from Gum Swamp and Black Pond?

CHAPTER 2

Literature Review

Fire history studies based on sedimentary charcoal have been conducted using sediment cores from lakes, ponds, swamps, and small hollows throughout North America. Many of these studies used macroscopic charcoal as an indicator of local fire events. In the southeastern United States and eastern Tennessee, pollen and microscopic charcoal have been the primary proxies in paleoenvironmental studies. Here, I discuss studies using charcoal, some in combination with other proxies, that have been conducted in the temperate United States and Tennessee. I follow this with a discussion of pollen studies of vegetation history and forest disturbance in the southeastern U.S., including studies that have used disturbance pollen, such as *Ambrosia*, as a signal of land clearance.

Reconstruction of Fire Regimes in Temperate Regions Using Charcoal and Associations with Other Proxies

Long et al. (1998) used macroscopic charcoal and pollen analysis to reconstruct a 9000-year record of fire and vegetation history at Little Lake in the Cascade Range, Oregon. They concluded that the variability in fire frequency on a millennial time scale was a result of climate change. Macroscopic charcoal results indicated that the current fire regime has been in place for no longer than 1000 years.

Whitlock and Millspaugh (1996) used known fire events (1988 fires in Yellowstone National Park) to test the various assumptions in fire history reconstruction.

They extracted short cores from eight different lakes immediately after and four years after the 1988 fires and compared charcoal stratigraphies with known wind directions, weather and climate patterns, and the spatial extent of the fires. Even though secondary deposition of charcoal caused by surface runoff, bioturbation, waves, and incoming streams created a higher concentration of charcoal for years after a fire event, this study found that an increase in charcoal is a relatively accurate way of identifying the 1988 fires.

Another important conclusion was that the size of macroscopic charcoal fragments chosen for quantification did not matter as all size classes showed similar patterns after fire events. This finding has relevance for choosing which sieve size(s) to use for separating charcoal from sediment. Sieve sizes can be chosen based on initial examination of the charcoal present in particular lake sediments, rather than based on a set standard. As mentioned, smaller charcoal particles have been interpreted as reflecting more distant fires because of their ease of transport. Whitlock and Millspaugh (1996) showed, however, that macroscopic charcoal of different size classes showed a similar pattern in distance traveled after a fire event. This was true even for fragments $<125\text{ }\mu\text{m}$ that overlap in size with fragments found on pollen slides, suggesting that even some microscopic charcoal in Yellowstone lake sediments may indicate local fires. Finally, Whitlock and Millspaugh (1996) found that lakes surrounded by both burned and unburned vegetation recorded charcoal deposition from smoke plume convection that caused charcoal to travel long distances during the 1988 fires. Lakes with burned areas,

however, showed a higher quantity of charcoal in the lake sediments caused by later secondary deposition of charcoal from the surrounding burned areas.

Millspaugh et al. (2000) used macroscopic charcoal to create a 17,000 year fire history from a lake on the Yellowstone plateau. This record, combined with corresponding pollen records of specific taxa and with dendrochronological data, allowed Millspaugh et al. (2000) to infer past climate in Yellowstone National Park. The sedimentary pollen and charcoal data corresponded with fluctuations in seasonal cycles of insolation caused by orbital forcing. The authors noted an increase in the number of fires as insolation increased and the climate became warmer and drier around 9900 yr BP (years before present). Millspaugh et al. (2000) detected a decrease in fires since 9900 yr BP, as insolation decreased and the climate became cooler and wetter.

Higuera et al. (2005) investigated macroscopic charcoal records from small forest hollows in the San Juan Islands of Washington state. Comparing macroscopic charcoal with dendrochronological data on stand ages and fire history led Higuera et al. (2005) to conclude that the charcoal and dendrochronological records of fire differed, possibly because of secondary charcoal accumulation or bioturbation. Also, in small hollows, low severity fires produced macroscopic charcoal records that were inconsistent with records from other sites within the fire area, but high severity fires produced a very consistent record of fire history, as these high severity fires produced more charcoal. The inconsistency of the charcoal signal of low severity fires was likely caused by limitations in charcoal transport, specifically the ability of charcoal from such fires to consistently reach the hollow through wind transport in the absence of inflowing streams.

In the eastern United States, Clark and Royall (1995) used the thin-section method and the pollen-slide method to explore how the charcoal particle size studied affected the accuracy of reconstructions of fire history. The thin-section method involves taking sections of sediment from the lake cores (5 cm long x 2 cm wide in this study), dehydrating the sediments using acetone, and then embedding epoxy resin into the sediments before petrographically sectioning them. The goal of this method is to determine the area that charcoal particles cover rather than the number of charcoal particles, as do most microscopic and macroscopic charcoal analyses. Using sediments spanning the last 250 years from a transect of lakes from Minnesota to New York, Clark and Royall (1995) found that microscopic charcoal (5 to 50 μm) showed little change even though the land became settled by Euro-Americans. Thin-section charcoal greater than 50 μm , however, decreased as wildfires began declining after settlement. Microscopic charcoal (<50 μm in this study) showed a more consistent charcoal influx or accumulation rate (CHAR) over time and across regions because fragments of this size come from both local and regional sources. Thin-section methods examine charcoal particles larger than 50 μm yield records that reflect local fire events but still include a small regional component.

Carcaillet et al. (2001b) conducted a study comparing microscopic charcoal on pollen slides and macroscopic charcoal sieved from core samples from a lake in eastern Canada with laminated sediments. They found that charcoal fragments were excessively broken apart during pollen-slide preparation, which created a higher CHAR than would be expected based on the amount of charcoal found through macroscopic charcoal

analysis. Although both methods showed similar tendencies, they gave different signals. Determining the background charcoal component by recognizing a base level of steadily incoming charcoal fragments in all of the samples allowed Carcaillet et al. (2001b) to estimate how much charcoal was secondary (from late sedimentation, incoming rivers, or slope wash) and how much was from a local fire event. Microscopic charcoal at this site contained about a 50% background component, while the sieved macroscopic samples contained a relatively low background component. Because of their low background component, sieved samples provided better recognition of local fire events at this temperate site.

Reconstruction of Fire Regimes in the Southeastern United States

Delcourt and Delcourt (1997) compared pollen and microscopic charcoal in peat deposits from a pond in North Carolina to provide a perspective on the likely effects of recent prescribed burning on forest heterogeneity. The authors found that the percentage of charcoal from a local source (interpreted by analyzing several different size classes of microscopic charcoal) varied over the period studied. Fires set by Native Americans to clear land for agriculture were expected to have reached ridge tops, and were likely the cause of the fluctuation of larger microscopic charcoal believed to originate from the local area. These fires promoted the maintenance of fire-adapted and fire-tolerant species and allowed a heterogeneous group of taxa to develop and grow around the pond.

Similarly, Delcourt et al. (1998) used pollen samples and microscopic charcoal greater than 50 μm to reconstruct vegetation and fire history around Cliff Palace Pond,

Kentucky. This study revealed a sharp decline in *Tsuga* (hemlock) around 4800 yr BP that coincided with an increase of charcoal. It was assumed that an infestation of insects killed a large number of *Tsuga*, leaving abundant fuel for fires. After the fires, *Juniperus* (cedar) increased, possibly filling in where the hemlock had once grown. During the late Holocene, fire-dependent or fire-adapted species increased as fire increased. This increase in charcoal also coincided with prehistoric human settlement, and was thought to be caused by the clearing of forests for agriculture.

Kneller and Peteet (1999) provided an example of using fire history based on pollen associated with macroscopic charcoal data to understand past climate change. In cores extracted from a pond at 620 m elevation in Virginia, Kneller and Peteet (1999) used these proxies to identify a warming trend that occurred around 12,730 yr BP and a cold reversal around 12,200 yr BP, which correlates with the Younger Dryas and was thought to possibly indicate the southern limit of Younger Dryas cooling in eastern North America. This warming of the climate after the Younger Dryas in the Appalachians led to a change in vegetation from *Abies* (fir) to *Tsuga* and an increase in fires.

Lynch and Clark (2002) used macroscopic charcoal (>180 μm) and pollen from sediment cores extracted from ponds and bogs in Maryland, Virginia, and North Carolina to determine how fire, Native Americans, and Euro-Americans have changed the vegetative landscape in the southern Appalachians. They found that fire was a factor in creating prehistoric vegetation assemblages but that the numbers of fires and the extent of disturbance from fire varied greatly between sites. Lynch and Clark (2002) also determined that human disturbance, from both burning for clearing and agriculture and,

later, fire suppression, have changed the vegetation diversity in the southern Appalachians.

Several studies on fire history have been undertaken in Great Smoky Mountains National Park in eastern Tennessee and western North Carolina. Harmon (1982) used tree-ring samples from fire-scarred trees to reconstruct the recent fire history of the western portion of Great Smoky Mountains National Park. He concluded that 90% of plots surveyed had fire scars and many had multiple fire scars, indicating recurring fires set by human activity, lightning, or both. The high frequency fire regime in the western portion of the park, including in Cades Cove, led to an increase in fire-resistant taxa. This study was useful for understanding the fire history of the area over the last 130 years, but did not provide any information on prehistoric fire regimes because of the relatively short length of the tree-ring records analyzed.

Current fire history research in the Southern Appalachians includes an ongoing study by Dr. Henri Grissino-Mayer, Dr. Sally Horn, and their students at the University of Tennessee using fire scars on trees, age structure and stand composition of the forests, and soil and sedimentary charcoal. The goals of this study are to understand how fire has played a part in the development of the vegetation that exists in the southern Appalachians today and to help guide the use of prescribed fire to restore plant communities (H. Grissino-Mayer, pers. comm.). Soil charcoal work for this project is currently being carried out by UT student Christopher Underwood as part of his dissertation research. Underwood's work builds upon an earlier soil charcoal study by Horn and Grissino-Mayer (in preparation) within stands of *Pinus pungens* Lamb. (Table

Mountain pine) from which former MS student Michael Armbrister (2002) developed fire-scar chronologies. Underwood's study is also paired with tree-ring analyses and has the goal of using macroscopic charcoal fragments found in soil to develop fire history records that, while coarser than dendrochronological records of past fire, potentially extend much further back in time (C. Underwood, pers. comm.).

In 1981, Gum Swamp (also known as Lake in the Woods) in Cades Cove, Great Smoky Mountains National Park, was cored as part of a paleoecological study by Davidson (1983), working with Drs. Paul and Hazel Delcourt. This study included the use of pollen and microscopic charcoal to develop a local vegetation history for Gum Swamp. Davidson (1983) concluded that this ca. 0.3 ha wetland receives mostly local pollen as predicted for small sites such as this (Jackson and Bradshaw 1981). While Davidson (1983) developed an extensive vegetation history and a generalized fire history for Gum Swamp, her chronological results were based on radiocarbon dates obtained from bulk sediment that showed inconsistencies. The poor chronological control presented a problem as Davidson (1983) used the available radiocarbon dates to determine sedimentation rates and expressed charcoal data as influx values calculated using these inferred sedimentation rates. She interpreted a peak in charcoal at a depth of about 0.15 m to represent a fire about 1700 yr BP, but regarded a peak lower in the profile, in sediments thought to have been deposited between 6600 and 6300 yr BP, as caused by a low sedimentation rate, not an actual fire. However, these and other conclusions were based on dates that appear unreliable by today's standards. Without better chronological control, the fire history of Gum Swamp is inconclusive.

Additional evidence for past local fires at Gum Swamp was discovered by University of Tennessee undergraduate geography students Jessica Jones and John Thomason in a study of soil charcoal directed by S. Horn. The students found macroscopic charcoal >2 mm in size in almost every 10 cm increment of three soil cores 0.40 to 0.60 m long that they recovered from the uplands around the site (Horn, unpublished data). However, no radiocarbon dates were obtained for these samples.

Pollen as a Proxy for the Reconstruction of Vegetation and Human Disturbance

Pollen has been used for many years to reconstruct the vegetation that previously existed around a study site (Birks and Birks 1980). Pollen grains are produced by plants and are subsequently deposited into a lake or wetland by means of overland flow, wind, rain, or a biological agent, such as birds, insects, or mammals (Birks and Birks 1980). While other indicators of vegetation might exist in sediment, such as leaves, needles, and bark, pollen is particularly suited for the reconstruction of vegetation hundreds to thousands of years ago because individual pollen grains are very resistant to decay (Birks and Birks 1980). By collecting sediment from lakes and wetlands and separating the pollen grains preserved within the sediments from other material (such as sediment and large macrofossils) at various stratigraphic levels, a researcher can identify and quantify pollen and use these data to create a vegetation history.

The reconstruction of past vegetation can assist in understanding climate change, land use, and human impacts and settlement patterns. During the Late Quaternary, glaciers have grown and receded and climate has changed in terms of both temperature

and precipitation. Although the southeastern United States was not covered by glaciers, the vegetation of this region was affected by cooler temperatures during glacial periods (Delcourt 2002). Developing detailed pollen records can help land managers and researchers understand how a certain vegetation community evolved through time and came to be the community that exists in the present day. Pollen records can also characterize human settlement patterns, including when land was cleared, when certain plants moved into the area, and how humans lived in association with the land. The genus *Ambrosia* (ragweed), for example, is considered to be a good indicator of the timing of forest clearance as the plant invades agricultural areas easily and quickly (Delcourt and Delcourt 2004). Pollen of *Ambrosia* was shown to be less than 5% of total pollen in a modern pollen sample from a forested area in Canada (Delcourt and Delcourt 2004). Where the land was cleared, *Ambrosia* accounted for more than 50% of the pollen sum (Delcourt and Delcourt 2004).

Pollen analysis has been used for reconstructing vegetation in many areas of the world. For example, Kennedy et al. (2005) studied pollen and pine stomata in modern surface samples in the Dominican Republic to aid in understanding pollen records that extend further back in time. Long et al. (2007) used pollen and macroscopic charcoal to reconstruct vegetation and climate change in western Oregon. Dull (2007) used pollen (especially maize) in El Salvador to determine human occupation and disturbance. Mumbi et al. (2008) used pollen and isotopes in Tanzania to understand climatic shifts and their effect on vegetation. Hammarlund et al. (2008) used pollen, spores, and

isotopes to understand how the iron industry in Sweden resulted in deforestation and lead in the atmosphere in the 17th century.

Many studies that used pollen analysis have also been conducted in the southeastern United States. Liu et al. (2008) used pollen records to evaluate the relationship between hurricanes and fires in Alabama and discovered that, following saltwater intrusion, post-hurricane increases in saltwater plants and shrubs and decreases in trees led to a higher fire frequency. Burney and Burney (1987) used pollen and microscopic charcoal in a sediment core from a bottomland pond to reconstruct the history of bottomland and upland vegetation on the North Carolina Outer Banks. Based on the findings that *Pinus* pollen declined and shrub pollen increased from the base of the sediment core to the top, they concluded that upland forest communities existed before the pond formed. They also discovered that, as *Pinus* (pine) pollen decreased, so did the microscopic charcoal, indicating that this type of vegetation was fire-dependent or fire-adapted. As *Pinus* pollen decreased, shrubs and “hydric forests” increased, suggesting a rise in the water table and possible intrusion of brackish waters.

For her dissertation at the University of Tennessee, Patricia Cridlebaugh used paleoecological data from two ponds in the Little Tennessee River Valley, Tuskegee Pond and Black Pond, together with archaeological data, to investigate prehistoric human occupancy, resource use, and impacts on vegetation (Cridlebaugh 1984, Delcourt et al. 1986). Tuskegee Pond, on the floodplain of the Little Tennessee River, is now flooded by Tellico Reservoir. Black Pond is located in the adjacent upland. From pollen, microscopic charcoal, and plant macrofossils analyzed in cores from Tuskegee and Black

Pond, Cridlebaugh (1984) determined that the most intensive human occupation occurred during the late Holocene. This is indicated by the occurrence of extensive agricultural pollen likely caused by agricultural practices near the Little Tennessee River and a limited amount of regional pollen (originating >200 m away from the pond). The Woodland cultural period (2850–1000 yr BP) contained the first appearance of maize, which continued to be cultivated through the Mississippian (1000–300 yr BP) and Historic (300 yr BP–present) cultural periods. During the Historic cultural period, other crops were introduced and grazing of livestock began. The late Mississippian and Historic cultural periods also showed greatly increased influxes of pollen and microscopic charcoal. Comparing the pollen records of two ponds located at different positions on the landscape led Cridlebaugh (1984) to conclude that early human settlement began on the floodplains around the Little Tennessee River at about 9000 yr BP, with little evidence of agriculture until about 2500 yr BP. Humans began moving to upland regions near Black Pond by the Historic Overhill Cherokee Period (300–130 yr BP).

An important result from Black Pond was the discovery of an *Ambrosia* rise about 400 yr BP (Cridlebaugh 1984). *Ambrosia* is a disturbance-adapted species that typically begins to show in a pollen record when land clearance has occurred (Schneider 1996). Many studies prior to Cridlebaugh's, such as Brugam (1978), focused mainly on historic periods and equated rises in *Ambrosia* to the settlement of Euro-Americans (Cridlebaugh 1984). Cridlebaugh (1984), however, found the *Ambrosia* rise to occur during the Mississippian cultural period. This *Ambrosia* rise provided evidence of the timing of

human settlement at Black Pond and is useful in my analysis of macroscopic charcoal because it provides a potential stratigraphic marker for correlating the sediment profiles from 2007 that I studied with Cridlebaugh's (1984) sediment core.

The microscopic charcoal analysis completed by Cridlebaugh (1984) shows a strong increase in charcoal influx around the time of the Mississippian *Ambrosia* rise, specifically 400 yr BP. This increased influx of microscopic charcoal provides another potential stratigraphic marker and an opportunity for me to determine whether macroscopic charcoal at Black Pond shows the same pattern.

CHAPTER 3

Study Sites

Study Sites

Gum Swamp (35°35' N 83°50' W; Figures 3.1, 3.2) is situated at the southwestern end of Cades Cove in Great Smoky Mountains National Park in eastern Tennessee. The pond has an elevation of 530 m and a maximum area of 0.3 ha (Davidson 1983; Figure 3.2). The water level can range from 75 cm in the spring or other wet times to 0 cm during dry times (Davidson 1983). The pond is presently fenced to keep wild boars from entering the site, which is a breeding ground for amphibians. This site was cored for Davidson's (1983) thesis. Researchers later inserted a white PVC tube into the sediment to mark the center of the pond. The pond was dry at the time of our coring expeditions in March 2007 and November 2007. In March 2007, the water table was just below the sediment surface and in November 2007, it was >1 m below the sediment surface.

Black Pond (35°37' N 84°11' W; Figures 3.1, 3.3) is a spring-fed sinkhole pond located in the Little Tennessee River watershed in Loudon County, Tennessee (Cridlebaugh 1984, Delcourt et al. 1986). It has an elevation of 262 m and, when full, is approximately 160 x 80 m in size (Delcourt et al. 1986). Black Pond is currently surrounded by *Typha* (cattail), a small ring of trees and shrubs, and cleared agricultural land. The pond is used for duck hunting and there are two duck hunting blinds on the perimeter of the lake, one on the southern side and one on the northwestern side. Local

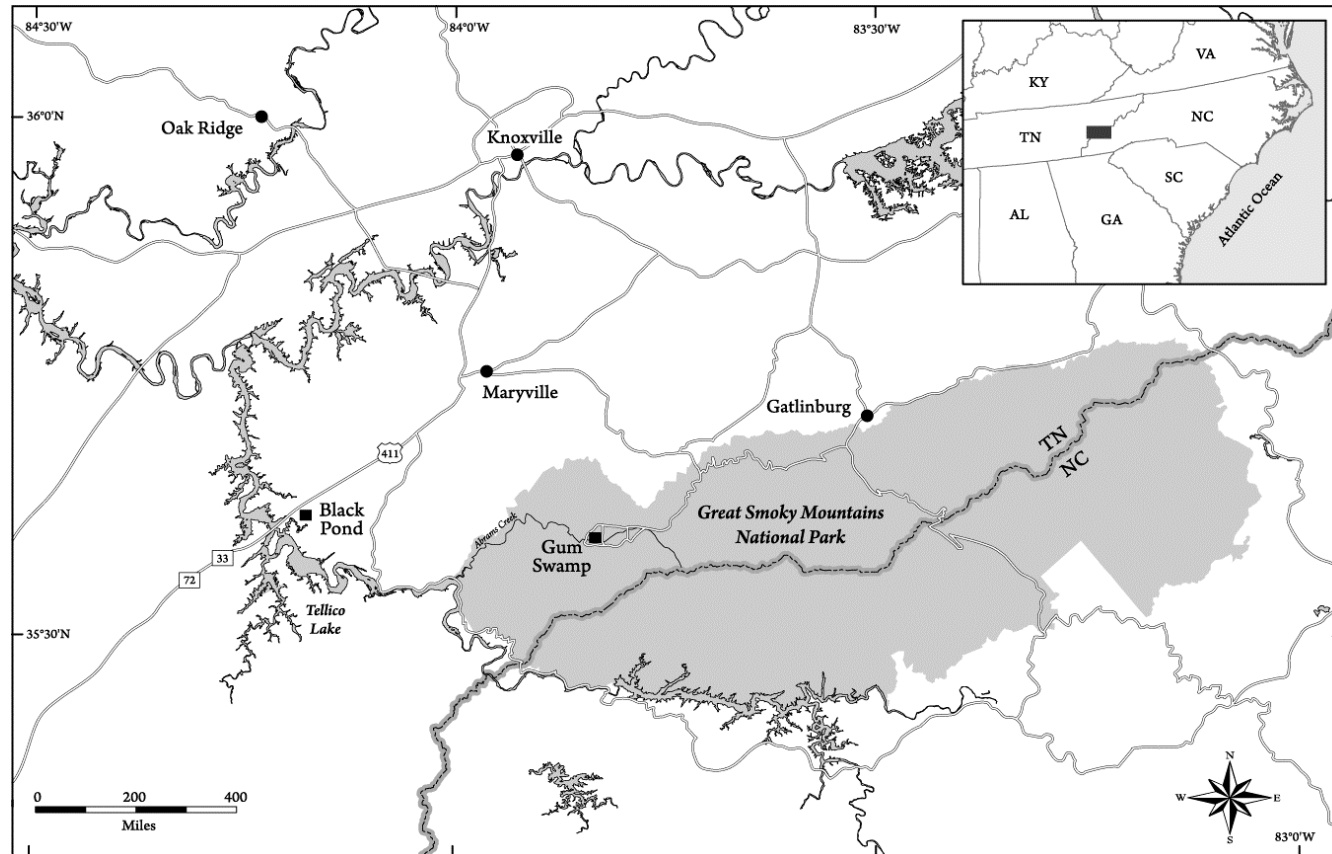


Figure 3.1. Location of Gum Swamp and Black Pond in relation to Knoxville, TN.

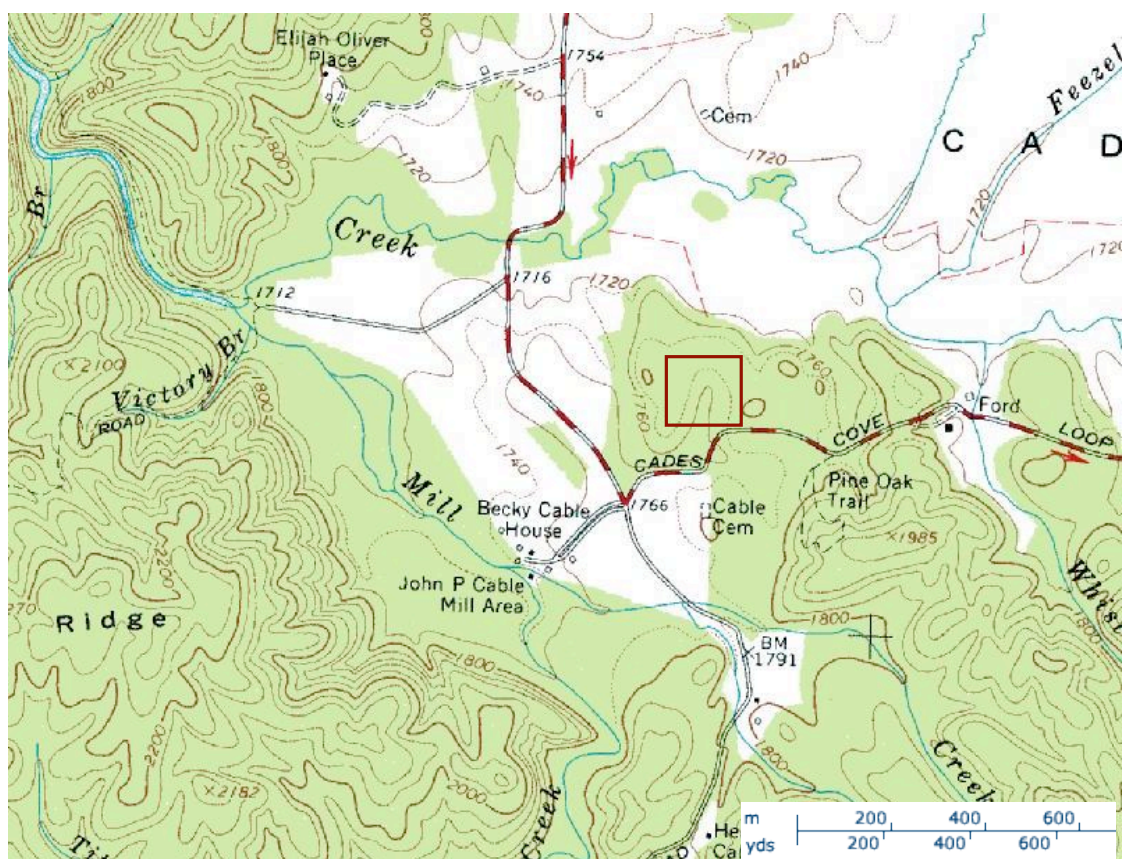


Figure 3.2. Location (in red square) of Gum Swamp in Cades Cove, Great Smoky Mountains National Park. Modified from the 1:250,000, 1981 USGS topographic map quadrangle (TerraServer-USA 2008).

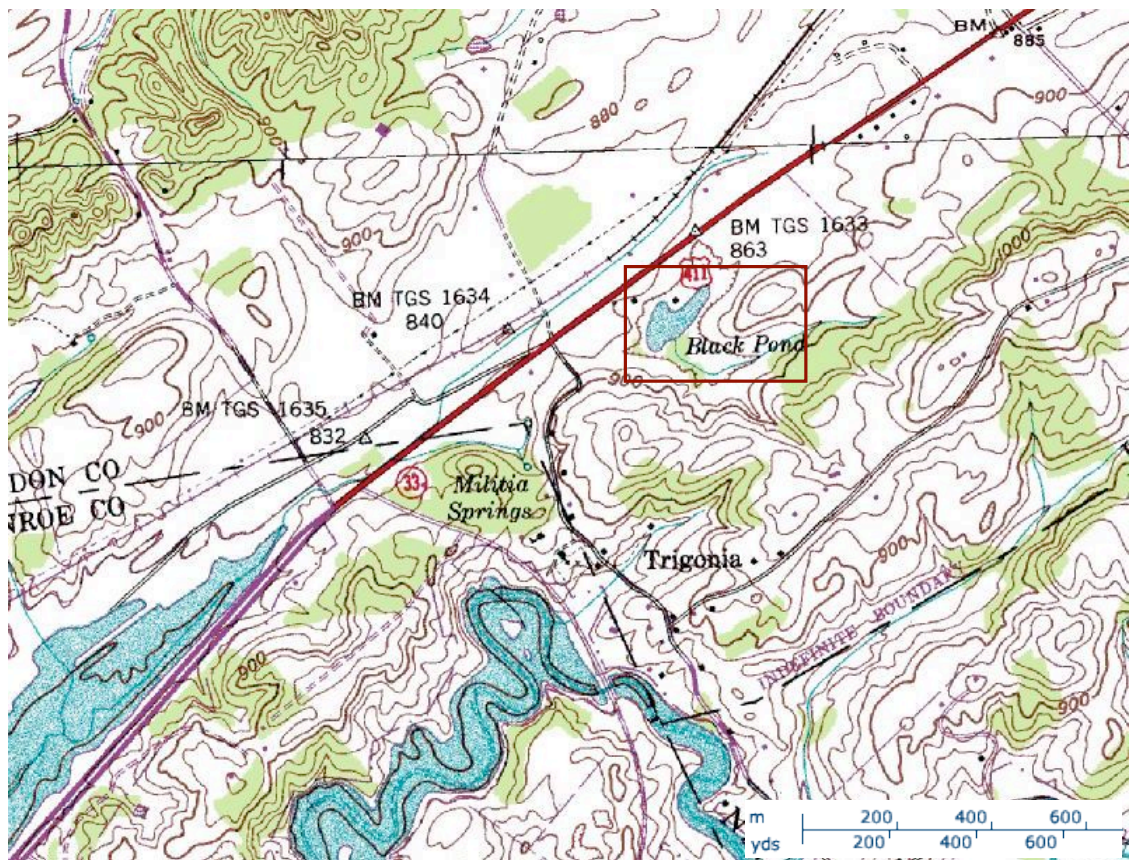


Figure 3.3. Location (in red square) of Black Pond in Loudon County, Tennessee. Modified from the 1:250,000, 1981 USGS topographic map quadrangle (TerraServer-USA 2008).

resident Tommy Brewster (pers. comm. 2007) reported that Black Pond was previously used for a swimming hole. When I visited this site with Sally Horn and Chris Underwood in August 2007, the water level was low. At the time of coring, in November 2007, the pond had shrunk considerably and very little water remained in the pond.

Geological and Physiographic Setting

Eastern Tennessee is divided into three physiographic provinces: the Blue Ridge Province (Unaka Mountains), the Ridge and Valley, and the Plateau. The Blue Ridge Province, at the extreme eastern edge of Tennessee, encompasses both the Blue Ridge and Great Smoky Mountains, and is characterized by ancient, eroded mountains and resistant rocks that have been dissected (Wyckoff 1999). The Ridge and Valley Province, west of the Blue Ridge Province, is characterized by long, parallel ridges that resulted from erosion of larger folds (Wyckoff 1999). The Plateau Province west of the Ridge and Valley Province is characterized by low relief and somewhat steep slopes (Wyckoff 1999).

Gum Swamp is located in a valley (Cades Cove) of the Blue Ridge Province that formed because of differential erosion of limestone and sandstone (Davidson 1983). Abrams Creek runs through the middle of Cades Cove and flows westward to drain into the Little Tennessee River (Davidson 1983). During early settlement in the 1800s, Cades Cove contained a few permanent ponds but these were drained for agricultural and settlement purposes and the well-drained nature of the landscape caused other wetland

areas and ponds to dry naturally (Delcourt 2002). Today, Cades Cove contains no permanent ponds and few wetland areas (Delcourt 2002).

Black Pond is situated in the Ridge and Valley Province (Delcourt et al. 1986). It is located east of the Tellico Reservoir on the Little Tennessee River. The Little Tennessee River flows northwesterly from Georgia and empties into the Tennessee River. Black Pond is located on an upland bedrock surface (Cridlebaugh 1984). The Tellico Reservoir was impounded in 1979 and currently floods 33 miles of the Little Tennessee River (TVA 2008).

Climate

Eastern Tennessee has a humid temperate climate with moderate temperatures, between 29.9 and –3.3 °C at Gum Swamp and 31.2 and 5.6 °C at Black Pond (SRCC 2007). Precipitation is high and fairly steady throughout the year with an average of 141.5 cm/year at Gum Swamp and 145.9 cm/year at Black Pond and no normal drought seasons (SRCC 2007). This area receives its weather mostly from the west. Southeast Tennessee is dominated by the Westerlies wind belt and warm, humid air (maritime tropical) flows north from the Gulf of Mexico and cooler, dry air (continental polar) flows south from Canada. In recent years, eastern Tennessee, as well as much of the southeastern United States, has experienced an extreme drought. This drought has affected the water levels at both of my study sites.

Vegetation

Gum Swamp and Black Pond are located in the oak-hickory forest region (also known as Appalachian oak forest; Watts 1980, Delcourt et al. 1986, Delcourt 2002). Earlier, this forest region was known as the oak-chestnut forest (Braun 1950), as *Castanea dentata* (chestnut) once covered 60–80% of the region (Delcourt 2002). In the early 1900s, chestnut blight spread through the area and killed most of the chestnut trees (Keever 1953, Delcourt 2002). The successional forests that filled in where the chestnut blight had occurred included a large proportion of *Quercus* (oak) and *Carya* (hickory) trees (Keever 1953, Delcourt 2002).

The vegetation at Gum Swamp and Black Pond has been heavily influenced by humans. Based on lithic artifacts found within Cades Cove, this area was used by Native American hunters beginning in the early Archaic period, between about 9500 and 8500 yr BP (Bass 1977). Prehistoric human occupation in Cades Cove resulted in some forest clearance and burning (Davidson 1983). Davidson cites local disturbance, such as clearing, around Gum Swamp as occurring between 6600 to 6500 yr BP based on increases in pollen from willows (*Salix* sp.), which could have prospered because of open areas. At about 6400 yr BP, Davidson found peaks in *Quercus*, *Castanea*, *Pinus*, and *Cephalanthus occidentalis* (buttonbush), which also indicated landscape disturbance, possibly from human clearing and burning or from natural fires, wind, or ice storms. However, these interpretations were based on the original dating of the Gum Swamp sediments, which is cast into some doubt by the results of a recent radiocarbon date obtained for my study.

In the mid- to late 1800s, Euro-Americans cleared most of the rest of Cades Cove for agricultural and grazing purposes. Since the designation of the area as a national park in 1934, burning and grazing within the park has been restricted. In 1941, a plan was implemented to preserve the historical and aesthetic landscape of Cades Cove that allowed leasing of farmland and grasslands for agriculture and grazing to prevent succession of the forests as long as those leasing the land followed park rules (Young 2006). Although this plan was implemented for almost 40 years, environmental degradation occurred because of runoff from farmland and livestock. Policies were revised in 1982 to include more environmentally sound practices and no grazing or farming permits have been issued since 1999 (Young 2006).

The forests near Cades Cove are characterized as containing mostly *Quercus montana* (chestnut oak), *Oxydendrum arboretum* (Lily of the Valley), *Nyssa sylvatica* (black gum), and various species of *Pinus* (Harmon 1982, Davidson 1983). Gum Swamp is currently surrounded by vegetation that includes *Liquidambar styraciflua* (sweetgum), *Acer rubrum* (red maple), *Nyssa sylvatica*, *Fagus grandifolia* (beech), and *Cephalanthus occidentalis* (Davidson 1983, Delcourt 2002).

The vegetation that surrounds Black Pond has also experienced extensive clearance for agricultural purposes. At intervals for at least the last several decades, vegetation surrounding the pond has been cleared to the edge of the pond (Tommy Brewster, pers. comm.). A photograph from the 1980s shared by a local resident showed pasture to the pond edge. Today, the pond is surrounded by a ring of *Typha* and grasses,

and beyond that by a border of tress including *Pinus*, *Quercus*, and *Carya* (Cridlebaugh 1984, Delcourt et al. 1986, Delcourt 1987).

Prehistoric Human Settlement

From the Archaic to the Late Woodland cultural periods (about 3000–1000 yrs BP) in the southeastern United States, prehistoric Native Americans, or Paleo-Indians, subsisted as hunter-gatherers living mostly in rockshelters and bottomlands (Delcourt and Delcourt 2004). Some Paleo-Indian groups also fished or planted small gardens on floodplains where the soil was rich in nutrients or on small plots of cleared land (Delcourt and Delcourt 2004). Fire was used to clear land and establish gardens as well as to promote growth of mastng trees. These fires also promoted the growth of fire-tolerant and disturbance-adapted species such as *Pinus* (Harmon 1982, Delcourt and Delcourt 2004).

The Little Tennessee River Valley was also used as a human migration corridor between modern day southeastern Tennessee and northern Georgia. Fertile soils allowed productive vegetation growth and animals for hunting were plentiful (Delcourt and Delcourt 2004). As agriculture became more important to the Native Americans, they began to move their villages to higher ground and used the floodplains and bottomlands for agriculture (Delcourt and Delcourt 2004). Although cultivated crops were becoming a larger portion of the Native American diet, hunting and gathering were still heavily used through the Woodland cultural period (Delcourt 1987).

During the Mississippian cultural period (about 1000–300 yrs BP), forests were cleared further for settlement and agriculture and forest fragmentation was widespread (Delcourt and Delcourt 2004). Examples of agricultural plants during the early Mississippian cultural period include maize, squash, and beans. More permanent settlements and the development of extensive agricultural land also led to the development of trade networks in the eastern United States (Delcourt and Delcourt 2004). During this period, grasses and other disturbance-adapted herbs such as *Ambrosia* became established in many gardens and cleared lands that were abandoned because of human movement and field rotation (Delcourt and Delcourt 2004). Pollen and microscopic charcoal profiles from Tuskegee Pond and Black Pond in the Little Tennessee River Valley, for example, reveal evidence of agriculture and burning during this period (Delcourt and Delcourt 2004).

Historic Human Settlement and Impacts

Euro-American settlement began at the Atlantic coast of the United States and spread westward towards the Mississippi River Valley between 350–150 yrs BP (Delcourt and Delcourt 2004). As Euro-American settlement progressed, Native American populations moved out of the area ahead of the Euro-American settlement front. The previously used agricultural land developed into late-successional ecosystems that appeared to be untouched wilderness when the Euro-Americans first saw them. In fact, the stands were only in their first successional cycle after the land was allowed to regenerate on its own (Delcourt and Delcourt 2004).

Between 300 and 130 yrs BP, during the Historic Overhill Cherokee period, Euro-Americans began to remove the Cherokee Indians from the Little Tennessee River Valley and use this area for settlement (Delcourt et al. 1986). Euro-Americans are thought to have continued burning in the southeastern United States, including eastern Tennessee, and the number of fires is thought to have increased because of intensive logging and the movement of charcoal and iron industries into the area (Harmon 1982, Brose et al. 2001).

Official fire management by the United States government began around 1886 in response to the fatal 1871 Peshtigo, Wisconsin fire, with the objective of preserving national parks and forests (Stephens and Ruth 2005). Originally, the main goal of forest fire management was complete fire suppression. At this point, fire was still considered to negatively affect forests and all fires threatened humans (Williams 1995). Full fire exclusion was extended to Great Smoky Mountains National Park in 1934, at the time of park establishment. Meanwhile, scientists began to study the effects of controlled burns based on culturally-accepted beliefs in the southeastern United States that fire is beneficial to forests (Stephens and Ruth 2005).

Scientific studies in the late 1950s and early 1960s began to reveal an increase in fuel loads and aging stand compositions in stands that were not allowed to burn (Stephens and Ruth 2005). Private forests in the southeast, where “cultural burning” (burning that is culturally acceptable) was in use, contained little fuel for fire and fire-tolerant vegetation continued to prosper (Stephens and Ruth 2005). Lafon et al. (2005) suggested that, after many years of fire suppression, fuels have been allowed to build up in the Appalachians to levels that can lead to high-intensity fires that would be difficult to

suppress. In the 1950s and 1960s, researchers expected fire suppression to be the leading factor in the increasing intensity of forest fires throughout the United States, but federal policy did not take these studies into account and kept the policy of fire exclusion until the 1970s (Stephens and Ruth 2005). The lack of fire throughout the eastern United States has also contributed to the infestation of forests with diseases and insects such as bark beetles, which kill trees, creating fallen trees that add to the fuel load and can result in larger, more intense fires (Mutch 1994).

CHAPTER 4

Methods

Field Methods

I participated, along with Sally Horn and several students, in coring Gum Swamp in March 2007, using a Colinvaux-Vohnout (C-V) locking piston corer (Colinvaux et al. 1999). Standing water was not present during coring, but the water table was visible just below the sediment surface. We encountered some difficulty in coring and recovered three core sections from different holes located a few tens of centimeters apart rather than a continuous core. The holes were all located 1.35–1.45 m from the white pipe marking the center of Gum Swamp. In our first attempt, we pushed one meter into the sediment but only recovered 0.41 m of sediment because of compaction, plowing (pushing through sediment without collecting it), loss of sediment, or some combination. Our second attempt, again from the sediment surface, also yielded less sediment (0.58 m) than the depth of our push (approximately 1.00 m). In our third attempt, we started our push 0.40 m below the sediment surface and reached rock at a depth of 1.10 m from the sediment surface. The resulting core section was approximately 0.60 m long. Following the recovery of these core sections, we probed at several other locations within Gum Swamp and did not find any location with sediment deeper than about 1.10 m. The core sections were transported to the Laboratory of Paleoenvironmental Research at the University of Tennessee in their original aluminum core tubes and refrigerated at 6 °C.

After opening and describing the Gum Swamp core tubes (described in the next section), questions remained about how the different core sections lined up with each other. Also, very little organic material was available for radiocarbon dating. For that reason, Sally Horn and I, together with several students, cored Gum Swamp again in November 2007 using an 8-cm diameter root corer (Horn et al. 1994). This device, commonly used for soils, is not appropriate for saturated sediments, but the water table at Gum Swamp was below a depth of 1 m at this time. We chose to use the root auger because the sediment at Gum Swamp was very sticky and difficult to core. Shorter core lengths were easier to remove and more completely recovered using the 8 cm root auger. We obtained two full parallel cores, each in 10 cm increments. Both cores reached a depth of about 1 m. Each 10 cm increment was placed in a plastic bag, labeled, and refrigerated at 6 °C upon return to the lab. The upper 10-cm increments of each core crumbled and mixed in the bags, but all core increments below 10 cm held together as intact sections of sediment. I later reassembled each core to photograph and describe in the same manner as the earlier cores recovered with the C-V corer. For both cores, I did not photograph, describe, or analyze the top 10-cm increments that had fallen apart because of lack of moisture.

Black Pond was cored in November 2007 by me, Sally Horn, and several students. Since the initial investigation of the site in August 2007, the pond had dried considerably, producing a difficult coring situation. We cored Black Pond using a C-V locking piston corer close to the edge of the pond in a few centimeters of water.

The clay-rich sediments proved difficult to recover and we were unable to retrieve a full record from a single hole. We therefore drove into a parallel hole so that we would be able to try to determine where gaps in our first core existed and obtain more organic material for radiocarbon dating. From Hole 1, we drove down 1 m from the mud-water interface and recovered 0.86 m of sediment. We drove 1.00–2.00 m from the mud-water interface in Hole 1 and 0.95–1.95 m in Hole 2, located 0.26 m from Hole 1, and recovered about 0.65 m from each drive. From Hole 1, we drove down 2.00–3.00 m from the mud-water interface and recovered 0.66 m and from Hole 2, we drove from 1.95–2.95 m and recovered 0.93 m. All sediments were stored in their original aluminum core tubes and refrigerated at 6 °C upon return to the lab.

Laboratory Methods

The aluminum tubes were opened longitudinally in the lab using a modified router, and the sediment was then sliced lengthwise with a wire. This produced two halves for each core section, one for sampling and the other serving as an archive. Each pair of core sections was photographed and described for Munsell color, stratigraphy, and sediment type. All section halves were wrapped in plastic wrap, placed in a plastic bag, and refrigerated at 6 °C. The 10-cm core increments collected from Gum Swamp in November 2007 were removed from their plastic bags, placed according to depth in rectangular boxes, and photographed. The 10-cm core increments were cut in half and inspected for organic material suitable for radiocarbon dating. The reassembled 1-m cores in boxes were then covered in plastic wrap, placed in a plastic bag, and refrigerated at 6 °C.

Radiocarbon Dating

Sally Horn and I submitted organic macrofossils to Beta Analytic, Inc. (one sample) and the University of Arizona AMS Laboratory (five samples) for Accelerator Mass Spectrometry (AMS) radiocarbon dating. Radiocarbon dating provides age estimates for the Gum Swamp and Black Pond core sections and allows comparison of the new charcoal records with previously published studies of other cores from the sites. The sample submitted to Beta Analytic, Inc., was charred organic material removed at a depth of 0.46–0.45 m from the 10-cm sediment increments extracted from Gum Swamp in November 2007. The Gum Swamp date from Beta Analytic, Inc. was calibrated by Sally Horn using CALIB rev. 5.0⁻¹ (Stuiver and Reimer 1993) and the dataset of Reimer et al. (2004). Sally Horn also calculated the weighted mean calibrated age (Telford et al. 2004).

The five samples submitted to the University of Arizona AMS Laboratory were all from the Black Pond core sections. They consisted of unidentified charcoal (Hole 2, 1.95–2.95 m core section, 0.04–0.05 m depth within section), charcoal from a diffuse porous hardwood (Hole 1, 2.00–3.00 m, 0.36–0.37 m), two sticks (Hole 1, 1.00–2.00 m, 0.58–0.61 m, and Hole 2, 0.95–1.95 m, 0.09–0.10 m), and a piece of pine bark (Hole 2, 1.95–2.95 m, 0.69–0.70 m). Ph.D. student Chris Underwood identified the bark as pine bark and one of the charcoal samples as coming from a hardwood with a diffuse porous ring structure. All samples were removed from the core directly, or from a sieve when processing samples for macroscopic charcoal analysis. These samples were cleaned, rinsed with distilled water, placed in an ignited vial, and dried for 24 hours at 100 °C before packaging in foil folders for shipping to the Arizona AMS Lab.

Charcoal Analysis

The profiles from both sites were sampled at contiguous, 1-cm intervals for macroscopic charcoal analysis. A 4-cc brass sampler fabricated by Roger Horn was used to remove samples in the shape of a rectangular prism, with each sample taken adjacent to the previous sample such that a longitudinal trough was created in the sediment surface. The samples were disaggregated for at least 24 hours in 3% U.S.P. cosmetic grade hydrogen peroxide (Schlachter and Horn, in review). The samples were then rinsed through 125, 250, and 500 μm sized nested sieves using deionized water sprayed from a pump manufactured for garden use. The material retained on the sieve was rinsed into Petri dishes for analysis.

All macroscopic charcoal fragments in three size classes (125–250 μm , 250–500 μm , and >500 μm) were counted from the Petri dishes using a stereozoom dissecting scope at 10–40x magnifications. I followed standard practice (e.g., Whitlock and Larsen 2001) regarding particles that pass through the 500 μm sieve but are retained on the 250 μm sieve to constitute the 250–500 μm size class, and those that pass through the 250 μm sieve but are retained on the 125 μm sieve to constitute the 125–250 μm size class. A grid was scored into the bottom of the Petri dishes to prevent counting charcoal fragments more than once. Charcoal was identified as black, angular fragments of various sizes and shapes. At both Gum Swamp and Black Pond, sediment, rocks, dirt, and insects were easily identified separately from charcoal based on color, texture, and shape. Large pieces of charcoal and other macrofossils found during the sieving or otherwise identified within the core were removed, cleaned, rinsed with distilled water, dried for 24 hours at

100 °C, and saved for radiocarbon dating. Charcoal concentration (fragments/cm³) was calculated for Gum Swamp and Black Pond and influx (fragments/cm²/yr) was calculated for Gum Swamp only.

For the Gum Swamp samples, the core section extracted during our first attempt at coring in March 2007 (Hole 1) was sampled and analyzed for charcoal as a preliminary procedure. I completed this to determine if enough charcoal existed in the Gum Swamp sediments for macroscopic charcoal analysis and the data are not presented in this study. After determining that enough charcoal existed for macroscopic charcoal analysis from the preliminary analysis, I processed the second and third sediment core sections according to the procedure described above. To align the depths of Hole 2 and 3, I used a distinctive Munsell color change from 10YR 3/1 (very dark gray) and 10YR 6/1 (gray) to 10YR 6/2 (light grayish brown) that was present in both core sections. This color change began at 48 cm in Hole 2 and at 11 cm in Hole 3. This offset is reasonable as the core section from Hole 2 began at the sediment surface and the core section from Hole 3 began 40 cm below the sediment surface, thus the Munsell color change was only 3 cm higher in the Hole 2 core section than in the Hole 3 core section.

Associating the parallel Black Pond sediment core sections based on visible stratigraphy proved difficult. To provide myself with enough data to confidently align the core sections and to obtain the most data possible, I processed all five core sections for macroscopic charcoal analysis.

Pollen Analysis

I carried out limited pollen analysis of the Black Pond sediment to obtain pollen data that would help me align the 2007 cores with the core used in Cridlebaugh's (1984) study. Specifically, I was interested in identifying the position of the *Ambrosia* rise in the 2007 profile. I sampled 0.5 cm³ of sediment from six levels, at depths chosen based on Cridlebaugh's (1984) determination that the *Ambrosia* rise occurred at a depth between 1.90 and 1.95 m in the core she analyzed. I sampled at depths of 1.45, 1.66, 2.04, 2.28, 2.46, and 2.64 m. The lower portion of the core was sampled at closer intervals to be sure that I had caught the *Ambrosia* rise. With the help of MS student Joshua Albritton, I processed the six samples according to Laboratory of Paleoenvironmental Research's Temperate pollen processing procedure (JR2-SE). Processing included the addition of *Lycopodium* control spores to enable calculation of pollen concentrations (Stockmarr 1971). The samples were rinsed with TBA (tertiary butyl alcohol), mixed with silicone oil, and allowed to air dry in a dust-free cabinet. When all the TBA evaporated, at least one slide was made from each level for analysis.

I focused the process of counting pollen grains on my decision to compare *Ambrosia* and *Pinus* pollen ratios and concentrations. I counted all *Ambrosia* pollen grains, all *Lycopodium* control spores, and all *Pinus* pollen grains until I reached 100 *Pinus* pollen grains. Broken *Pinus* pollen grains were counted only if the grain contained the body (cap) and at least one bladder. I calculated the ratio of *Ambrosia* to *Pinus* by dividing the number of *Ambrosia* pollen grains counted at each level by the number of *Pinus* pollen grains counted at each level. I calculated the concentration of both *Pinus*

and *Ambrosia* pollen by dividing the number of *Lycopodium* control spores in each tablet used during processing (about 13,911 spores in my processing and 16,180 spores in Cridlebaugh's processing) by the number of control spores counted on the slide. This number was multiplied by the number of pollen grains counted on each slide and then divided by the volume of the sediment sample processed (0.5 cc in my processing and 1 cc in Cridlebaugh's processing). This was completed for both my own data and Cridlebaugh's (1984) data. When using Cridlebaugh's (1984) *Pinus* data, I combined *Pinus* undifferentiated and *Pinus Diploxylon* because I had not distinguished types of *Pinus* pollen when analyzing the 2007 Black Pond cores.

I also attempted to process samples from the Gum Swamp sediment cores for pollen analysis to facilitate comparison with Davidson's (1983) record. This proved difficult because of the high amount of silica in the sediment. One attempt to remove the silica included three HF treatments on each sample, but even this did not remove enough of the silica to allow for proper slides to be made or enough pollen to be left in the residue to count. I also attempted to use a fine nitex screen (10 μm) secured to the top of an Erlenmeyer flask to remove silica particles (Limnological Research Center, University of Minnesota 2003). After partly processing the sample (immediately before the HF step), I placed the sample on the screen, rinsed the sample through using distilled water, and then attached a hose to the side of the flask and to the fume hood vacuum. The vacuum was used to pull silica particles <10 μm in size through the screen, leaving pollen grains and other organics and inorganics >10 μm on the screen. Ultimately, this procedure was not applicable to my sediments as a lot of silica remained in the sample

and I was unable to quantify the probability of the loss of pollen grains. Because of the difficulty of obtaining a final pollen residue suitable for analysis, I decided not to continue with pollen analysis for Gum Swamp.

Loss on Ignition

The Gum Swamp and Black Pond sediments were sampled for loss on ignition analysis at the same levels processed for pollen analysis. I placed 0.5 cm³ of sediment in a preweighed crucible, dried the samples at 100 °C for 24 hours, and then weighed the samples again to estimate water content. Next, the samples were ignited at 550 °C for one hour, weighed, ignited for one more hour at 1000 °C, and weighed again. This process allows the estimation of organic, non-carbonate inorganic, and carbonate content in the sediments (Dean 1974).

CHAPTER 5

Results

Gum Swamp Sediment Stratigraphy

The core sections from the three holes sampled using a C-V corer at Gum Swamp in March 2007 consist primarily of fine-grained sediment (silt and clay). Here, I describe the stratigraphy of each core section, from the bottom upwards, at each hole sampled. The 0.40 m core section from Hole 1, recovered beginning at the sediment surface, consists of clay and silt with a Munsell color of 10YR 4/1 (dark gray) from 0.40 m to 0.14 m and 10YR 6/2 (light grayish brown) below 0.32 m where oxidation has occurred. The top 0.14 m of the core section is composed of leaf litter and other unconsolidated organic material with a Munsell color of 10YR 3/1 (very dark gray). This core section was examined in a preliminary study and is not discussed further. For my analysis here, I used the upper core section recovered from Hole 2 (coring also started at the sediment surface). This section consists of mottled clay and silt with Munsell colors of 10 YR 6/2 (light grayish brown) and 10 YR 5/2 (grayish brown) from the base of the section (0.59 m) to 0.47 m. From 0.47 m to 0.09 m, the sediment consists of mottled clay and silt with a Munsell color of 10YR 5/1 (gray). From 0.09 m to the surface, the core section consists of leaf litter with a Munsell color of 10 YR 3/1 (very dark gray). The core section recovered beginning at 0.40 m below the sediment surface from Hole 3 contains fine-grained sediment with a Munsell color of 10 YR 7/1 (light gray) from its base (0.56 m) to 0.42 m. A gap in the sediment, which likely occurred because of slippage of sediment in the aluminum tube, exists between 0.42 and

0.31 m. Between 0.31 and 0.11 m, the sediment varies between Munsell colors of 10YR 6/1 (gray) and 10YR 7/1 (light gray). The top 0.11 m of the core section consists of fine-grained sediments with a Munsell color of 10YR 3/1 (very dark gray).

The stratigraphy of the two cores retrieved in November 2007 using an 8-cm diameter soil auger is similar and will be described together here. Coring at Hole 1 resulted in the recovery of 0.99 m of sediment and coring at Hole 2 resulted in the recovery of 0.90 m of sediment. Both cores consist of fine-grained sediment (clay and silt) for the full length of recovery. From 0.99–0.90 m in Hole 2, the sediment shows some oxidation and a Munsell color of 10YR 6/2 (light grayish brown). From 0.90 m to 0.60 m in both sets of sediment cores, the Munsell colors are 10 YR 5/1 (gray) and 10YR 5/2 (grayish brown) with a small amount of oxidation. From 0.60 to 0.50 m depth, there are some oxidized sections and dark striations with a Munsell color of 10YR 6/2 (light grayish brown). The core increments from 0.50 to 0.10 m have a Munsell color of 10YR 4/1 (dark gray). The top 0.10 m increments of both cores were not described as they had fallen apart after coring.

Black Pond Sediment Stratigraphy

The lowest core section from Hole 1, recovered starting at 2.00 m below the mud/water interface, contains very fine clay sediments with Munsell colors of Gley 1 6/10Y (greenish gray) and Gley 1 5/10Y (greenish gray) from the base of the section (0.66 m) to 0.37 m. At 0.37 m, an abrupt transition occurs to peaty sediment with scattered wood and a Munsell color of 10YR 3/1 (very dark gray). This peaty sediment extends to about 0.11 m. From 0.11 m to the top of the core section, the sediments are fine-grained with a Munsell

color of 2.5Y 5/2 (grayish brown). Above this, the middle core section recovered beginning at 1.00 m below the sediment surface in Hole 1 contains sediments with abundant organic matter and Munsell colors of 2.5Y 5/1 (gray) and 2.5Y 4/1 (dark gray) from the base of the core section (0.66 m) to 0.43 m. From 0.43 m to 0.00, the sediment is fine-grained with a Munsell color of 2.5Y 5/2 (grayish brown). The upper core section from Hole 1 (recovered beginning from the sediment surface) consists of a 0.86 m long increment of very fine and sticky sediments (clay and silt) with Munsell colors of 2.5Y 4/2 (dark grayish brown), 2.5Y 5/2 (grayish brown), and 2.5Y 5/1 (gray).

The lowest core section from Hole 2, recovered starting at 1.95 m below the mud/water interface, consists of fine-grained sediments with Munsell colors of Gley 1 6/10Y (greenish gray), 5Y 6/1 (gray), and Gley 1 6/2 (pale green) from the bottom of the section (0.93 m) to 0.54 m. At 0.54 m, an abrupt transition occurs to peaty sediment with large pieces of wood and a Munsell color of 2.5Y 3/1 (very dark gray). This sediment type extends to 0.03 m. From 0.03 m to 0.00 m, the sediment is clay and silt with a Munsell color of 2.5Y 5/2 (grayish brown). The core section starting at 0.95 m below the sediment surface in Hole 2 consists of clay and silt with some organic material scattered throughout. The Munsell colors for this increment are 2.5Y 5/2 (grayish brown), 2.5Y 4/2 (dark grayish brown), and 2.5Y 4/1 (dark gray).

Radiocarbon Dating

The charcoal from a depth of 0.46–0.45 m below the sediment surface at Gum Swamp yielded a radiocarbon age of 200 ± 40 yr BP (Table 5.1). The result is many

Table 5.1. Radiocarbon determination and calibration for sample from the Gum Swamp sediment profile.

Lab number ^a	Depth (m)	$\delta^{13}\text{C}$ (‰)	Uncalibrated ^{14}C age (^{14}C yr BP)	Calibrated age range ^b ($\pm 2 \sigma$)	Area under probability curve	Weighted mean calibration age ^c
B-242665	0.45–0.46	–24.7	200 $\pm$ 40	308–253 cal yr BP	0.267	174 cal yr BP
				226–135 cal yr BP	0.511	
				116–72 cal yr BP	0.498	
				34 to –2 cal yr BP	0.172	

^aAnalyses were performed by Beta Analytic Laboratory. Sample consisted of multiple pieces of charcoal and partially charred wood taken from a depth of 0.45–0.46 m from the 10 cm increment samples collected in November 2007 (material combined from both cores).

^bCalibrations were calculated using CALIB (Stuiver and Reimer 1993, vers. 5.0.1) and the dataset of Reimer et al. (2004).

^cWeighted mean of the 2 σ calibration probability distribution.

thousands of years younger than the radiocarbon date of 6300 ± 90 yr BP on bulk sediment obtained at a depth of 0.35–0.25 m in the core from Gum Swamp that Davidson (1983) analyzed. The weighted mean of the calibrated age of the macroscopic charcoal I dated is 174 cal yr BP (calibrated years before present). The results from Black Pond macrofossils that were sent to the University of Arizona's AMS Laboratory are pending at this time.

Gum Swamp Macroscopic Charcoal Analysis

The three size ranges of charcoal show similar stratigraphic patterns within each of the two core sections from Gum Swamp analyzed for macroscopic charcoal (Figures 5.1, 5.2). Concentrations are inversely proportional to the size fractions, with particles in the smallest size fraction (125–250 μm) most abundant and those in the largest size fraction (>500 μm) least abundant. The Hole 2 sediments show low charcoal concentration (fragments/ cm^3) from the base of the section (0.59 m) to 0.44 m, with a slightly higher concentration at about 0.51 m. A general increase in charcoal concentration occurs from 0.44 m to 0.10 m, though concentrations vary. Peaks in charcoal concentration occur at 0.32 m and 0.11 m. Low charcoal concentrations occur from 0.10–0.00 m.

The sediments recovered starting at 0.40 m below the sediment surface in Hole 3 show a charcoal peak at about 0.53 m but otherwise low concentrations between the bottom of the core section (0.56 m) and 0.42 m (Figure 5.2). Above a gap between 0.42 and 0.31 m, charcoal concentrations begin to increase, with peaks occurring at 0.20 and 0.15 m. Charcoal concentrations are highest between 0.12 and the surface.

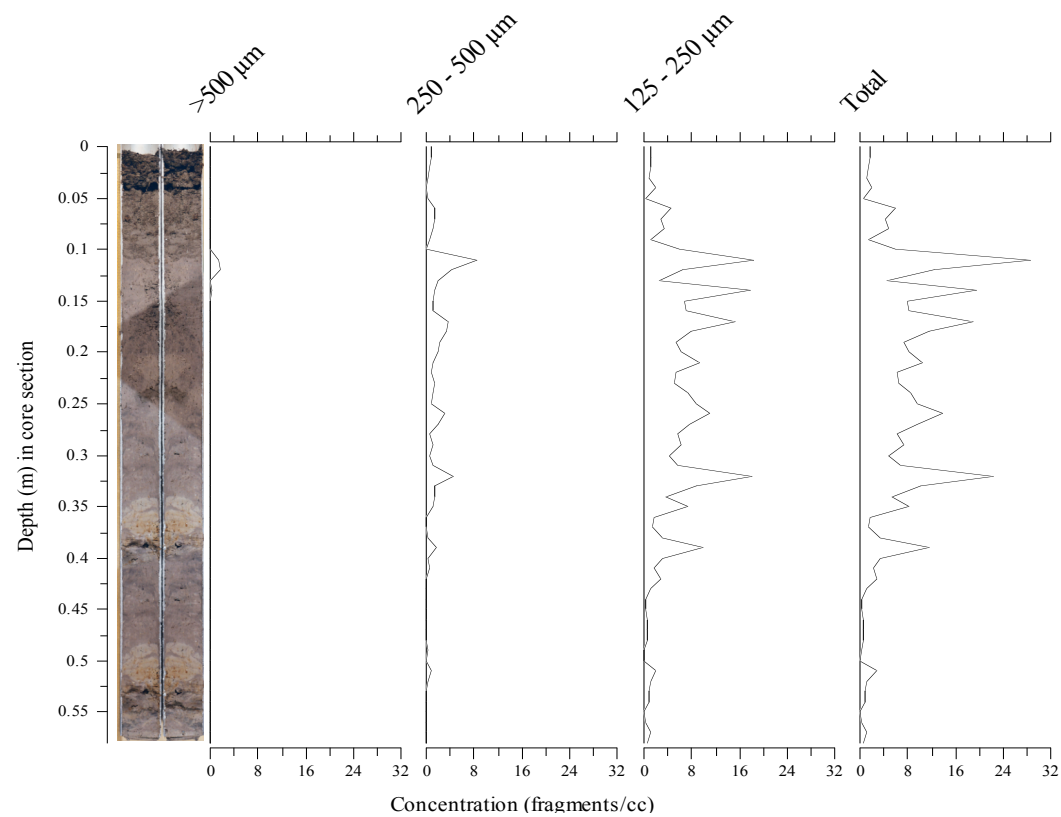


Figure 5.1. Photograph of sediment core section and macroscopic charcoal concentrations from Gum Swamp, Hole 2, 0.00–1.00 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figure 5.2.

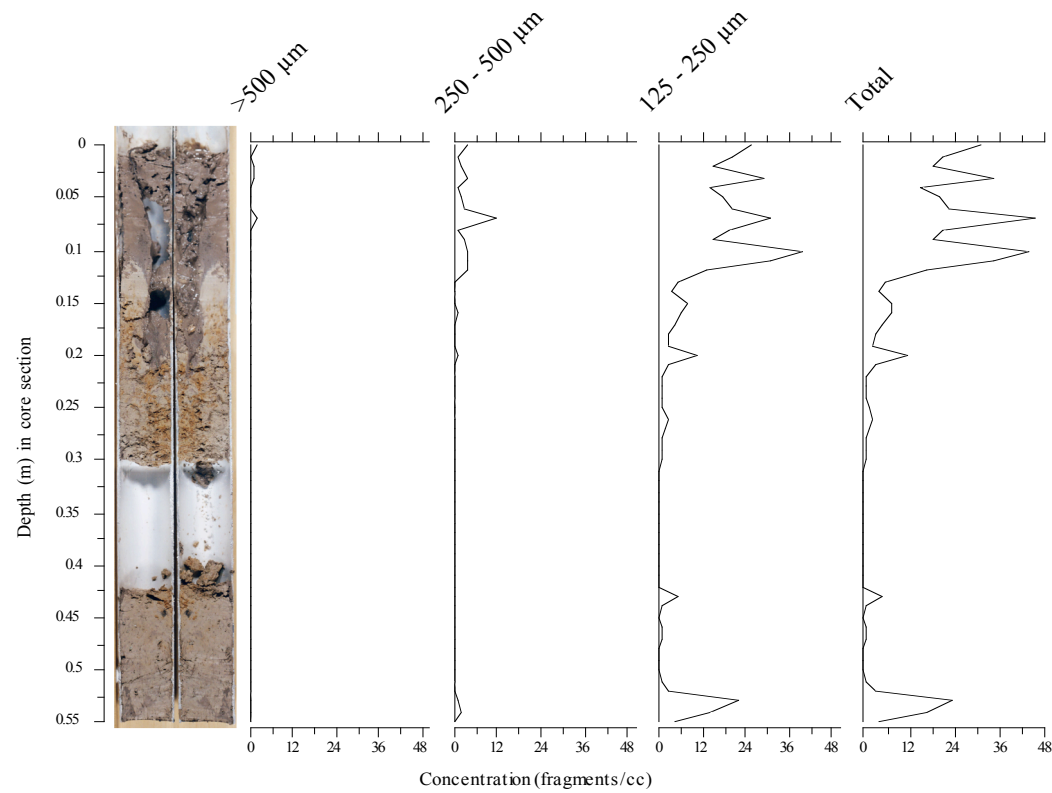


Figure 5.2. Photograph of sediment core section and macroscopic charcoal concentrations from Gum Swamp, Hole 3, 0.40–1.10 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figure 5.1.

Using the weighted mean of the calibrated radiocarbon date from 0.46–0.45 m below the sediment surface mentioned above, and assuming a uniform sedimentation rate above the dated horizon, I calculated the sedimentation rate for the interval from 0.46 m to the surface to be 0.197 cm/yr. Assuming this rate prevailed over the deposition of the entire record allowed me to add a time scale to the charcoal profile (Figure 5.3) and to construct a diagram showing charcoal influx (charcoal fragments/cm²/yr; Figure 5.4). This time scale is based only on one radiocarbon date and should be considered tentative. It is at odds with the prior study of Gum Swamp sediments by Davidson (1983), as will be discussed in the following chapter. Hole 3 shows notable increases in charcoal concentration around 415 and 206 cal yr BP with low concentrations occurring between these time periods. Hole 2 shows increased concentrations at 140 and 105 cal yr BP, as well as between 14 and –1 cal yr BP (AD 1936–1951), with relatively low charcoal concentrations afterwards, to present day. Charcoal influx at Gum Swamp shows the same pattern as charcoal concentration since the same sedimentation rate was applied to the entire profile.

Gum Swamp Loss on Ignition

The LOI results from Hole 2 in Gum Swamp show little variation with depth (Table 5.2). Organic content ranges from 6.5–8.0% calculated on a dry weight basis. Non-carbonate inorganic content ranges from 90.0–92.7%. The estimated carbonate contents mainly range from 1.4–1.8%, with one sample, from 0.24 m, slightly higher at 3.1%.

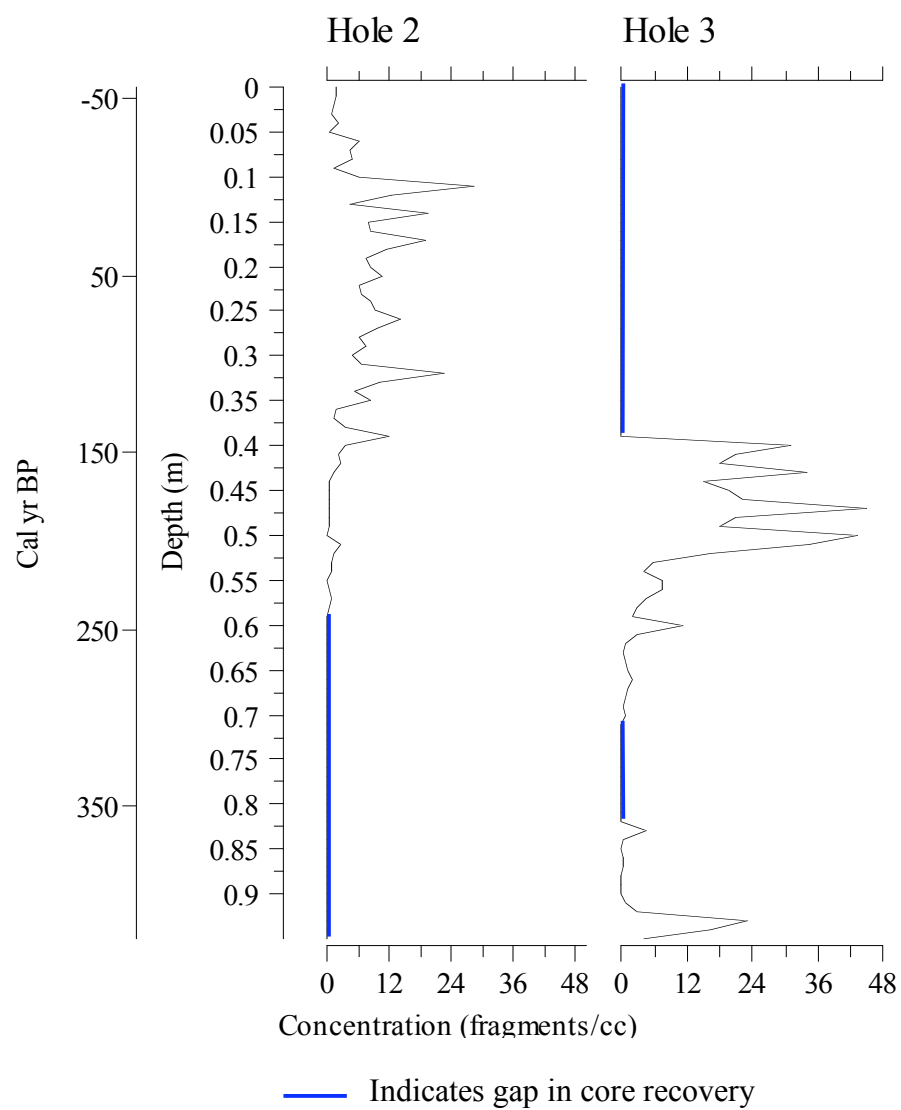


Figure 5.3. Gum Swamp charcoal concentrations for Holes 2 and 3 by depth and calibrated years before present.

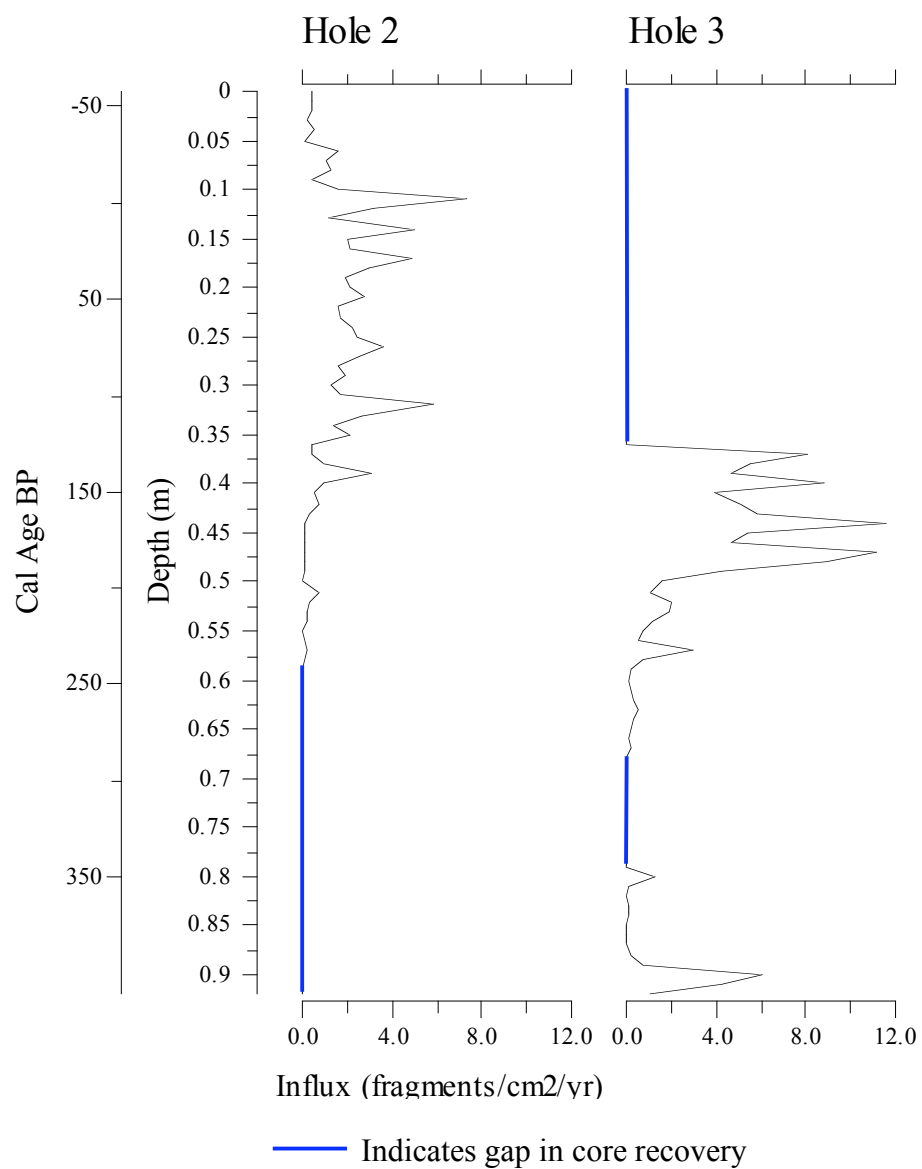


Figure 5.4. Gum Swamp charcoal influx for Holes 2 and 3 by depth and calibrated years before present.

Table 5.2. Gum Swamp loss on ignition results.

Location/Depth below surface (m)	Organic Content (% dry weight)	Non-Carbonate Inorganic Content (% dry weight)	Carbonate Content (% dry weight)
Hole 2: 0.16	6.69	91.87	1.44
Hole 2: 0.24	6.84	90.01	3.15
Hole 2: 0.32	6.91	91.61	1.48
Hole 2: 0.40	5.96	92.67	1.37
Hole 2: 0.48	6.52	91.78	1.70
Hole 2: 0.56	7.98	90.17	1.85

Black Pond Macroscopic Charcoal Analysis

As at Gum Swamp, macroscopic charcoal in the five Black Pond core sections analyzed is principally in the smallest size fraction (125–250 μm), and the three size fractions show similar stratigraphic patterns within each core section (Figures 5.5–5.9). The Hole 1, 2.00–3.00 m core section exhibits very low charcoal concentrations from the bottom of the core section (0.66 m) to 0.37 m, which corresponds to a basal layer of light-colored, fine sediments that may predate lake formation (Figure 5.7). This is followed by a large, varying increase in charcoal concentration from 0.37–0.03 m, which coincides with a layer of peaty sediment with scattered macrofossils. Peaks in charcoal concentration occur at 0.32 and 0.10 m. From 0.03 to 0.00 m, I found relatively low charcoal concentrations.

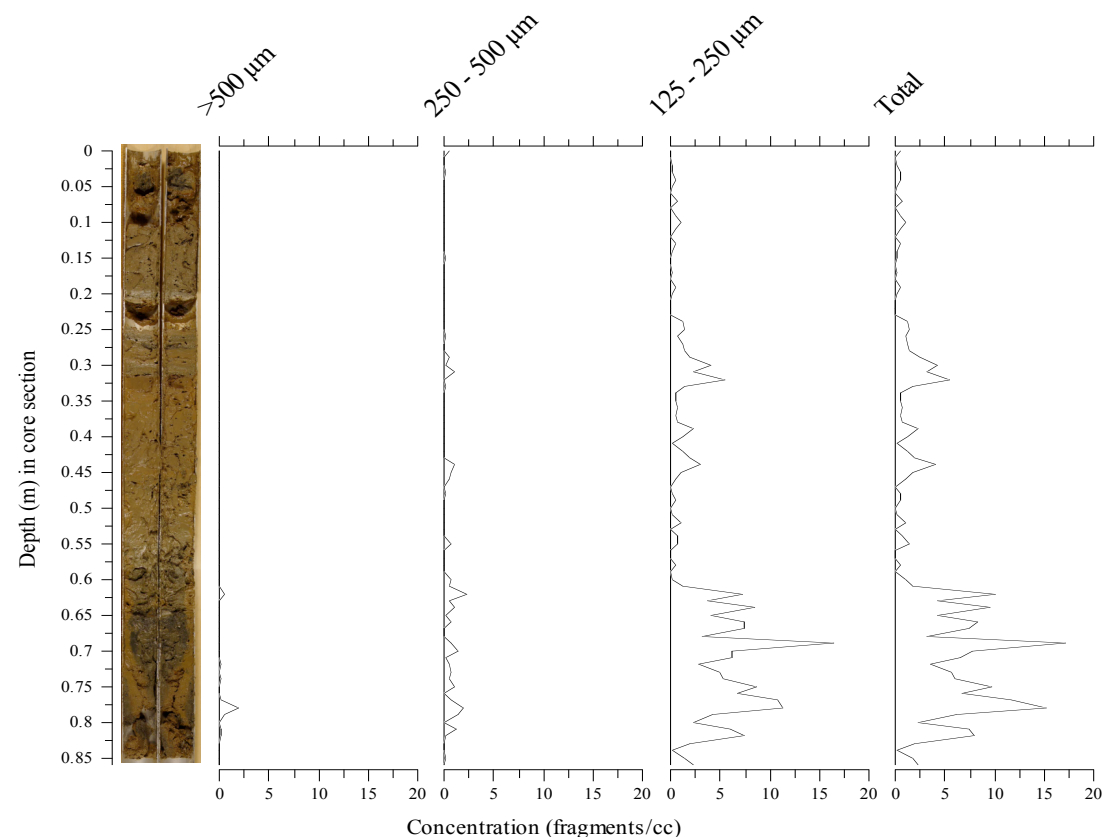


Figure 5.5. Photograph of sediment core section and macroscopic charcoal concentrations from Black Pond, Hole 1, 0.00–1.00 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figures 5.6–5.9.

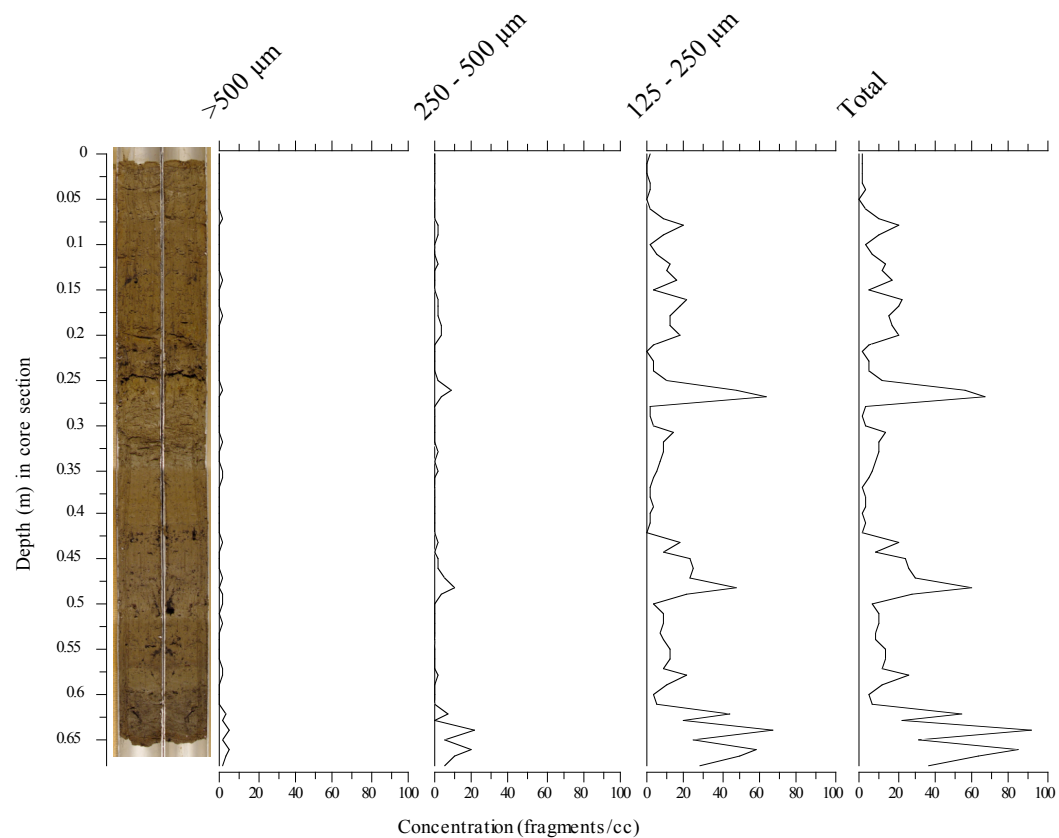


Figure 5.6. Photograph of sediment core section and macroscopic charcoal concentrations from Black Pond, Hole 1, 1.00–2.00 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figure 5.5 and Figures 5.7–5.9.

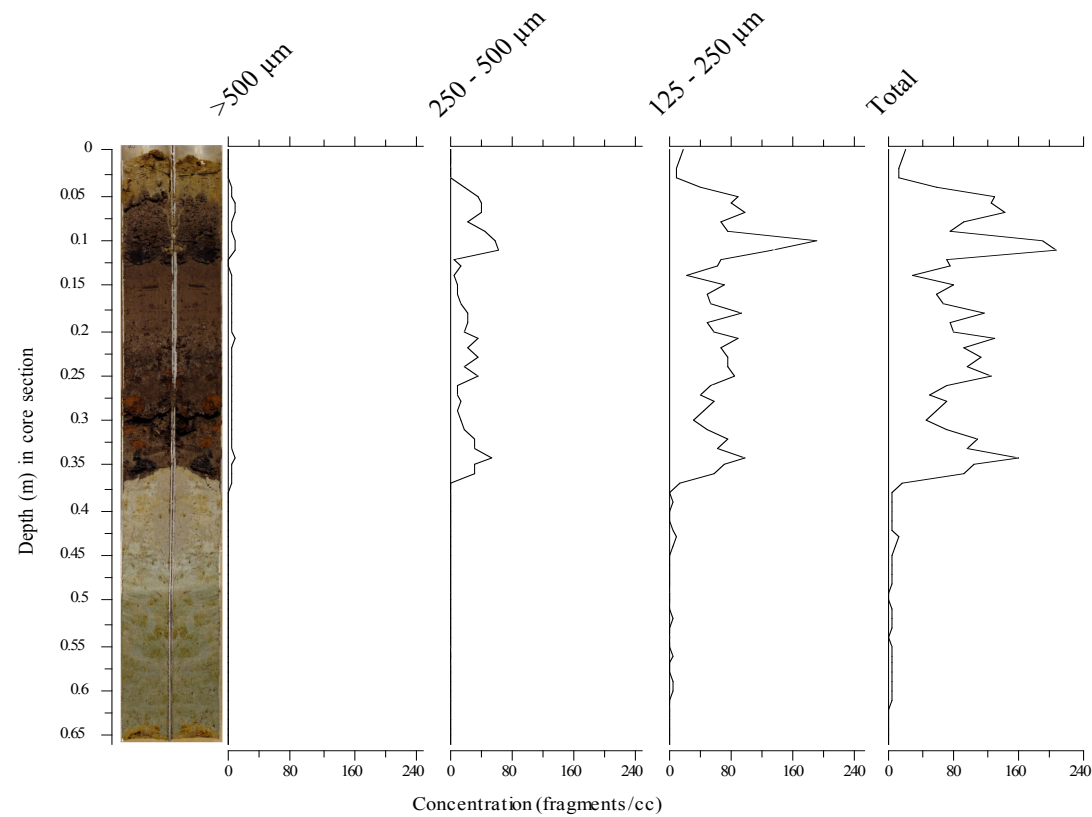


Figure 5.7. Photograph of sediment core section and macroscopic charcoal concentrations from Black Pond, Hole 1, 2.00–3.00 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figures 5.5–5.6 and Figure 5.8.

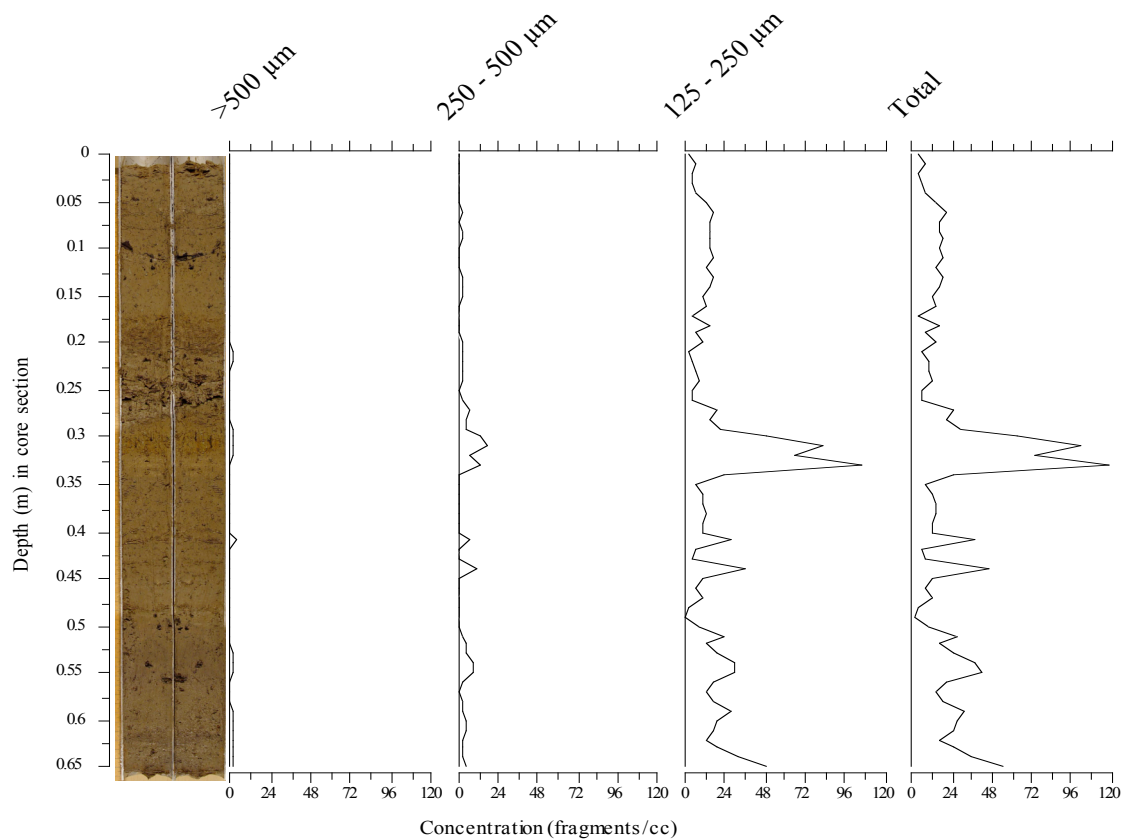


Figure 5.8. Photograph of sediment core section and macroscopic charcoal concentrations from Black Pond, Hole 2, 0.95–1.95 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figures 5.5–5.7 and Figure 5.9.

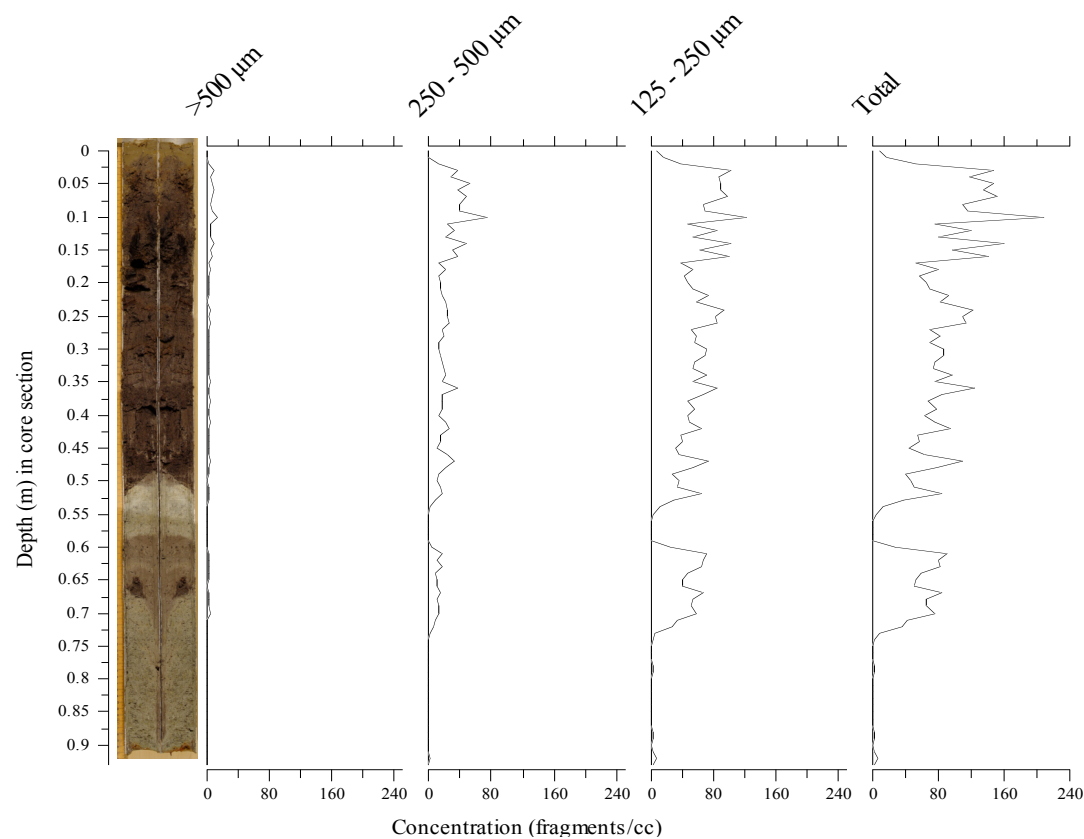


Figure 5.9. Photograph of sediment core section and macroscopic charcoal concentrations from Black Pond, Hole 2, 1.95–2.95 m. Note: the scale was chosen based on the maximum charcoal concentrations in this section and differs from the scale in Figures 5.5–5.6 and Figure 5.8.

The 1.00–2.00 m core section from Hole 1 has generally high charcoal concentrations from 0.66 m (base of core section) to 0.46 m. with higher concentrations at 0.67, 0.64, 0.58, and 0.48 m (Figure 5.6). Lower charcoal concentrations occur from 0.42 to 0.28 m. Concentrations show a peak from 0.27 to 0.25 m, followed by lower, varying values from 0.25 to 0.05 m. Between 0.05 and the top of the core, charcoal concentrations are low. Overall, concentrations in the 1.00–2.00 m core section are generally lower than in the Hole 1 2.00–3.00 m core section.

The 0.00–1.00 m core section from Hole 1 (Figure 5.5) has generally lower charcoal concentrations than the 1.00–2.00 m core section. Highest charcoal concentrations within this section occur between 0.79 and 0.57 m, with peaks at 0.78 and 0.69 m. From 0.57 to 0.00 m, the charcoal concentration is low and varying with small peaks at 0.31 and 0.45 m.

The Hole 2, 1.95–2.95 m core section has similar overall charcoal concentration as Hole 1, 2.00–3.00 m. From 0.93 m (base of the core section) to 0.72 m, charcoal concentrations are very low, followed by high concentrations from 0.72–0.60 m (Figure 5.9). From 0.60–0.53, there is a dramatic dip in charcoal concentration. Between 0.53 and 0.01 m, there are very high charcoal concentrations in the peaty sediment with scattered macrofossils.

The Hole 2, 0.95–1.95 m core section has similar overall concentrations as the Hole 1, 1.00–2.00 m core section. From the end of the core section (0.65 m) to 0.34 m, charcoal concentrations vary with higher levels occurring at 0.64–0.65, 0.55, 0.51, and 0.41 m (Figure 5.8). An increase in charcoal concentration occurs from 0.34 to 0.26 m. From 0.26 to the top of the core, charcoal concentrations are fairly low.

The charcoal records for the composite profiles from Hole 1 and 2 at Black Pond match fairly well (Figure 5.10). The core section from Hole 1, 1.00–2.00 m and that from Hole 2, 0.95–1.95 m show similar peaks in charcoal at about 1.26 m below the sediment surface. The core sections from 2.00–3.00 m below the sediment surface in Hole 1 and 1.95–2.95 m in Hole 2 can be matched stratigraphically using the peaty sediment layer found in both core sections, which contains high concentrations of charcoal. To match the bottom core sections from each hole, I used the transition from peaty sediment to Gley-colored clay/silt and a major decrease in charcoal concentration at about 2.49 m below the sediment surface. Based on this match, it appears that the core section from 2.00–3.00 m in Hole 1 represents the depth interval of about 2.12–2.78 m. I adjusted depths for the Hole 1 samples accordingly in constructing Figure 5.10.

Black Pond Loss on Ignition

The six samples processed for LOI were from the Hole 1, 1.00–2.00 m and Hole 2, 1.95–2.95 m core sections (Table 5.3). In samples from depths of 2.64, 1.66, and 1.45 m, which correspond to clay and silty sediments, the organic content is low (5.5–7.4%), the non-carbonate inorganic content is high (91.7–91.9%), and the carbonate content ranges from 1.0–2.7%. In samples from 2.46, 2.28, and 2.04 m, organic content is high (21.2–28.5%), non-carbonate inorganic content is lower (67.2–78%), and carbonate content is slightly higher (2.8–4.1%). More organic-rich samples all correspond to the layer of peaty sediments with scattered macrofossils found in the lower core section from both holes.

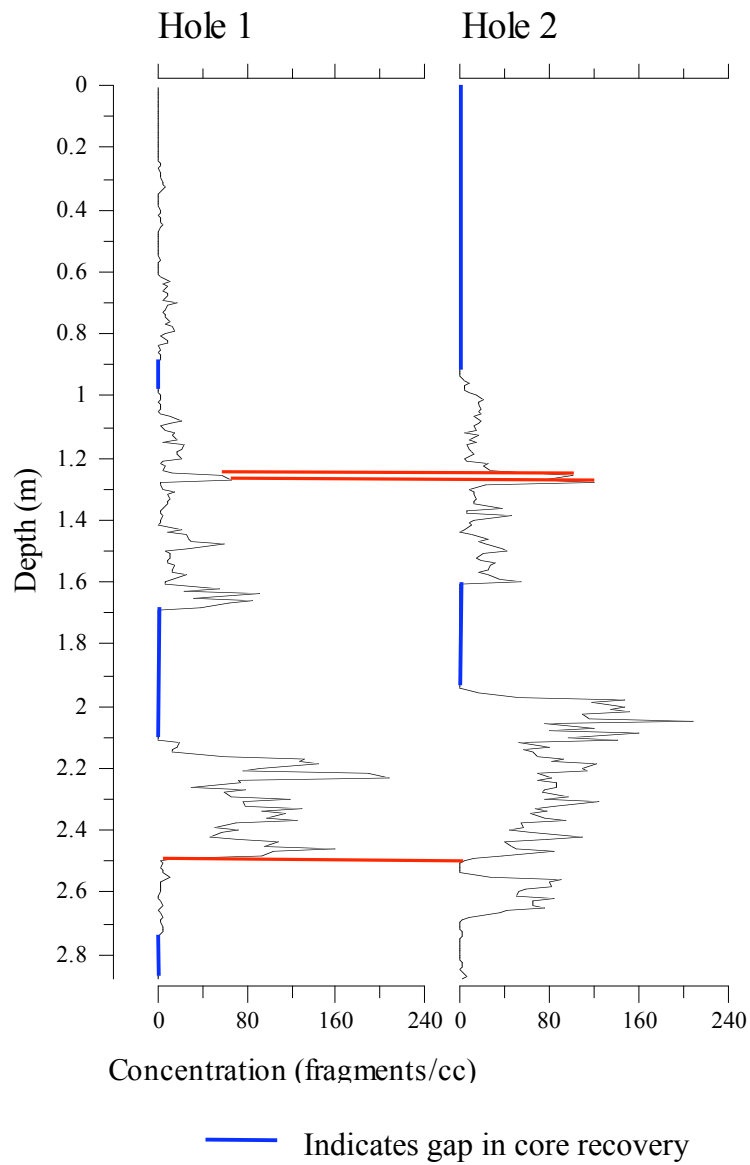


Figure 5.10. Black Pond charcoal concentrations for Holes 1 and 2 by depth. Red lines indicate possible matches between the cores. The match suggested in the lower part of the core is based on sediment stratigraphy as well as charcoal concentrations.

Table 5.3. Black Pond loss on ignition results.

Location/Depth below surface (m)	Organic Content (% dry weight)	Non-Carbonate Inorganic Content (% dry weight)	Carbonate Content (% dry weight)
Hole 1: 1.45	5.45	91.90	2.65
Hole 1: 1.66	7.36	91.69	0.95
Hole 2: 2.04	21.25	75.96	2.80
Hole 2: 2.28	27.96	68.52	3.53
Hole 2: 2.46	28.54	67.28	4.18
Hole 2: 2.64	5.87	91.79	2.34

Black Pond Pollen Analysis

The pollen results (Table 5.4) show that the raw number of *Ambrosia* pollen grains counted increases dramatically at 1.45 m below the sediment surface at Black Pond. At this level, the ratio of *Ambrosia* to *Pinus* pollen is very high at 2.19. In samples taken at greater depth, the ratio is much lower, from 0.07–0.01. Pollen concentrations for these two pollen types were calculated based on the count of control spores.

Gum Swamp and Black Pond Macroscopic Charcoal and LOI Comparisons

Charcoal concentrations in the upper meter of the Gum Swamp record are higher than those in the upper meter of the Black Pond record (Figure 5.11). However, sediments below 1.00 m depth at Black Pond show charcoal concentrations much higher than recorded at Gum Swamp (Figure 5.10). Discounting the sections of the Black Pond cores with high organic content, the LOI results at the two sites are similar (Tables 5.2 and 5.3).

Table 5.4. *Ambrosia* and *Pinus* pollen counts, ratios, and concentrations in Black Pond sediments.

Location/depth below surface (m)	<i>Ambrosia</i> pollen count	<i>Pinus</i> pollen count	Ratio of <i>Ambrosia</i> to <i>Pinus</i>	Number of control spores	<i>Ambrosia</i> concentrations (pollen/cm³)	<i>Pinus</i> concentrations (pollen/cm³)
Hole 1: 1.45	219	100	2.19	115	52982	24193
Hole 1: 1.66	7	100	0.07	333	585	8355
Hole 2: 2.04	1	100	0.01	208	134	13376
Hole 2: 2.28	2	100	0.02	179	311	15543
Hole 2: 2.46	1	100	0.01	84	331	33121
Hole 2: 2.64	1	100	0.01	86	324	32351

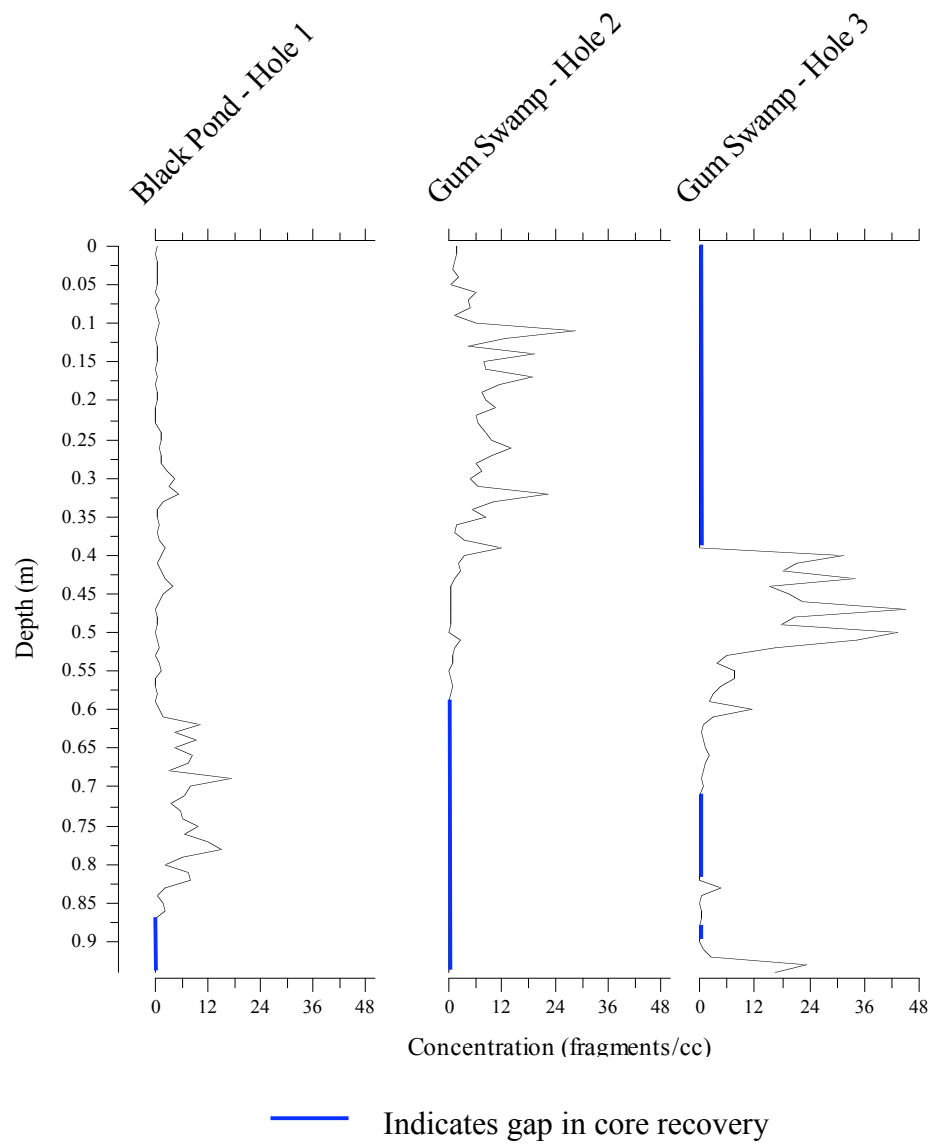


Figure 5.11. Macroscopic charcoal concentrations in upper 1 m of Black Pond and Gum Swamp profiles.

CHAPTER 6

Discussion

The macroscopic charcoal records from Gum Swamp and Black Pond improve upon prior studies of microscopic charcoal in sediment cores from these sites and complement tree-ring and soil charcoal evidence of fire at other sites in Great Smoky Mountains National Park and east Tennessee. This chapter discusses the fire history at Gum Swamp and Black Pond, connects and contrasts the findings with previous studies at and around these sites, and explores management implications of the fire history records.

What are the general trends in fires at Gum Swamp in Cades Cove, Great Smoky Mountains National Park as seen through macroscopic charcoal analysis of pond sediments?

Davidson (1983) interpreted microscopic charcoal in the Gum Swamp core she studied to reflect nearby fires. This interpretation is based on the small size of the watershed and Davidson's assumption that microscopic charcoal, like pollen, that is deposited in a small forest hollow would be derived from a small source area. The presence of macroscopic charcoal in the Gum Swamp sediments strengthens the evidence for local fires, as macroscopic charcoal particles ($\geq 125 \mu\text{m}$) are not believed to travel long distances by wind and convection because of the size and weight of the fragments (Long et al. 1998, Millspaugh et al. 2000, Whitlock and Larsen 2001). However, the

timing of past fires as well as shifts in vegetation identified by Davidson (1983) in her study of microscopic charcoal and pollen in the Gum Swamp sediments is not confirmed by the results of my study. The radiocarbon dates on bulk sediment from the site obtained by Davidson do not match the AMS ^{14}C date on charcoal that I obtained. Although I was able to obtain only one date, an AMS date on charcoal is, by today's standards, a more reliable indication of the age of sediments than a bulk date on low-carbon sediment. My date of 200 ± 40 yrs BP at 0.45–0.46 m depth calls into question Davidson's interpretation that a peak in charcoal at only about 0.15 m in her core corresponds to a fire around 1700 yr BP. I tentatively interpret the entire Gum Swamp profile as spanning hundreds of years, not many thousands as Davidson (1983) interpreted from her dates.

Future confirmation of this revised chronology will require additional dates on charcoal or other macrofossils in the Gum Swamp sediments. New cores will be needed to attempt this, however, as existing cores do not contain suitable material for dating. It is important to note that without additional dates for confirmation, I cannot rule out the possibility that the charcoal that I extracted from the soil auger cores taken in November 2007 could have been affected by bioturbation. However, the fact that charcoal dated was removed from a depth that matches exactly with a major increase in charcoal concentration in the macroscopic charcoal record would appear to argue against bioturbation. For this reason, I regard the charcoal date as accurately indicating the age of the sediments.

The macroscopic charcoal record for Gum Swamp shows generally lower charcoal concentration and influx prior to about 200 cal yr BP (AD 1750) than after this time. Although Native Americans were known to have cleared and burned some areas within the southeastern United States, extensive clearing and burning likely did not take place until Euro-American settlement (Delcourt and Delcourt 1997). A charcoal peak around 415 cal yr BP (AD 1540) could signal Native American or natural burning within the area. The lower part of the Gum Swamp macroscopic charcoal record contains gaps caused by poor sediment recovery so some fire events could be missing within this time frame.

Higher charcoal concentration and influx above depths of 0.39 m (141 cal yr BP or AD 1809) in Hole 2 and 0.51 m (201 cal yr BP or AD 1749) in Hole 3 can be attributed to Euro-American settlement within Cades Cove. Euro-American settlement began in the mid- to late 1800s in Cades Cove and resulted in extensive clearing and burning of the land (Davidson 1983). The macroscopic charcoal data from Gum Swamp appear to match the known land use history.

The low charcoal abundance in the upper 0.10 m of the Hole 2 sediment core section indicates few fires in recent decades. One reason for a small amount of incoming charcoal is fire suppression. As part of Great Smoky Mountains National Park, Cades Cove has been subjected to fire suppression since the 1930s (Harmon 1982).

Although Great Smoky Mountains National Park has experienced fire suppression since the 1930s, the macroscopic charcoal record of Gum Swamp does not show this initial decline in incoming charcoal fragments until about –6 cal yr BP (AD 1956).

However, given that all ages are extrapolated from one date, there may be no discrepancy. If the Gum Swamp record does reveal a true delay in the macroscopic charcoal signal, the explanation could be an influx of secondary charcoal entering the pond through surface runoff (Whitlock and Larsen 2001), or primary charcoal arriving from fires that continued to be set in association with farming and grazing within Cades Cove (Young 2006).

What are the general trends in fires at Black Pond in eastern Tennessee as seen through macroscopic charcoal analysis of pond sediments?

As at Gum Swamp, my analyses of macroscopic charcoal in the Black Pond sediments follow previous research on microscopic charcoal. Cridlebaugh (1984) studied charcoal on pollen slides prepared from a core recovered in 1982 that reached the same depth and had a stratigraphy similar to that of the profiles I studied. Based on two radiocarbon dates on bulk sediment (a third date was out of sequence and rejected), she estimated that the record covered about 3030 years. Although I am confident in the stratigraphic match between the core sections I analyzed and Cridlebaugh's original core, I have not adopted her core chronology. I report and discuss the macroscopic charcoal data only in terms of concentration, not influx. For now, while my AMS radiocarbon determinations are pending, I focus on patterns of charcoal abundance in the Black Pond sediments according to depth, but do indicate possible approximate time frames suggested by Cridlebaugh's analysis. It should be pointed out that her study also relied on standard radiocarbon dates on bulk sediment. Such analyses have largely been

replaced today by AMS dating of macrofossils, an approach generally regarded as yielding more accurate dates. My in-progress AMS analyses will provide a chronology for the new macroscopic charcoal record and a more secure chronology for Cridlebaugh's analyses.

The trends in variations of macroscopic charcoal abundance at Black Pond likely reflect variations in natural as well as human-set fires. The high-charcoal sections below the sediment gaps correspond stratigraphically to a section in the Cridlebaugh (1984) pollen record from Black Pond that predated the earliest maize pollen and appeared to contain no other evidence of human activity (Delcourt et al. 1986, Delcourt 2002). Based on that, I tentatively attribute the charcoal peaks during this interval to natural fires.

The sections of moderate charcoal concentration from about 1.70 to 1.00 m may correspond to the early period of human activity and settlement in the area, based on stratigraphic comparison with the Cridlebaugh (1984) core. The lower charcoal concentrations at depths of 0.88–0.62 m may indicate a shift to low-intensity agricultural burning, which might produce smaller charcoal fragments (Whitlock and Larsen 2001). Other factors, however, could also explain this pattern. For example, the more numerous charcoal fragments found in the lower portions of the cores may have been from fires that occurred directly surrounding the pond, whereas the less numerous charcoal fragments in the upper portions of the cores may have been deposited from fires that occurred farther away from the pond via winds, overland flow, or other secondary depositional means.

The very low charcoal concentrations at depths of 0.62–0.00 m likely reflect times of modern-day agriculture and general fire suppression throughout the United States. It is

possible that while these sediments were accumulating, the area surrounding Black Pond was mostly or completely cleared, leaving little fuel for fires to be ignited or for ignited fires to spread (Carcaillet et al. 2001a). Cridlebaugh's (1984) study of Black Pond revealed that for approximately the last 200 years, the land surrounding the pond was used for grazing, agriculture, or allowed to lie fallow. This historic land use may not have included intentional burning. Whatever the cause, the decline in charcoal concentration indicates few fires close to Black Pond during the most recent interval of sediment deposition. However, fires probably occurred at some distance from the site as smaller charcoal fragments (125–250 μm in this study and <100 μm in Cridlebaugh's study) were found in the sediment.

How do the macroscopic charcoal records from two sites with similar forest composition compare?

As the Black Pond AMS radiocarbon dates are not yet available and sedimentation rates at each site are unique, I will discuss this question in terms of charcoal concentration and depth, rather than charcoal influx over time. In comparing the first meter of sediment at each site, Gum Swamp had an overall higher macroscopic charcoal concentration, but with all core sections from Black Pond considered, Black Pond had a higher concentration overall. Many explanations are possible for the differences in charcoal concentration in cores from sites with similar forest composition. First and foremost, sedimentation rates at the sites will have a great impact on charcoal concentration. If sedimentation is slow at a site that has a large amount of incoming

charcoal, charcoal concentrations will be higher. Likewise, if sedimentation is rapid at a site that has the same high amount of incoming charcoal, charcoal concentration will be lower. Also, the amount, intensity, and severity of fires can differ between sites. Gum Swamp is located in an area that was apparently settled well before upland Black Pond, so the historic and prehistoric structure of the forests likely differed, affecting fire occurrence, even though the forest composition might be similar at the sites.

Unlike Gum Swamp, Black Pond is not located within a protected area. Therefore, the Black Pond macroscopic charcoal record does not show the dramatic decrease in charcoal concentration associated with historic fire suppression that was found at Gum Swamp. Also, the overall higher macroscopic charcoal abundance in the Black Pond sediments, which corresponds to a higher abundance of all plant macrofossils, contrasts sharply with that of the Gum Swamp sediments, which contained very few macrofossils.

How do the new macroscopic charcoal data compare to the previous pollen and microscopic charcoal records produced by Davidson (1983) and Cridlebaugh (1984) at these sites?

Davidson (1983) and Cridlebaugh (1984) both expressed their microscopic charcoal data as charcoal area influx (μm^2 charcoal/ cm^2 /year), and graphed their results by time, not depth. Both researchers included tables of raw data in their theses that included charcoal area counts on transects across pollen slides. Davidson, unfortunately, did not indicate the number of grains of *Eucalyptus* pollen, which she had added as a

spike, that were tallied while counting charcoal, making it is impossible to calculate charcoal area concentration (μm^2 charcoal/ cm^3) from her data. However, in addition to a charcoal area influx curve, Davidson presented a second curve that she labeled “charcoal μm^2 * *Eucalyptus* grain counted.” This label appears to be a typographical error (missing a “-1” after “counted,” S. Horn, pers. comm.) as the curve seems to actually show the charcoal area values divided by the pollen spikes counted. In the text of her thesis, Davidson explained that she adjusted the *Eucalyptus* values to account for the different number of control tablets she added to the samples. Assuming she did this correctly, her curve provides a measure of relative charcoal area concentration because the same volume of sediment was processed for each sample (S. Horn, personal comm.). To plot the same data by depth to compare with my macroscopic charcoal concentration data from Gum Swamp (Figure 6.1), Sally Horn and I visually estimated values from Davidson’s curve. This was difficult for samples below 0.30 m because she graphed these points very close together as her age model indicated they were close in age. The straight line below 0.30 m in Figure 6.1 shows the maximum concentration for that set of samples.

The macroscopic charcoal concentrations for the 2007 Gum Swamp core profiles are more variable than the relative microscopic charcoal data presented in Davidson’s (1983) study (Figure 6.1). This higher variability appears to be caused by sampling resolution, which was at continuous 1-cm intervals in the 2007 profiles but at coarser resolution in the 1983 profile based on charcoal on pollen slides. The 2007 profile from Hole 3 and Davidson’s 1983 profile both show a general upcore increase in charcoal

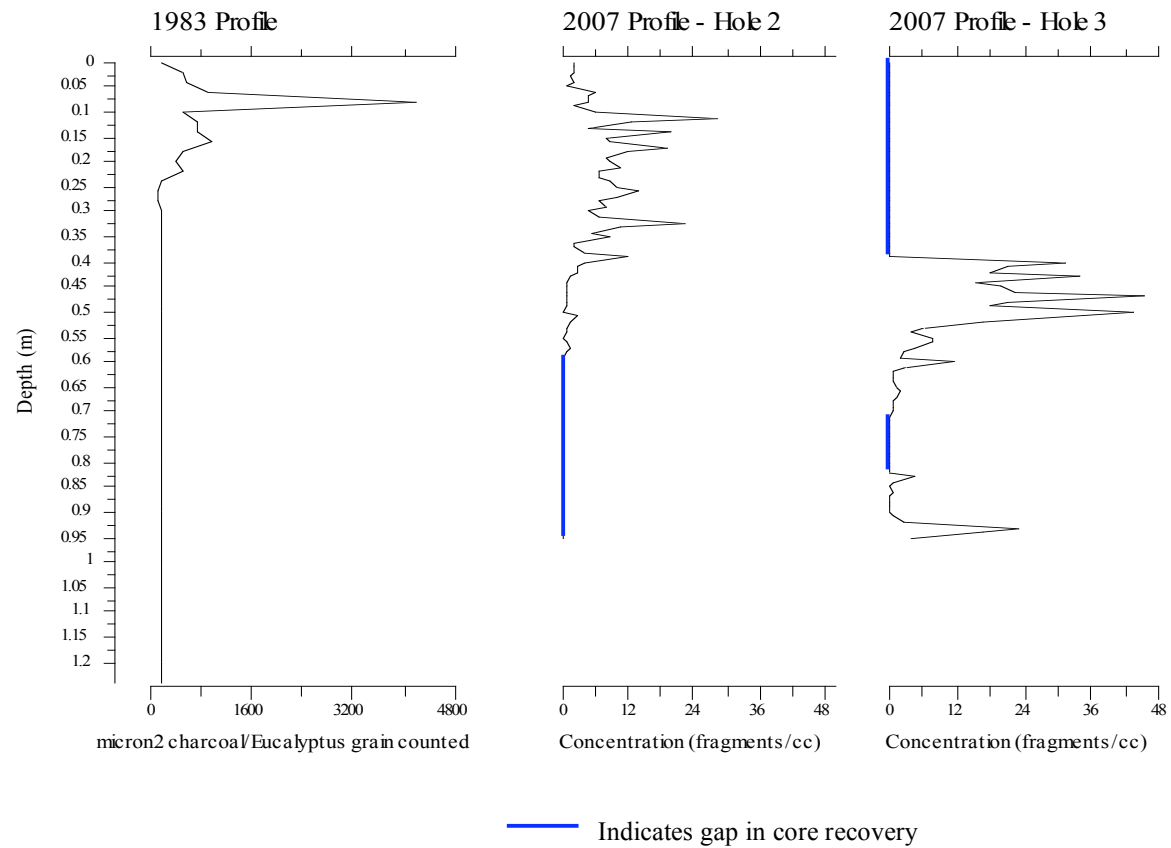


Figure 6.1. Gum Swamp relative microscopic charcoal concentrations (based on charcoal area recalculated from Davidson, 1983) and macroscopic charcoal concentrations (this study).

concentrations. Hole 3, however, shows some charcoal peaks at 0.93 and 0.83 m, possibly missed by Davidson's coarser sampling interval. Davidson's (1983) study also shows a generally low charcoal concentration to the end of her core (1.24 m). A sudden increase in charcoal at 0.51 m in the 2007 sediments might signal disturbance of the forests surrounding Gum Swamp. Davidson (1983) cites a major decline in *Salix* (willow) and *Liquidambar styraciflua* (sweetgum) and an increase in shrubs and herbs at about 0.30 m depth in her profile. The decrease in arboreal species and increase in shrubs could signify a major episode of land clearance in Cades Cove that included the use of fire.

Davidson's (1983) study indicates a major increase in charcoal concentration at about 0.08 m. The macroscopic charcoal concentrations show a peak in charcoal at 0.11 m that could correlate with Davidson's peak. My charcoal record would be expected to show a peak a little deeper in the profile because the sediment I studied could include about 25 more years of accumulated sediment.

The general similarities of the microscopic and macroscopic charcoal trends in the upper 0.25 m of the 1983 and 2007 profiles from Gum Swamp suggest that microscopic charcoal records local fires in recent decades. This finding is in keeping with Whitlock and Millspaugh's (1996) conclusions that charcoal fragments of different size classes show a similar pattern in distance traveled after a fire event and that microscopic charcoal in some situations can signal local fires. However, below 0.25 m, the records diverge for unknown reasons.

As stated before, a major issue with Davidson's (1983) study is poor chronological control. Davidson (1983) determined that the age of the sediment at 0.30 m was about 6300 yr BP while the age of the sediment at 0.70 m was 6410 yr BP. This indicated very fast sedimentation below 0.30 m depth (1.75 cm/yr) and very slow sedimentation above this (0.005 cm/yr). While it is possible that sedimentation in a basin can change over time, a decrease of this magnitude seems hard to explain, especially given the likelihood that historic human activities would have increased erosion in areas surrounding the pond, leading to higher sedimentation. Gum Swamp does not have any incoming streams to carry in sediment and is a fairly enclosed site that would likely inhibit excessive wind erosion, likely resulting in slow sedimentation rates (Sundborg 1992). The date obtained in this study, of about 174 cal yr BP at a depth of 0.45–0.46 m, indicates a sedimentation rate of 0.197 cm/yr, perhaps not as slow as would be expected though much slower than as Davidson interpreted for the lower part of her record. Rather than using the weighted mean of the calibrated age for the charcoal I dated, it may be more appropriate to use the high (older) end of the calibrated age range, or 308 cal yr BP (Table 5.1).

It is also important to note that Davidson's (1983) sediment core was 1.24 m while our sediment cores extended to no deeper than 1.00 m. Probing of the sediments to bedrock in various locations throughout the pond in 2007 revealed maximum sediment depths of 1.08 m. It is possible that Davidson cored in a location that was not probed or cored for this study, as there were variations in sediment depth. It is also possible that between 1983 and 2007, Gum Swamp experienced an interval or intervals of sediment

deflation during droughts. This could have consequences for how the 2007 and 1983 cores match up. If recent sediment is missing, our sediment surface could have actually been deeper, and subsequently older, than Davidson's (1983) sediment surface.

Cridlebaugh (1984), like Davidson (1983), expressed her data on microscopic charcoal in the Black Pond sediments as charcoal area influx (μm^2 charcoal/ cm^2/year), and graphed the influx data by time rather than depth. Her data tables, however, included all information I needed to calculate charcoal area concentrations (μm^2 charcoal/ cm^3) and replot them by depth to facilitate comparison with my macroscopic charcoal profiles (Figure 6.2). The comparison reveals that Cridlebaugh's (1984) microscopic charcoal concentrations show a trend somewhat similar to the macroscopic charcoal profiles presented in this study.

Both studies indicate low charcoal abundance at the bottom of the sediment cores (from approximately the bottom of the core to 2.65 m in this study). The macroscopic charcoal profiles show an increase in charcoal concentrations between about 2.65 m (Hole 2) or 2.50 m (Hole 1) and 2.00 m, whereas the microscopic charcoal values show only a small peak between 2.50 and 2.30 m and do not reach highest values for this interval until somewhat later in the record, about 2.00 m. These differences might be explained by variations in coring positions within the pond. Cridlebaugh (1984) cored this pond close to the geometric center while this study used two cores extracted from adjacent but off-center locations. A study by Whitlock and Millspaugh (1996) illustrated the variability in charcoal and sediment accumulation that occurs between sites by analyzing sediment cores taken across lake transects. Despite how these differences occurred, Cridlebaugh (1984)

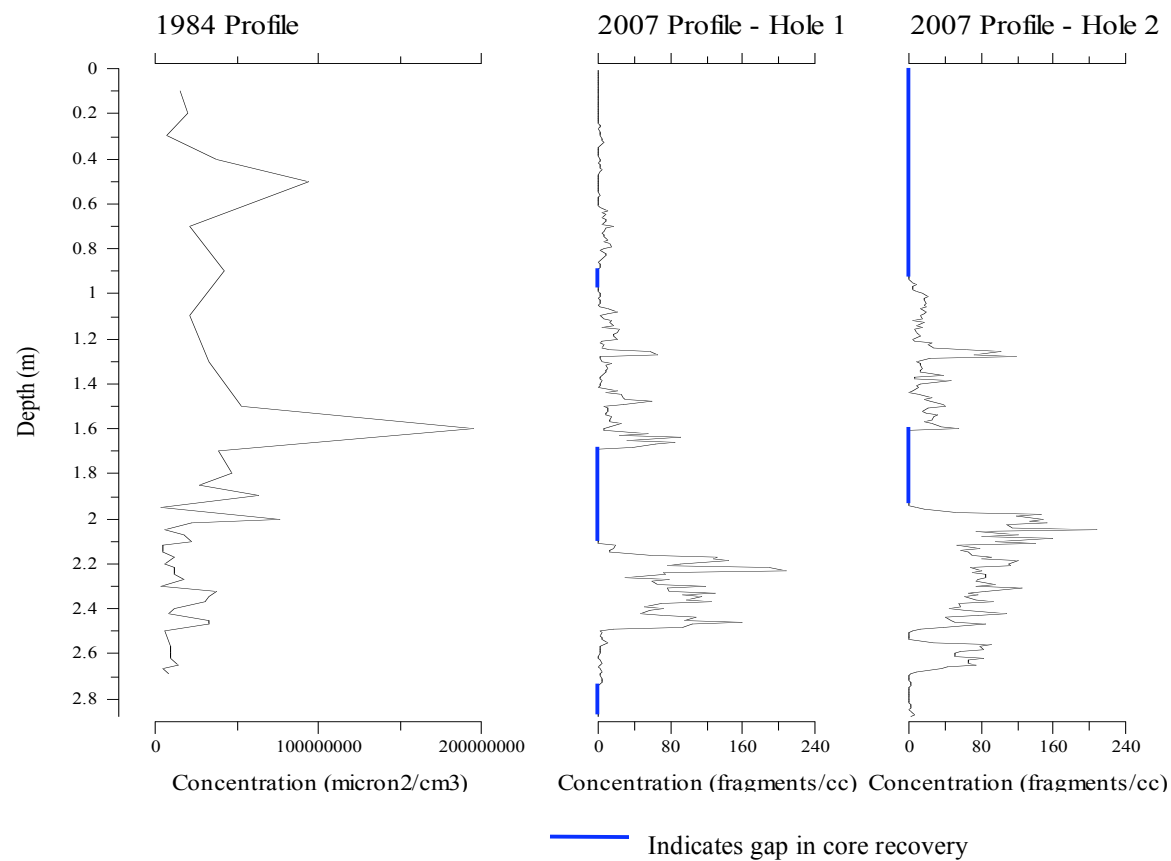


Figure 6.2. Black Pond microscopic charcoal concentrations (recalculated from Cridlebaugh, 1984) and macroscopic charcoal concentrations (this study).

cites 2.00 m to be the beginning of the *Ambrosia* rise. This increase in *Ambrosia* pollen percentages signals land disturbance, likely major land clearance that was accompanied by increased use of fire.

The charcoal peak near 1.60 m in the 2007 Hole 1 profile matches Cridlebaugh's (1984) largest peak in microscopic charcoal. Above that, both records show a general decrease in charcoal abundance to the present day, with a few peaks in the high resolution macroscopic charcoal profile that could indicate fire missed in the microscopic charcoal study. Just as with Gum Swamp, comparing the macroscopic and microscopic charcoal records shows the tendency of the microscopic charcoal concentrations at this lake to somewhat mimic the macroscopic charcoal concentrations (Whitlock and Millspaugh 1996). More variability in charcoal concentrations is evident in the upper portions of the sediment from the macroscopic charcoal record than in the microscopic charcoal record caused by a higher sampling resolution. The peak at about 0.50 m in the microscopic charcoal record was not found in the macroscopic charcoal record, perhaps indicating that this was not the result of a local fire.

How do the LOI data from Davidson's (1983) Gum Swamp study and this study compare?

The LOI organic content data obtained in 1983 (Table 6.1) and in 2007 (Table 5.2) are similar. The data from the 1983 study by Davidson (1983) show more variable organic contents, especially in the upper 0.15 m of her core, which was higher in the profile than I sampled. In the levels sampled for the 2007 study, organic percentages match closely

Table 6.1. Gum Swamp loss on ignition data for 1983 profile (Davidson 1983) and 2007 profile (this study).

Location/Depth below surface (m)	Organic Content (% dry weight): <i>1983 Profile</i>	Organic Content (% dry weight): <i>2007 Profile</i>
0.00	22.31	
0.02	21.92	
0.04	18.17	
0.06	13.28	
0.08	17.82	
0.10	11.15	
0.12	14.94	
0.14	1.25	
0.16	8.67	6.69
0.18	7.89	
0.20	8.19	
0.22	8.41	
0.24	7.89	6.84
0.26	7.63	
0.29	2.24	
0.30	7.39	
0.32		6.91
0.34	6.73	
0.40		5.96
0.48		6.52
0.50	7.14	
0.56		7.98
0.60	12.03	
0.80	6.12	
0.90	6.17	
1.00	10.21	
1.20	6.00	

(mostly within a 1% difference) with results from the study completed in 1983. The close values in the middle portions of the cores from each study help to confirm the match between the Hole 2 and 3 profiles from 2007 and Davidson's (1983) core.

How do the LOI data from Gum Swamp and Black Pond compare?

The six samples from each of Black Pond and Gum Swamp that were processed for LOI show some similarities and differences. The Gum Swamp sediments did not contain a peaty layer of sediment as did Black Pond so the Gum Swamp profile does not show an interval of high organic content. The change in the Black Pond sediment to more organic and then back to less organic shows a change in the conditions surrounding the pond that Gum Swamp did not experience.

How does the pollen record completed by Cridlebaugh (1984) at Black Pond compare to the limited pollen record completed for this study?

To try to identify the rise in *Ambrosia* pollen percentages interpreted by Cridlebaugh as a signal of late Mississippian-age human impact at Black Pond, I determined ratios of *Ambrosia* to *Pinus* pollen in six samples and compared the results to ratios calculated from Cridlebaugh's (1984) original data. I found similar *Ambrosia* to *Pinus* ratios around 1.70 and 1.30 m (1984 record) and 1.45 m (2007 record; Figure 6.3). Based on Cridlebaugh's pollen ratios, the *Ambrosia* rise must be above 1.66 m in the 2007 profiles because no samples after the *Ambrosia* rise have ratios as low as found in the 1.66 m sample.

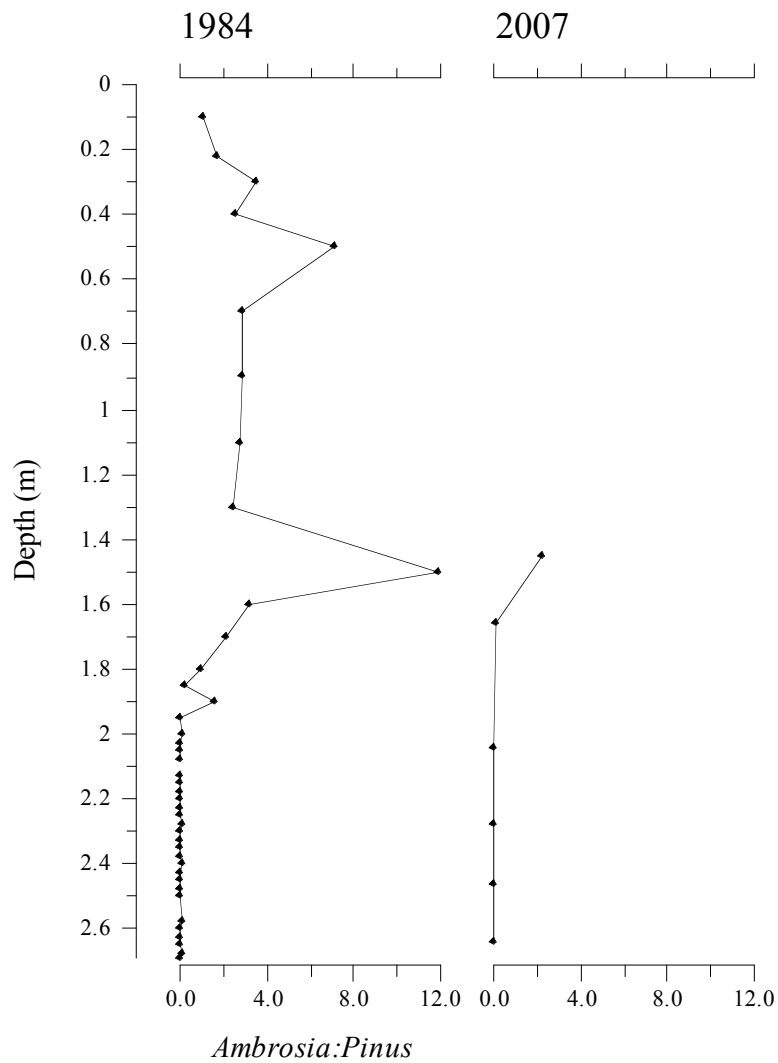


Figure 6.3. Comparison of *Ambrosia:Pinus* pollen ratios in 1984 and 2007 profiles from Black Pond. 1984 data are from Criddlebaugh (1984).

Both pollen records show low *Ambrosia* to *Pinus* ratios in the lower part of the profiles, from the base to 1.95 m in the 1984 record and from the base to 1.66 m in the 2007 record. An increase in the *Ambrosia* to *Pinus* ratio in the 1984 record begins at 1.90 m, decreases at 1.85 m, and then rises with a peak in the ratio occurring at 1.50 m. While the 2007 pollen profile does not show an increase in the *Ambrosia* to *Pinus* ratio until 1.45 m, higher ratios might exist in unsampled sediment between 1.66 and 1.45 m. Based on similarities in ratios, I cautiously suggest that the 1.66 m and 1.45 m depths in the 2007 profile correspond to depths of 1.85 and 1.70 m in the 1984 record (Figure 6.3).

The offset of about 0.25 m in depths of the spike in *Ambrosia* to *Pinus* ratio cannot be attributed to the lag time between coring for the studies. Cridlebaugh (1984) cored Black Pond in 1982, leaving about 25 years of deposition between that time and the time when we cored the lake. Sedimentation is to be expected. The 2007 data, however, show the rise in *Ambrosia* to *Pinus* ratio occurred at a shallower depth than the 1984 data. Because the 2007 record is very coarsely sampled, however, it is possible that a large peak in ratio may exist between 1.66 and 1.45 m that would match the peak found in higher sediments (shallower depth) in the 1984 core. In this case, the explanation for the offset could be sedimentation since 1982.

Other possibilities as to why my *Ambrosia* rise might not align with Cridlebaugh's (1984) data are coring location and core slippage. We cored in an area no longer covered by water, though the sediment was still saturated, and somewhat closer to the edge of the pond than the site that Cridlebaugh (1984) selected for coring. At this location, especially with water no longer covering the sediment, erosion or less

sedimentation could have occurred closer to the edge of the pond. The possibility of the core slipping in the core tube or the piston not engaging immediately is relevant as we did have trouble with the C-V corer at this site. These problems could also produce an apparent offset.

Cridlebaugh (1984) separated Black Pond's depths, cultural periods, and calculated dates into these four intervals: Late Archaic (3000–2850 yr BP, 2.69–2.65 m depth), Woodland (2850–1000 yr BP, 2.65–2.17 m depth), Mississippian (1000–300 yr BP, 2.17–1.50 m depth), and Historic (300 yr BP–Present, 1.50–0.0 m depth). The 1984 record shows the rise in *Ambrosia* pollen percentages occurred between 1.95 and 1.90 m, and a similar increase in *Ambrosia* to *Pinus* ratio occurred at 1.70 m, all during the Mississippian interval. Based on Cridlebaugh's (1984) radiocarbon chronology, I cautiously interpret the *Ambrosia* rise recorded at 1.45 m in the 2007 profile as occurring during the Mississippian Period, sometime between 1000–300 yr BP. This tentative association between the two records provides an interim chronology while the results of AMS radiocarbon dating are pending.

How do the macroscopic charcoal studies at Gum Swamp and Black Pond compare to tree-ring and soil charcoal records of fire at other sites in Great Smoky Mountains National Park and eastern Tennessee?

Several dendroecological studies completed in Great Smoky Mountains National Park and eastern Tennessee in general show some association with the macroscopic charcoal records presented in this document. Harmon (1982) studied fire in Great Smoky

Mountains National Park using tree rings and determined that anthropogenic fires increased in occurrence in the lowlands (such as Cades Cove) from 1850–1940 because of Euro-American settlement. The macroscopic charcoal record for Hole 2 at Gum Swamp does show relatively high charcoal concentrations during this period with lower concentrations prior to this period. However, Hole 3 shows higher charcoal concentration prior to 1850. A possibility as to why Gum Swamp might have peaks in charcoal concentration before the interval of high fire frequency in Harmon's (1982) study is that his study focused mostly on time periods after 1856. The area near Gum Swamp was likely settled by Native Americans prior to Euro-American settlement and would have experienced burning for land clearance and agriculture (Davidson 1983).

The presence of macroscopic charcoal in the 2007 Gum Swamp profile is consistent with the results of the preliminary study of charcoal in soil cores taken from the area surrounding the pond by University of Tennessee undergraduate students Jessica Jones and John Thomason (Horn, unpublished data). Additional soil charcoal work in this area, including identification and dating of charcoal particles recovered, could contribute a coarse fire history for the area that might help improve the interpretation of my high-resolution study of charcoal in the pond sediments. However, forest clearance and agriculture around Gum Swamp has likely mixed the soils and charcoal within them, making it difficult to infer fire history from charcoal stratigraphy within soil cores.

Because of the lack of firm chronological control for the Black Pond macroscopic charcoal record, this site is less easily correlated with previous studies of

soil charcoal. Hart et al. (2008) used soil charcoal to determine fire history in a mixed hardwood forest on the Cumberland Plateau of Tennessee. The abundant charcoal found in surface soils may have resulted from fires associated with historic logging, but radiocarbon dating of deeper charcoal revealed at least four separate fire events during the prehistoric period, between approximately 6700 cal yr BP and 1500 yr BP. The Black Pond macroscopic charcoal record is similar in that it also indicates fires during both the prehistoric and historic periods at a mixed hardwood site. Identification of charcoal particles in the Hart et al. (2008) study showed that fires on the Cumberland Plateau had burned in stands that included mesic hardwood species with diffuse porous ring structure that are not considered to be fire-tolerant, such as possibly *Acer* spp., *Fagus grandifolia*, and *Liriodendron tulipifera*. The vegetation reconstruction by Criddlebaugh (1984) at Black Pond showed that this site also supported some mesic fire-sensitive hardwood tree species in the past, although species of oak (*Quercus*) and hickory (*Carya*) along with chestnut (*Castanea dentate*) were proportionally more important based on the pollen results.

What are possible management implications of the long-term records of local fire history from Gum Swamp and Black Pond?

According to Pyne (2004), four options exist for managing fire: (1) fire can be allowed to burn freely; (2) fire can be completely suppressed; (3) fire can be prescribed for the health of the vegetation and soil; or (4) fire can be limited by controlling the fuels that feed the fire. Gum Swamp is a site that is located within a highly managed

environment and is surrounded by historical and cultural landscapes and roads. The option to let a fire burn freely at this area is not appropriate because of the risks to humans involved. Currently, Cades Cove is classified as a Class 1 Fire Zone where all fires are suppressed immediately and prescribed fires are used only when necessary (NPS, 2008). Revealing what fire patterns originally created and maintained the forests that are desired in Cades Cove could help fire managers within Great Smoky Mountains National Park determine how often and where prescribed fires should burn to help create and maintain the forests. Fire and forest managers also have the option to remove excess fuel that is a potential fire hazard to keep with the desired fire regime and to reduce the danger of unwanted fires spreading to populated and sensitive areas.

Black Pond has a different fire management policy than Gum Swamp as it is located on private property and surrounded by agricultural fields. Burning around Black Pond in historic times may have been carried out to clear the land and to encourage pasture grasses. While small patches of forest exist in the vicinity of the site, prescribing fire in the immediate area is not necessarily a priority. For sites with a similar forest composition, however, the long-term fire history of Black Pond can provide a perspective for determining how best to manage those sites using prescribed fires. The fire history near Black Pond can also help to document how fire was used by Native Americans and historic farmers to enhance agriculture. Such information may be useful to archeologists and potentially to modern agriculturalists. Recreating the fire histories of sites with different degrees of land management can highlight the differing responses of forests and fires to modern fire suppression.

CHAPTER 7

Conclusions

The macroscopic charcoal record from Gum Swamp shows an increase in charcoal concentrations prior to and around the time of Euro-American settlement and a decrease in present times. The increased charcoal concentrations reflect changes in the delivery of charcoal to the sites, increased fire activity, or both. A change of secondary charcoal input patterns brought about by an increase in erosion or in increase in overland flow could have caused an increase in charcoal concentration. The higher charcoal values during the Euro-American period seem likely to indicate either a greater number or increasing size and intensity of fires around the sites. Macroscopic charcoal of the size ranges studied here does not travel far, and likely indicates fires associated with the clearing of nearby forests for agricultural or settlement purposes.

The macroscopic charcoal record from Black Pond shows a decrease in charcoal concentrations prior to Euro-American settlement and then variable and decreasing concentrations during the sediment interval that is believed to span the period from Euro-American settlement to the present day. The variations in charcoal concentrations are likely showing changes in fire occurrence and characteristics near Black Pond caused by land clearance and differing fuel types and loads.

The decrease in charcoal concentrations in more recent times reflects fire suppression at Gum Swamp and lower ignition rates or fuel loads at Black Pond. Beginning in the 1930s, all fires were suppressed within Great Smoky Mountains

National Park, except small agricultural fires in some areas of Cades Cove (Young 2006). This suppression is seen in the Gum Swamp macroscopic charcoal record around 1950, with a possible lag time caused by secondary charcoal entering the pond. The land surrounding Black Pond has been used for agriculture for many years and fuel loads and ignition rates were likely greatly reduced after land clearance, resulting in smaller, less intense fires occurring around the pond. Although Gum Swamp and Black Pond have similar forest composition and both experienced a decrease in charcoal concentration in the recent past, Gum Swamp records a more dramatic decrease because of the sudden fire suppression that occurred in Great Smoky Mountains National Park.

The macroscopic charcoal records at Gum Swamp and Black Pond show similar trends as previous studies that used microscopic charcoal (Davidson 1983, Cridlebaugh 1984). The similar trends in both proxies reveal that microscopic charcoal, in small basins in eastern Tennessee, provides a good reconstruction of local fire history. However, macroscopic charcoal may be plentiful in sediments, and sieving sediments to quantify macroscopic charcoal offers a time-efficient means of determining local fire history. By sieving contiguous core samples, macroscopic charcoal studies can yield fire records of much higher resolution than is typically possible in the labor-intensive process of preparing and studying pollen slides to quantify microscopic charcoal.

The similarity in patterns of macroscopic charcoal abundance in different size classes at Gum Swamp and Black Pond suggests that future studies could save time by only focusing on one size class of macroscopic charcoal, rather than three. Based on my results, I conclude that the 125–250 μm size range would be the best to focus on when

studying charcoal in the sediments of small ponds in eastern Tennessee. This size range, unlike the ranges of >500 and $250\text{--}500\text{ }\mu\text{m}$, is likely to capture more fire events, as these smaller macroscopic fragments are more easily dispersed to adjacent basins. In this study, the $125\text{--}250\text{ }\mu\text{m}$ size range was the only range that recorded charcoal at almost every stratigraphic level for both Gum Swamp and Black Pond. A sediment sample with a volume similar to that used in my study (4 cm^3) is likely to contain sufficient charcoal of this size class for analysis. In the sediments of a small pond or lake with limited stream input, in a region in which most fires are expected to be surface fires, the $125\text{--}250\text{ }\mu\text{m}$ size range of macroscopic charcoal probably mainly represents fires within or adjacent to the watershed. However, charcoal deposition studies carried out in different contexts point to some charcoal of this size potentially traveling greater distances. For this reason, it may be more appropriate to select a larger size class of charcoal if the study objectives call for the reconstruction of fires of certain local origin.

While Davidson (1983) interpreted the base of the Gum Swamp sediment profile as dating to 6600 yr BP, this study found that the oldest sediment may only be about 425 cal yr BP old. The fluctuations in pollen and charcoal concentrations cited by Davidson (1983) may thus have occurred over much shorter time frames than originally thought. The peak in microscopic charcoal that Davidson (1983) interpreted as indicating a major fire event or episode about 1700 yr BP may actually reflect a fire during the Euro-American period. Further efforts to date the Gum Swamp sediments, or macroscopic charcoal in soil cores from the adjacent upland, would help strengthen my

reinterpretation of the Davidson (1983) study. With only a single AMS radiocarbon date, the possibility exists of an error in my reinterpretation.

The ability to align the Black Pond cores with Cridlebaugh's (1984) cores using *Ambrosia* and *Pinus* pollen ratios provides an interim chronology prior to having radiocarbon dates and confirms the linkages between the two sediment cores. The dates pending for this study are expected to follow fairly closely to the radiocarbon dates that were obtained during Cridlebaugh's (1984) pollen and microscopic charcoal study of Black Pond. Even though Cridlebaugh relied on bulk sediment dates that are considered inferior to AMS ^{14}C dates on macrofossils, her data and chronology are convincing. The sudden *Ambrosia* rise at a depth of 1.95 m (400 yr BP) appears in keeping with other evidence of indigenous settlement patterns in the area (Delcourt et al. 1996). However, the pending radiocarbon dates could show this *Ambrosia* peak to actually reflect forest clearance during Euro-American settlement, as has been found at other sites in the eastern United States (Delcourt and Delcourt 2004).

My results from Gum Swamp and Black Pond show some similarities with dendrochronological and soil charcoal studies completed in the southeastern United States. My study adds to an already rich assemblage of studies that demonstrates the effects of land clearance and changes in fire occurrence on vegetation in the southern Appalachians. The records created from macroscopic charcoal in pond sediments are some of the first of their kind in the southeastern United States and provide land managers and researchers insights on local fire histories hundreds of years ago. Using such data, land and fire managers are able to better understand the local fire history that

created the forests that exist at these sites today and are able to take better action in suppression and prescribing fires as well as reducing unwanted fuels. In the future, studies that use macroscopic charcoal at other locations would likely prove useful for highly managed sites, such as Great Smoky Mountains National Park. Fire histories produced using macroscopic charcoal would also allow managers and those studying fire and anthropogenic patterns to better understand which factors might have been most important to settlement and which may or may not have contributed to an increase or decrease in fires. Continuing to combine sedimentary charcoal records with other proxies such as pollen, dendrochronology, and soil charcoal will enhance these records and provide a wealth of information.

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VITA

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As a graduate student in Geography at the University of Tennessee, Knoxville, Alisa took courses in biogeography, natural hazards, and GIS, and served as a teaching assistant for physical geography, world regional geography, and cultural geography courses. She carried out charcoal analysis for her thesis and several other research projects in the Department of Geography's Laboratory of Paleoenvironmental Research. Alisa received her M.S. in Geography in December, 2008 and hopes to pursue a career in environmental GIS.