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Fire-Regime Management in Western North Carolina

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Abstract

Records of forest fire disturbance are relatively short (~50-100 years) in many regions across the southeastern United States. For much of the southeast, the historical fire records only cover approximately the past 50 years. Therefore, there is a need to develop proxy records of fire history to better understand the natural variability of fire regimes. This research will attempt to develop proxy fire histories using bog sediment records collected in Western North Carolina in the Southern Appalachian Mountains. Identifying connections between historic fire and climate patterns may help determine how ecosystems have responded to past changes in climate so that this information can be used to improve land-use and forest management plans in the future. Records of fire activity were determined by analyzing sedimentary macroscopic (>125 µm) charcoal preserved in the sediments of the Panthertown Valley Wetland Complex in Sapphire, NC. The sediment records were dated using ^{14}C dating at Woods Hole - National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility, in Woods Hole, Massachusetts. Analysis of the region's fire history will inform decision makers about the management of forest resources and guide the use of prescribed fire as a management tool in the region.

1. Introduction

Allowing forests to burn is critical to implementing restoration of ecological processes. Wildfires eliminate overgrown underbrush and allow species to recolonize the habitat lost due to competition and spread of invasive species. Natural fires are essential ecosystem drivers and can suppress the overgrowth of local forests into wetland ecosystems[1]. Fires also affect vegetation community composition, wildlife dynamics, and bog biochemistry[2]. However, present day efforts to suppress naturally occurring fires are obstructing ecological succession[3]. Historical fire records can provide insight into previous fire regimes, and could be beneficial to land managers working to maintain a healthy, functioning ecosystem.

In Western North Carolina, fire has become a useful restoration tool that is implemented to reduce invasive spread and impact in sensitive wetland/bog habitats[4]. To date, however, there is a very limited amount of information about historic fire patterns in Western Carolina. Fire history data would provide information on the severity of historic fires through charcoal analysis. Charcoal analysis is a crucial method used to understand the history of fire regimes. By quantifying size and amount of charcoal, one can determine the frequency and severity of historic fires[1,2]. This information can then be used to create the most effective fire protocol for land managers to following habitat restoration and maintenance[1,2].

The goals of this study are twofold. First, charcoal analysis will be used to identify the fire history in Panthertown Bog. The second goal is to determine the most efficient and least damaging method to process charcoal from soil cores. This will include a series of experimental trials to evaluate a new charcoal processing methodology involving agitation of samples prior to counting individual charcoal pieces under a microscope. The agitation treatments will indicate the best processing method based on intact charcoal samples following separation from the sediment; the ultimate goal is to carefully loosen charcoal fragments of greater than 1µm. This research will assist land management organizations, including The Nature Conservancy and The United States Forest Service, in efforts to further conserve and manage these habitats.

2. Methods

2.1 Sediment collection

Fossil sedimentary sequences were collected using a GeoCore™ piston corer (GeoCore Basic Sediment Coring System http://www.geo-core.com/basicsystem.htm) and a Discrete Point Piston Corer™ (Aquatic Research Instruments http://www.aquaticresearch.com/discrete_point_corer) from bog sites. The coring device is manually driven into the bog sediment to collect 1-meter-long drives of undisturbed sediments and preserve the surface *Sphagnum* layer. The coring device takes a core barrel sample of 68mm (2 5/8 inches) in diameter. Four sedimentary cores were taken from the center, or deepest portion of bog/wetland (35.1665690 -83.0251750). Multiple samples were taken from the bog to ensure that all possible sedimentary layers were extracted. The cores were extruded and transported back to UNCA for laboratory analyses. One core from Panther Town Bog was evaluated for the experimental charcoal processing tests.

2.2 Lab Work

2.2.1 fossil macroscopic and microscopic charcoal analysis

Both microscopic and macroscopic (>125 µm) charcoal was analyzed in the sedimentary sequences. Macroscopic particle analysis reveals the presence of fire locally at a site, while microscopic charcoal indicates region-scale burning. Charcoal was sampled continuously at 2 cm intervals; additional 1 cm intervals were examined during periods of increased fire activity.
Charcoal analysis followed the most efficient processing method as determined by our experimental treatments. Charcoal fragments retained by the 120 µm Nitex screen were identified under an Olympus stereomicroscope.

2.2.2. experimental charcoal processing

Two different methods were used to process charcoal to determine the least damaging method for charcoal analysis. Two cubic centimeters of sediment were sampled for each method as a constant volume.

Charcoal analysis followed the standardized protocol of Courtney Mustaphi[5]. For this method we treated the subsample with a 5% solution of sodium metaphosphate (Calgon) [6] to help disaggregate the sample, and 2% H_2O_2 to bleach the non-charred organic matter. In one treatment, a 2 cm^3 sample was shaken vigorously for 3 minutes, after which the sample rested for 24 hours prior to filtration through a 250 µm, and then a 120 µm Nitex screen. In the other treatment, a 2 cm^3 sample was not shaken but was left to rest for 24 hours following the chemical treatments. All samples were filtered using a 120 µm mesh and 250 µm mesh (Figure 1).

Charcoal fragments retained by the 120 µm Nitex screen for each treatment type were identified under an Olympus stereomicroscope at 20X. The counts for each treatment type were compared to determine which method resulted in the highest proportion of >1 µm macrocharcoal pieces.

2.3. Soil Analysis

Subsamples of sediment were analyzed for C/N content at NC State University Environmental and Agricultural Testing Services. This data is important for determining the total carbon-to-nitrogen ratios of the samples.

2.3.1. radiocarbon dating

^{14}C Accelerator Mass Spectrometry (AMS) dates were taken to determine the age of the sediments. Calibration used Calib 5.2[7] to calculate calibrated years Before Present (BP).

2.3.2. loss on ignition

To determine the weight percentage of organic matter and carbohydrate content in the sample, loss on ignition (LOI), a sequential heating of samples in a furnace, was done[8,9,10]. This method is useful for indicating the amount of sediment that is required for radiocarbon dating[11]. The first reaction occurs at 550 degrees Celsius; the organic matter is oxidized to carbon dioxide and ash[10]. The second reaction, occurring at 950 degrees Celsius, results in a loss of carbonate, carbon dioxide leaving as oxide[10]. Measuring the weight lost between the reactions provides an accurate measure of organic matter and carbonate content.

3. Results

The processing treatment that resulted in the highest retained macrocharcoal fragments (fragments greater than 1 µm) was the 'No shake' method (Figure 1).

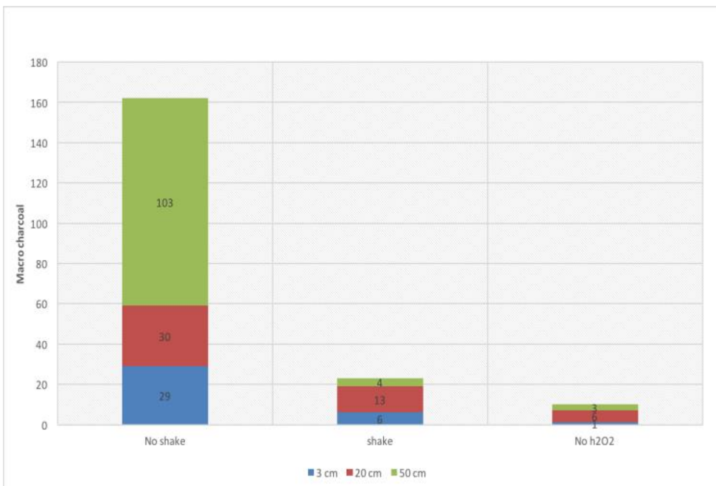

Figure 1

Figure 1. Amount of macrocharcoal found in each charcoal processing treatment type at 3 cm, 20 cm, and 50 cm depths.

Macro and Micro charcoal were found in the first 30 cm, correlating to 3,000 cal. Yr. BP. Additionally, Macro and Micro charcoal were found at 80 centimeters depth, corresponding to 5,600 cal. yr. BP (Figure 3). The age-depth model shows that the core was accurately dated within a 95% confidence interval and the calculated age per centimeter is 81 yr. BP (Figure 2).

Lithology shows that the upper region of the core was highly organic with large decomposing plant matter. The middle section of the core had smaller decomposing plant material and transitioned to sand, silica and clay toward the bottom end of the core (Figure 3, Table 2). Carbon % weight was at its highest at the top of the core where organic material was present and dropped off where organic material started to decompose and the core transitioned to inorganic sand and clay. Nitrogen % weight was extremely low due to acidic nutrient poor soil (Figure 3).

Table 1. Radiocarbon dates for Panthertown bog sediments. Reported as conventional radiocarbon years BP and calibrated years BP with standard deviations. Calibrated dates were calculated at 68% minimum probability of occurrence.

Depth (cm)	Uncalibrated age ^{14}C-age BP	Calibrated age (cal. yr. BP; 2 – sigma)	$\delta^{13}C$
45	3340 ± 40	3572 ± 59 (3512 – 3631)	-21
79	4860 ± 30	5616 ± 20 (5595 – 5636)	-23.2

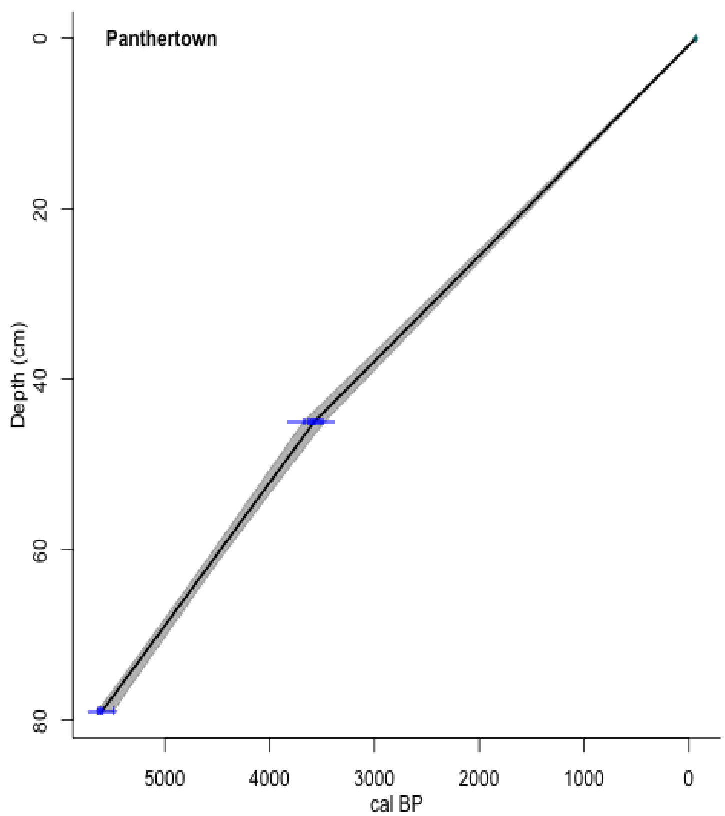

Figure 2

Figure 2. Age depth model for Panthertown Bog using interpolation.

The blue shading shows a 95% confidence range probability per sampled AMS date, and the gray shading depicts margin of error within the 95% confidence range for the interpolated age ranges. The calculated age per centimeter is 81 yr. BP.

Table 2. Sediment description for Pantertown Bog follows the Troels-Smith method (1995) and colour descriptions follow the Mussell Color Chart (1975).

Debh (cm)	Description	Troels-Smith Physical properties	Troels-Smith Degree of Humification	Mussel Colour
0-20	Homogenous with rootlets and plant parts	nig 4, strF 0, elas 3, sice 2, Lim 0, humo 2,	Tb 2.5, Th 1.5, Gs .5	10 YR 2/1 black
21-25	Few plant rootlets homogenous transition to next strata	nig 4, strf 1.5, elas 1.5, sice 3, lim 1, humo 4	Th 2, AG .05, Ld 1, Ga 1	21-40 color 10YR 2/1 black. 40-45 10YR2/2 very dark brown
26-45	Few plant rootlets homogenous transition to next strata	nig 3, strf 1.5, eslas 1.5, slice 3, lim 1, humo 4	Ga 1, Ag 0.5, Ld 3, Th 0.5	35-40 10YR 2/1 black, 40-45 10YR 2/2 very dark brown.
46-65	46-50 Heterogenous transition step 50-63 homogenous solid clay	nig1,46-50 strf 1, 50-63 strf 0,elast 0, sicc 4, 46-50 lim 1, 63-64 lim 2, humo 4	As 3, Ag 0.5, Gs 0.5, Ga 0.5	2.5 Y 5/3 light olive brown,
63-71	Gttyia clay homogenous	nig 2.5, strf 0, elas 0.5, sicc 4, lim 2, humo 4	As 2, Ag 0.5, Ld 2, Ga 0.5	2.5 Y 3/1 very dark gray
71-85	Intermediate homoinmindeposits	nig 2, strf 1.5, elast 0.5, elast 4, lim 2, humo 4	As 1, Ag 2.5, Ld 0.5, Gs 1	2.5 Y 3/2 very dark grayish brown

4. Discussion

These data indicate that fire has been a part of Panthertown's ecological system for the last 2-3 thousand years. Major fires were detected during the last 3,000 cal. yr. BP. The data suggests large localized fires occurred from 1,200-250 cal. Yr. BP, indicating large regional upland fires that likely included the wetland. A study conducted by Spencer *et al*. using charcoal analysis on two lakes in eastern NC found incidents of fires peaking during this time[14]. The wetland is currently supported by four stream/spring inputs, which keep the bog wet throughout the year. It is unlikely that high intensity fires occurred within the bog due to these inputs; however, during periods of drought the wetland can dry significantly and it could be possible for low intensity fire to move quickly across the dried vegetation. The recent high intensity fires, ~ 1,200 - 250 yr BP, likely occurred on the drier west and south facing slopes, and less on north and east facing slopes (Figure 3). This is probably due to the increased arid conditions of the south and west facing slopes[12]. Charcoal peaks were also detected at 5,600 cal. yrs BP, indicating a localized fire (Figure 3). Work by Lane *et al*. in eastern North Carolina evaluating environmental changes to the landscape also detected fire events occurring ~5,500 cal. yrs BP in eastern North Carolina[17]. They hypothesized that increased fires were due to increased *Pinus* dominance because of the *Pinus* pollen in the cores they collected. Alternatively, Native Americans started burning the land, which in turn increased Pine populations because they are fire adapted[17].

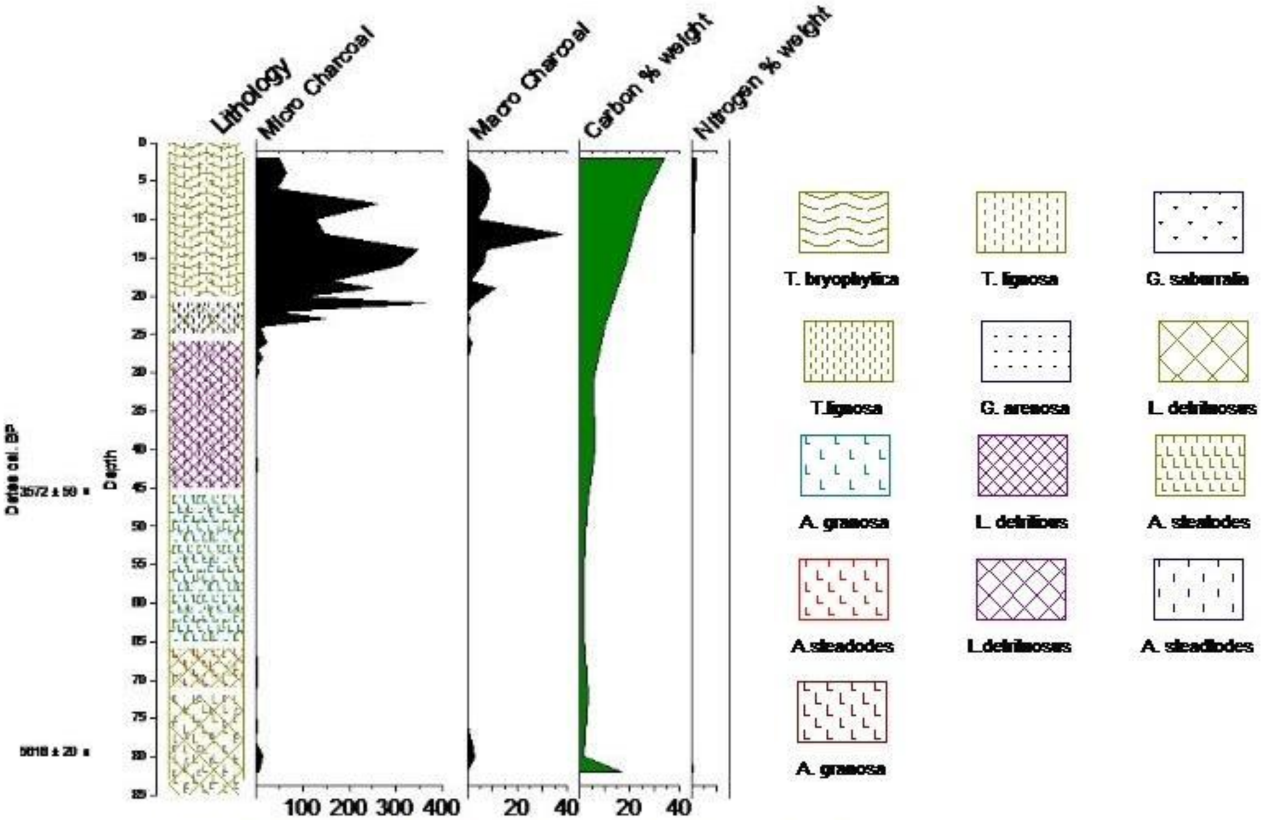

Figure 3. Amount of Micro Charcoal, Macro Charcoal, Carbon % weight, and Nitrogen % weight per centimeter depth. Lithology depicts sediment description. The accumulation rate is 81 years per cm.

In the past there have been arguments in literature concerning whether North Carolina was arid[13,14] or mesic[15,16] during the whole of the Holocene. More recently, studies prove that there were fluctuations of dry and wet periods throughout the Holocene[17]. These fluctuations could account for the different peaks in fire through time; for example, during dry and warmer years with increased drought, more fires occurred. Historical fire regimes in Georgia show frequent fire activity in the mid Holocene to be due to increased seasonality[18]. The same study also suggested that fire peaks existed many years apart due to the need for the leaf litter mass/fire load to increase prior to the next fire event[18]. For example, based on Kuchler's and the United States Department of Agriculture's estimation of fire-regime types, Western North Carolina landscapes would burn every 34 years according to the native flora found[19].

At the present, little research has been conducted on historical fires in North Carolina or in the Eastern United states. The lack of research is thought to be a result of the fire suppression campaign, along with the antiquated idea of plant communities and the broader ecological systems reaching equilibrium and stabilizing[19]. Modern ecologists and land managers are rejecting the idea of a state of equilibrium and instead supporting fires as an integral part of ecosystem management and natural processes[19]. Research shows that fire as a disturbance process affects the composition, structure and pattern of vegetation within the landscape and is necessary to maintain diversity and ecological processes[19]. An example of a fire suppressed systems in the southern Appalachian Mountains are the wetlands and bogs that require regular fires to prevent encroachment of woody plants[1,2,4,17,18,19]. To further understand fire history, more research needs to be conducted in the Southeast in order to understand how to best restore and conserve the land with a focus on preserving evolutionary processes and not equilibrium.

Future research could include analyzing plant macrofossils (large, greater than 0.5mm, preserved plant remains such as leaf, needle, cone, and stem debris used to identify an area's past flora) in sedimentary cores in order to understand how the vegetation responded to previous fire events and what the vegetative composition was like following fires. Additional sedimentary cores from Panthertown Bog can be used to obtain additional data and help uncover what happened during the large gap within the data. In conclusion, this research shows that fire was historically present in Western North Carolina prior to the arrival of early Europeans, indicating that fire was part of the natural systems in Western North Carolina during the Holocene. The data is imperative to consider when managing future conservation and restoration activities in Western North Carolina.

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