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FIRE HISTORY OF A GEORGIA MONTANE LONGLEAF PINE (*Pinus palustris*) COMMUNITY

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ABSTRACT

Montane longleaf pine forests, woodlands, and savannas are endangered, fire-dependent ecosystems of the Piedmont, Ridge and Valley, Appalachian, and Cumberland Plateau physiographic provinces of Georgia, Alabama, and North Carolina. Compared to other longleaf pine ecosystems, e.g., longleaf pine-wiregrass, little has been published about montane longleaf pine ecosystems. Understanding the historic fire regimes that once maintained montane longleaf pine ecosystems is an important first step toward achieving restoration and conservation goals for this ecosystem. I used two approaches to investigate historic fire regimes: 1) a dendrochronological study of fire scars on Sprewell Bluff Wildlife Management Area and 2) calculations of the average fire tolerance of tree species recorded on 1820s land lottery maps and 2005 surveys. Three distinct periods of fire history were revealed: pre-1840, with an average fire interval of 2.6 years; 1840–1915, with an average fire interval of 1.2 years; and 1915–present, with an average fire interval of 11.4 years. Season of fire differed between periods with all seasons of fire common prior to 1840, mostly winter fires from 1840 to 1915, and mostly spring and early summer fires from 1915 to the present. Land lottery data suggested montane longleaf ecosystems of the 1820s were most similar in fire tolerance to areas of longleaf-wiregrass, as compared to several other historic Georgia forest types. Modern forests had much lower scores of fire tolerance. Differences in species composition accounted for these changes in scores; historic montane longleaf ecosystems had larger components of pine (*Pinus* spp.), post oak (*Quercus stellate* Wangenh.), and blackjack oak (*Q. marilandica* Muenchh.), while modern forests had higher densities of chestnut oak (*Q. prinus* Willd.) and hickory (*Carya* spp.). My results suggest a fire return interval of two to three years is needed to halt the continued loss of the montane longleaf pine ecosystem.

Keywords: montane longleaf, mountain longleaf, dendrochronology, land lottery, fire, fire seasonality, fire frequency, Georgia.

INTRODUCTION

Three percent of the greater longleaf pine (*Pinus palustris* Mill.) ecosystem remains after almost two centuries of logging, land clearing, and fire suppression (Landers et al. 1995; Engstrom et al. 2001). While great strides are being made to restore longleaf pine in many portions of its former range, many longleaf systems continue to decline (Outcalt and Sheffield 1996; Noss 2012). Perhaps the most endangered longleaf system is the mountain, or montane, longleaf ecosystem (Stowe et al. 2002), much of which is listed as a globally endangered or a globally threatened ecosystem (Natureserve 2017), and which is often overlooked or at best lumped in with other ecosystems by conservation planners (Outcalt and Sheffield 1996; Noss et al. 1995). Montane longleaf occupies mountainous portions of the North Carolina Piedmont and northeastern Alabama and west-central Georgia's Ridge and Valley, Piedmont, Appalachian, and Cumberland Plateau physiographic provinces (Edwards et al. 2013; Patterson and Knapp 2016). Though this ecosystem is dominated by longleaf pine, many of the plant and animal species and species assemblages differ from longleaf pine ecosystems of the coastal plain by including elements from systems to the north, particularly the Southern Blue Ridge (Harper 1903; Jones 1974; Floyd 2008). The longleaf pine ecosystem is threatened by rapid urban development from the cities of Atlanta, Chattanooga, and Birmingham (Conner and Hartsell 2002). While there is substantial public ownership of montane longleaf (much of it in the Talladega National Forest and Longleaf National Wildlife Refuge in Alabama and the Franklin Delano Roosevelt [FDR] State Park in Georgia) much of it has been heavily impacted by repeated timber harvests and nearly a century of fire suppression (Outcalt 2000). Little work has been done to restore this ecosystem on public land, particularly in Georgia, and industrial pine plantations have replaced much of it on private land. Fire suppression continues to impact the health and vigor of the system, in part because of concerns over the effects of prescribed burning on air quality in the nearby cities (Stowe et al. 2002; Natureserve 2017).

One challenge to montane longleaf pine restoration is the lack of understanding of this unique ecosystem due to the limited research published to date (Stowe et al. 2002). Initial studies on key issues such as forest dynamics and regeneration (Varner et al. 2003), botanical composition (Maceina et al. 2000; Govus et al. 2004), wildlife habitat relationships, and fire ecology (Bale 2009) are few, relative to other longleaf ecosystems, and often in grey literature. A critical first step in conserving and restoring this ecosystem is to understand the history and effects of fire (Barnett 1999; Bale 2009).

I used two methods of inquiry to gain insight into the historic role of fire in maintaining the montane longleaf ecosystem of Pine Mountain. First, a standard dendrochronological study, also known as a tree-ring analysis investigation (Arno and Sneck 1977; Grissino-Mayer 2019), of remnant longleaf pine stumps on Sprewell Bluff Wildlife Management Area in Meriwether County, Georgia, was undertaken to identify and date fire scars. Second, land lottery maps were used to quantify the fire tolerance of species found there when the area was first surveyed (circa 1820) prior to settlement by colonists compared to a modern resurvey of tree composition. The objective of this study was to document the historic fire regimes and tree species composition of two areas of mountain longleaf to provide guidance for restoration efforts.

MATERIALS & METHODS

Sprewell Bluff Fire Scars

I constructed a fire history of the Pigeon Creek Tract of Sprewell Bluff Wildlife Management Area, which is near the eastern edge of the Pine Mountain escarpment, and which retains some of the best remaining montane longleaf in Georgia (Figure 1). I examined approximately 40 stumps and found 17 longleaf stumps suitable for further study; cross sections of these longleaf stumps were removed. These "fat lightered" stumps remained from several previous logging operations and had heartwood heavily impregnated with resin, making them highly-resistant to rot. Many of these trees had been cat-faced (bark and cambium were removed over a portion of the trunk to collect oleoresin) for naval stores production in the mid to late 1800s or had scarring where the cambium had been killed by the high heat of earlier fires. These exposed scars were highly flammable when these trees were alive and are excellent indicators of previous fires (Huffman et al. 2004; Bale 2009); approximately 70–90% of cat-faced longleaf tends to ignite when even a small (7–10 cm flame length) fire passes them (author's pers. obs.). I dried and sanded cross sections of stumps with progressively finer grades of sandpaper, finishing with 400 grit, and measured growth rings under a stereo microscope. I made several attempts to date cross sections by including an existing live-tree chronology developed from tree cores (n = 52) collected from longleaf trees on-site using COFECHA and Measure J2X software (Grissino-Mayer 2016), but efforts by three other researchers and myself to use these methods failed to date the samples; however, older methods (Douglass 1941; Stokes and Smiley 1968) proved successful. Cross-dating provided reasonable confidence that all tree rings were dated to the exact calendar year of formation. I recorded fire scar dates and calculated fire frequency statistics. I only counted trees as part of the sample when they had an active catface or exposed scar. I determined season of fire by examining the location of damage from fire within the earlywood to latewood growth ring. I defined winter season fire as a fire taking place prior to the initiation of earlywood growth for that year. A fire taking place during growth of earlywood was considered a spring or early summer fire, while a fire taking place during latewood growth was considered a summer or fall fire.

Land Lottery Data

My second line of inquiry into the fire history of Pine Mountain used land lottery maps to reconstruct tree species composition prior to most Anglo-American settlement for six regions in Georgia (Figure 1). Land lottery maps are the property of the State of Georgia and are held at the State Archives in Clayton Georgia. We accessed these maps through the Georgia GIS clearinghouse (2018). The land lottery maps recorded tree species composition for much of Georgia between 1804 and 1832. Twelve trees were identified, most to species (Mladenoff et al. 2002), per 101-hectare (250-acre) lot (Figure 2). Trees were of unknown diameters but were large enough for early surveyors to blaze with lot identification numbers (Cowell 1995; Plummer 1975). I assigned a subjective value of fire tolerance to each tree species ranging from -2 to +2 (Table I) based on expert opinion (M. Hodges, Georgia Chapter of The Nature Conservancy; S. Cammack, Georgia DNR Natural Heritage Program; and J. Moore, USFS Hitchiti Experimental Forest); higher values indicate greater fire tolerance. Land lottery surveyors did not distinguish among species of pine. Species denoted "Pine" may be longleaf, shortleaf (*P. echinata* Mill.), or loblolly pine (*P. taeda* L.) at the montane longleaf study area, also spruce pine (*P. glabra* Walter) at the Early County site and white (*P. strobus* L.), Virginia (*P. virginiana* Mill.), pitch (*P. rigida* Mill.) or table mountain pine (*P. pungens* Lamb.) at the Rabun County site. Species denoted as "Red Oak" likely included northern red (*Q. rubra* L.), scarlet (*Q. coccinea* Muenchh.), Georgia oak (*Q. georgiana* M.A. Curtis), or turkey

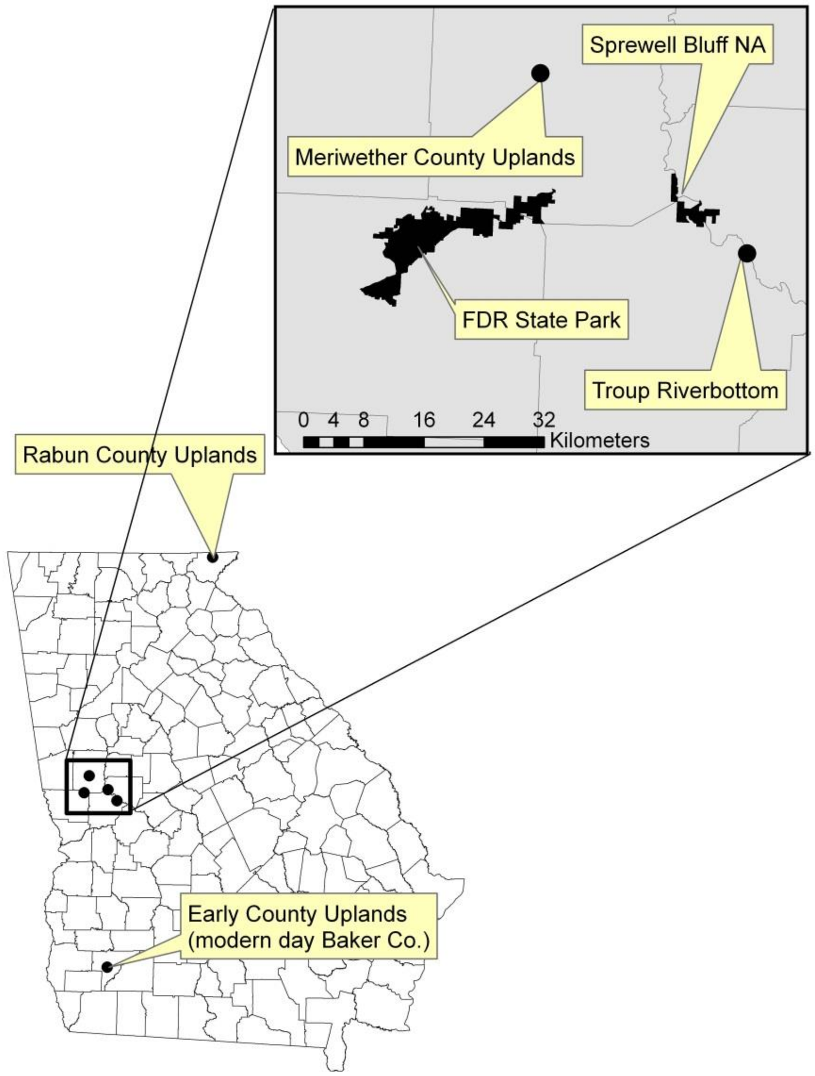

Figure 1. Study areas for dendrochronology and land lottery data (Georgia GIS clearinghouse 2018).

oak (*Q. laevis* Walter). Black (*Q. velutina* Lam.), southern red (*Q. falcata* Michx.), and blackjack oak were distinguished from each other by land lottery surveyors. Hickory species were not differentiated from other species by land lottery surveyors.

I calculated average fire tolerance values for each site, including the north and south face of Pine Mountain, to give a relative value of fire tolerance. I relocated land lot corners and, using the same methodology, outlined in the land lottery contract with surveyors, resurveyed contemporary forest composition on the same areas of Pine Mountain (FDR State Park) in 2005. I began my surveys at a land lot corner documented by 1800s surveys and relocated in 2005, using a global positioning system (GPS) to estimate the distance and heading of historic survey lines in order to relocate other historic land lot corners. Many land lot corners were apparently relocated precisely, as evidenced by rock piles or other markers indicating former property lines. Where markers were no longer evident, I sampled trees as close as possible to where the GPS unit indicated the corner was located. I calculated percent species composition for the 1820 and 2005 data, as well as relative fire tolerance.

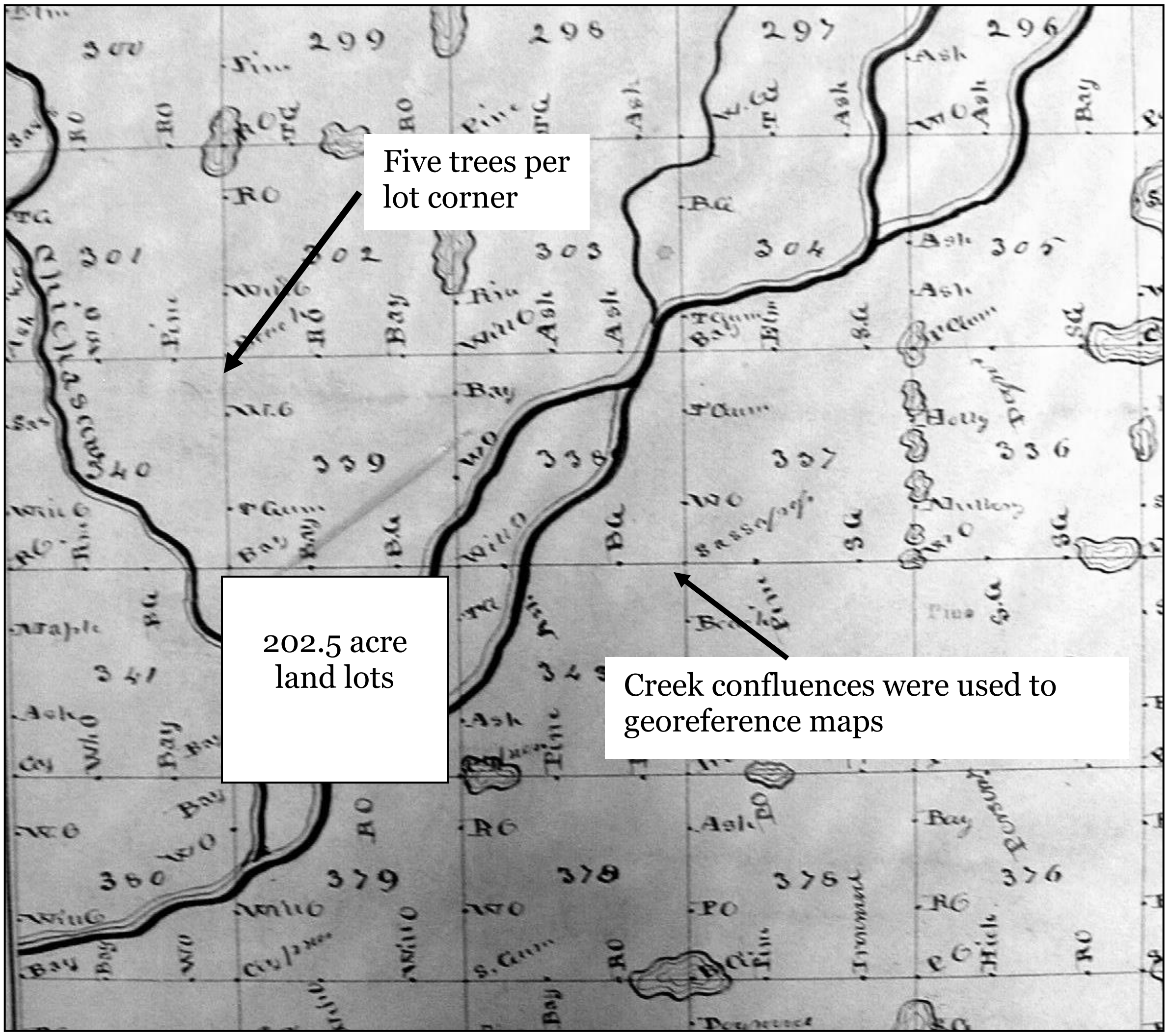

Figure 2. An example of a land lottery map from the Early County map (Georgia GIS clearinghouse 2018).

RESULTS

Sprewell Bluff Fire Scars

Most of the approximately 40 stumps I examined were decayed to the point of lacking discernible rings and could not be accurately dated. I could determine dates on only seven with enough certainty to include in the fire frequency data. I included only the trees showing at least three significant drought years that clearly matched reference material from living trees or accurately dated stumps. I recorded fire data from 1818 to 2005 (Figure 3). Three periods of distinct fire frequency are apparent: pre-1840 (mean fire interval 2.6 years), 1840–1915 (mean fire interval 1.2 years), and 1915–present (mean fire interval 11.4 years). I recorded season of fire, which differed between periods (Figure 4). Fires prior to 1840 burned in all seasons with at least half of all fires burning during the spring or early summer. Most fires (64%) during period 1840–1915 burned during winter. During the period 1915–present, most fires (58%) burned during spring; however, this last period is based upon relatively few fires (n = 8).

Table I. Species used to quantify fire tolerance across Georgia. Positive values indicate fire tolerance, negative values indicate fire intolerance, based on expert opinion. Species in quotations denote nonspecific names used by surveyors. Species with asterisks were only recorded during 2005 surveys. Modern records of such nonspecific groups were counted as zeros (e.g., species that could have been counted as "red oak" could be northern red oak [intolerant of fire], or scarlet oak [fairly tolerant], so both were scored a zero).

		Fire Tolerant			Fire Intolerant	
Species		+2	+1	0	-1	-2
Longleaf pine*	*Pinus palustris*	*				
Shortleaf pine*	*P. echinata*	*				
Loblolly pine*	*P. taeda*	*				
Virginia pine*	*P. virginiana*	*				
"Pine"	*Pinus* spp.	*				
Blackjack oak	*Q. marilandica*	*				
Post oak	*Q. stellata*	*				
Georgia oak*	*Q. georgiana*			*		
Chestnut oak	*Q. montana*		*			
White oak	*Q. alba* L.				*	
Southern red oak	*Q. falcata*			*		
Scarlet oak*	*Q. coccinea*			*		
Black oak	*Q. velutina*		*			
Live oak	*Q. virginiana* P. Mill.			*		
"Red oak"	*Quercus* spp.			*		
Pignut hickory*	*Carya glabra* P. Mill.			*		
Sand hickory*	*C. pallida* Ashe.			*		
"Hickory"	*C.* spp.			*		
American beech	*Fagus grandifolia* Ehrh.					*
Blackgum	*Nyssa sylvatica* Marsh			*		
River birch	*Betula nigra* L.					*
Sweetgum	*Liquidambar styraciflua* L.				*	
Tulip-poplar	*Liriodendron tulipifera* L.					*
Sassafras	*Sassafrass albidum* Nutt.			*		
Flow. dogwood	*Cornus florida* L.		*			
Sourwood	*Oxydendrum arboreum* L.			*		
Amer. chestnut	*Castanea dentata* Marsh.			*		
Bald cypress	*Taxodium distichum* L.			*		
Black locust	*Robinia pseudoacacia* L.			*		
Black willow	*Salix nigra* Marsh					*
American holly	*Ilex opaca* Ait.					*

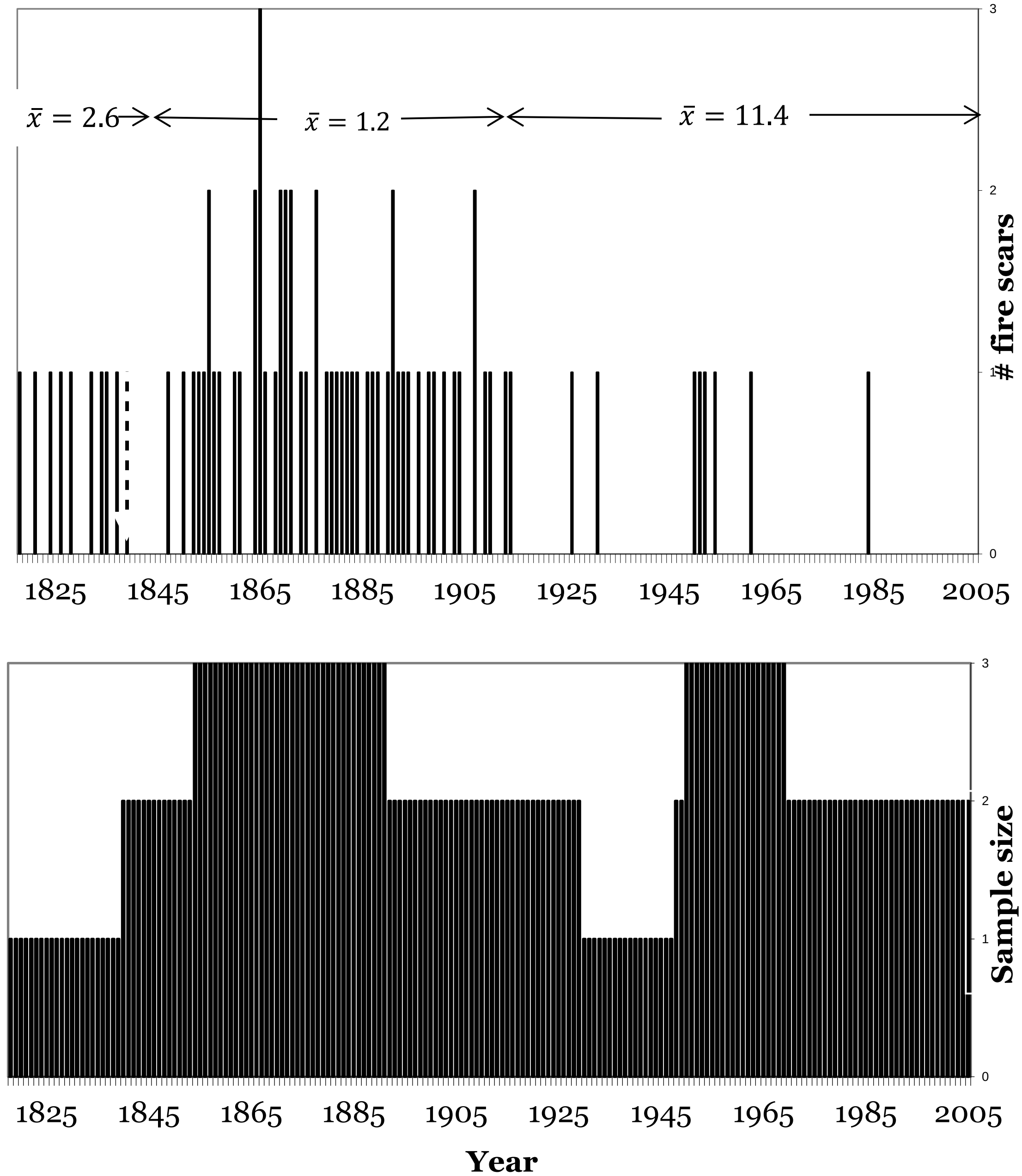

Figure 3. Fire frequency (top graph) and sample size (bottom graph) of three historic periods of fire frequency: pre-1840, 1840–1915, and 1915–present.

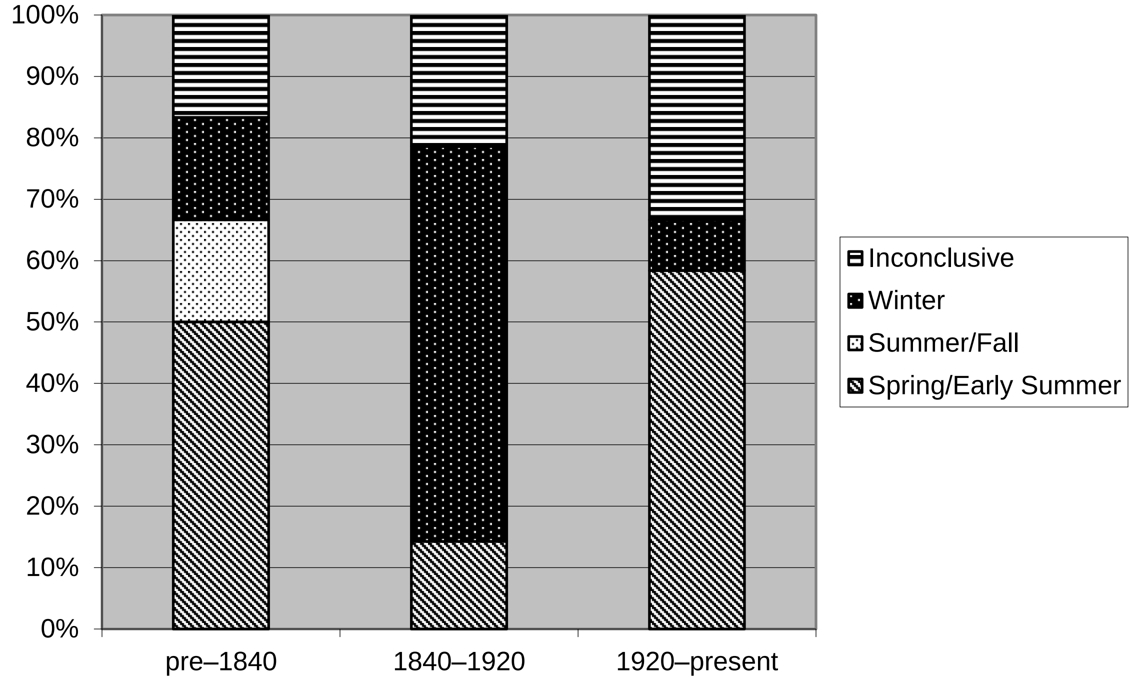

Figure 4. Fire seasonality by three historic periods of fire frequency: pre-1840, 1840–1915, and 1915–present.

Land Lottery Data

I calculated average fire tolerance values for eight regions in Georgia, six during the early 1800s as well as two in 2005 (Figure 1). Fire tolerance of Pine Mountain in the early 1800s was very high: the average value for south facing slopes was 1.72 and north facing slopes was 1.48 (Figure 5). When compared with other regions in the early 1800s, Pine Mountain's scores are closest to those of 1800s Early County (fire tolerance score 1.88), the present site of Joseph W. Jones Ecological Research Center, which is well known for its highly pyric longleaf pine-wiregrass ecosystem. Pine Mountain had much higher fire tolerance than that of the surrounding 1800s Meriwether County uplands, which scored 1.09; 1800s Rabun County pitch pine woodlands of the Southern Blue Ridge, which scored 0.36; and 1800s Piedmont bottomland hardwoods, which scored -0.22. Pine Mountain had much lower scores in 2005 compared to 1820, and the difference between the north and south faces has narrowed.

Tree species composition on Pine Mountain has shifted from predominantly pine in the 1820 survey to predominantly hardwood today. Chestnut oak (37%), sand hickory (20%), and pine, a relatively minor component (14%), dominate most of this area today (Table II). Surveys from 1820 indicate a forest more typical of the montane longleaf ecosystem, with as much as 43% of the trees surveyed as pine, presumably some combination of longleaf pine, shortleaf pine, and loblolly pine, remnants of which remain. Longleaf pine was a part of the pine component at the time of survey since many living longleaf pine on site today predate the 1820 surveys; however, the relative proportions of pine species were not recorded on land lottery surveys. Blackjack oak (24%) and post oak (24%) also comprised a significant portion of the species composition in 1820, and are greatly reduced in modern forests. American chestnut (*Castanea dentata*) was also a significant component (8%) of the species composition of Pine Mountain in the early 1800s and is now largely absent from the canopy, though sprouts and the rare canopy tree remain on Pine Mountain. It is worth noting that changes in chestnut abundance on Pine Mountain were likely caused largely by phytopthora root rot (*Phytopthora cinnamomic* Rands.), and later chestnut blight (*Cryphonectria parasitica* Barr.), rather than changes in fire regime, though fire regime may have also played a part.

Table II. Species occurrence by fire tolerance for north and south aspects of Pine Mountain in 1820 and 2005

Species	Fire Tolerance Value	Relative Density 1820 (%)	Relative Density 2005 (%)
North Aspect, *n* = 80			
Post oak	2	11	0
'Pine'	2	43	12
Blackjack oak	2	18	4
Southern red oak	1	2	0
Chestnut oak	1	5	41
Sourwood	0	0	2
Sassafrass	0	1	0
'Red oak'	0	6	12
'Hickory'	0	2	14
Georgia oak	0	0	4
Black gum	0	0	2
American chestnut	0	11	0
White oak	-1	0	8
South Aspect, *n* = 65			
Post oak	2	24	5
'Pine'	2	38	14
Blackjack oak	2	24	2
Chestnut oak	1	0	37
Black oak	1	0	2
Sourwood	0	0	3
'Red oak'	0	2	6
'Hickory'	0	2	20
Georgia oak	0	0	3
Blackgum	0	2	3
American chestnut	0	8	0
Yellow poplar	-1	0	2
Red maple	-2	0	2
American holly	-2	0	2

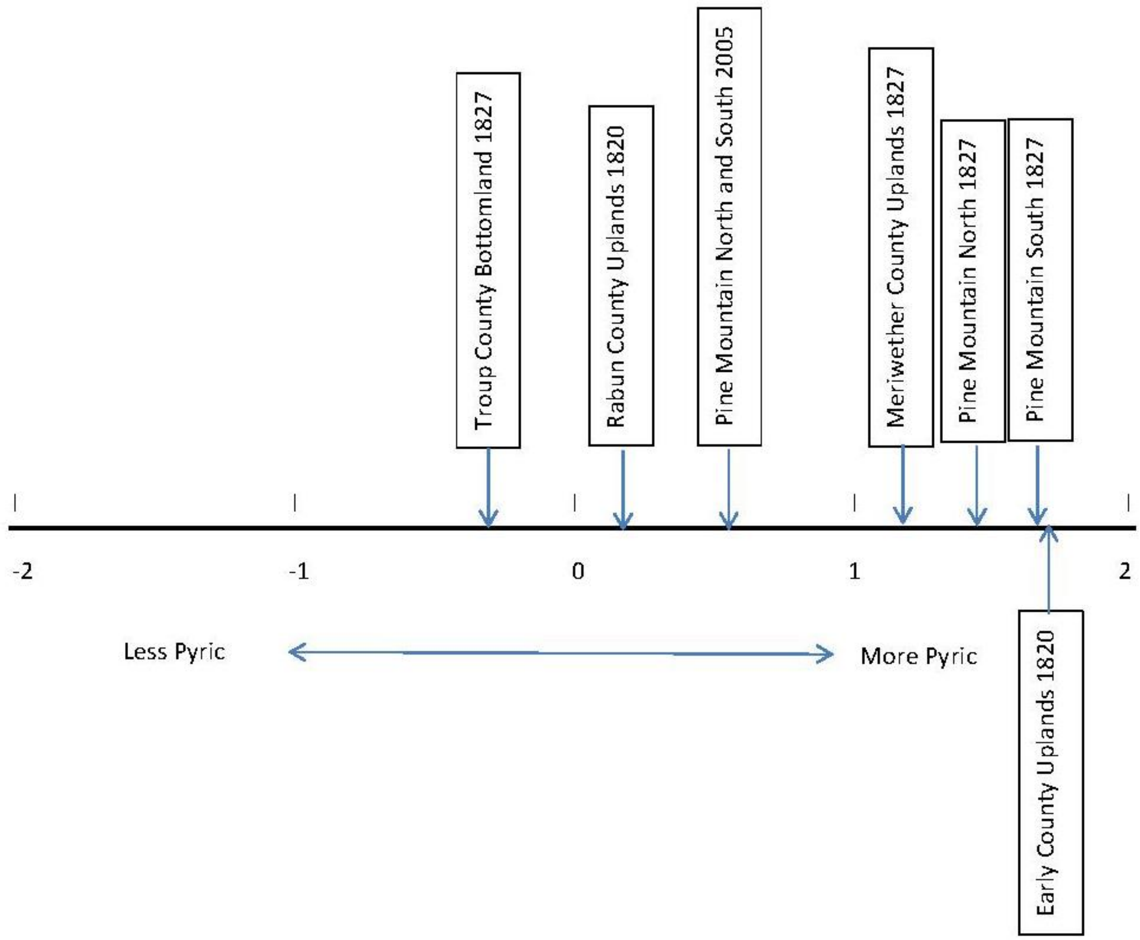

Figure 5. Average fire tolerance of six regions across Georgia circa 1820 and two regions, Pine Mountain north and south aspects, in 2005.

DISCUSSION

Fire on Pine Mountain is strongly correlated with human land use. Fire was a significant component of land management by Native Americans in my study areas prior to their forced removal in 1827 (Brender 1974; Cowell 1995; DeVivo 1990). European and African settlers used fire even more frequently, beginning in the late 1840s. Winter fires were likely used to manage this steep, rocky landscape for cattle forage; for naval stores production (Duvall and Whitaker 1964); to keep the woods open for soft mast production for humans; to maintain wildlife habitat; to reduce ticks, chiggers, and other pests; and to reduce fire hazards by lowering fuel loads. In the early 1920s, a nationwide campaign of suppression ended the use of fire as a land management tool (Kauffman 2004), and fire frequency diminished (Pyne 1982). The three periods of land use history I record were also observed in Alabama by the only other dendrochronology study performed on montane longleaf ecosystems (Bale 2009). Fire scar data prior to the early 1800s are not currently available for this site, but Bale (2009) found a similar average fire return interval prior to settlement in his study, with a mean fire return interval similar to that I observed on Pine Mountain. My land lottery data support Bale's observation of frequent fires prior to 1800, since fire tolerant forests surveyed in the land lottery were established in previous centuries.

The changes I observed in forest composition between 1820 land lottery surveys and surveys conducted in 2005 indicate an alarming loss of the montane longleaf ecosystem. Destructive logging practices focused on the selective extraction of longleaf pine, followed by decades of fire suppression (52 years based on tree core data from FDR State Park), have substantially changed the forests throughout the Piedmont (Nelson 1957; Cowell 1998). Fire tolerant taxa, particularly pine, post oak, and blackjack oak, have been reduced throughout Pine Mountain and eliminated from much of the study area. It is a logical conclusion that many other fire dependent species have also been lost, as evidenced by the long-abandoned red-cockaded woodpecker (*Leuconotopicus borealis* Vieillot.) cavities that remain on many of the oldest longleaf pine on Sprewell Bluff WMA and FDR State Park. Restoration of the frequent fire regime that established and maintained montane longleaf forests, woodlands, and savannas is a critical first step toward recovering this imperiled ecosystem. Concomitant with this effort must be restoration of the cultural heritage of prescribed fire, which once supported this ecosystem.

Fire may need to be differently applied to effect restoration than what I observed in this historical analysis. Cooler fires applied during wet winter periods may be initially required to reduce fuel loads (Bale 2009), particularly where there is heavy duff accumulation (Klaus 2016). Eventually, hotter summer fires may be needed in greater proportion to reduce hardwood encroachment; however, based upon fire scar and land survey data, a fire return interval of approximately every two years, with at least half of all burns occurring in the spring, may be a suitable fire regime to conserve mountain longleaf forests.

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