Am. Midl. Nat. 156:237–251

Fire Regime of an Ozark Wilderness Area, Arkansas

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ABSTRACT.—Many of the present day issues associated with fire management in wilderness areas are addressed by studying past interactions among fire, humans, vegetation and climate. In this paper we describe three centuries of the fire regime in the Lower Buffalo River Wilderness Area, Arkansas, USA. We reconstructed fire events from 159 tree-ring dated fire scars on 26 shortleaf pine (*Pinus echinata* Mill.) remnants and live trees. During the late-17th Century and early 18th Century the mean fire return interval (MFI) was 7.7 y. Fire frequency increased abruptly circa 1820 with fires burning every 2 y on average until 1920. The number of fires decreased during the 1900s as cultural values changed to favor fire suppression over multiple-use burning. Analyses of the influence of human ignitions and drought on the fire regime resulted in two important findings: (1) that fire frequency was positively correlated to human population density up to 1920 and (2) the influence of drought seemed to be masked by frequent anthropogenic fires and fire suppression. Fire events were associated with droughts only prior to Euro-American settlement. Studies of climate-fire relationships should consider the potential for anthropogenic influence and future studies should attempt to quantify the historic role of humans in the fire regime.

INTRODUCTION

Fire management in federally designated wilderness areas has been the subject of much attention (Brown *et al.*, 1995; Agee, 2000; Hourdequin, 2001) partially because managers have a mandate to maintain wildland fire as a natural ecological process. Departures from pre- Euro-American fire frequencies have occurred in many wilderness areas because of fire suppression. Wilderness managers are challenged to restore fire to its natural role while protecting wilderness character and managing the risks associated with prescribed burning (Parsons *et al.*, 2003). Fire history information that describes the long-term dynamics of fire helps wilderness area managers determine reference conditions and derive fire management policies (Allen *et al.*, 1995; Kipfmueller and Swetnam, 2000; Rollins *et al.*, 2002).

The Ozark Highlands fire regime.—The Ozark Highlands ecoregion (Bailey, 1998) comprises approximately 139,000 km^2 of Arkansas and Missouri and to a lesser extent Illinois, Kansas and Oklahoma. The Ozarks form a large portion of the ecotone between the Prairie Parkland and Eastern Broadleaf Forest Provinces. Today the region consists largely of closed-canopy forests, though relatively frequent fires prior to Euro-American settlement created and maintained a continuum of fire-mediated community structures (*e.g.,* forest, woodland, savanna and glade) (Batek *et al.*, 1999; Nelson, 2005). Wildfires in the region are almost exclusively surface fires and rarely stand replacing events (Oliver and Larson, 1996; Guyette and Kabrick, 2002). Severity of fires is largely dependent on climate, weather and conditions of the litter and 1-h fuels (Kolaks, 2004). During the fall, winter and spring of most years, dry warm weather of only a few days is sufficient to dry ground fuels (*e.g.,* litter and 1-h) and permit the spread of surface fires. Severe fires during the growing season are uncommon but can occur during droughts and in dry and windy conditions during the fire season

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(October to April). Topographic roughness of the Ozark landscape is an important control on the spatial variability of historic fire (Guyette and Dey, 2000; Jenness, 2004).

Humans have historically been an important source of wildfire ignitions in eastern U.S. forests (Braun, 1950; Pyne, 1982; Whitney, 1994; Clark and Royall, 1996; Delcourt and Delcourt, 2004). In the Ozarks, fire-scar studies have shown the association between human population density and fire frequency both pre- and post-Euro-American settlement (Guyette *et al.*, 2002; Guyette and Spetich, 2003; Guyette *et al.*, in press). Native American inhabitants of the Ozarks at the time of European contact included the Osage, Ouachita and Quapaw, and later eastern tribes including the Cherokee, Delaware and Shawnee temporarily resided there. All of these groups purportedly used fire (Nuttall, 1821; Mooney, 1900; DeVivo, 1991; Williams, 1994). Between 1763 and 1804 French and Spanish explorers encountered Osage Indians who had numerous seasonal hunting settlements between the White and Buffalo Rivers. Explorers made notes of Native Americans igniting fires, and they too burned to clear vegetation, mark terrain and illuminate mining prospects (Schoolcraft, 1821). Several decades later Euro-American settlers used fire to convert the forested hilltops and valley bottoms into pastures and croplands (Rossiter, 1992; Jenkins, 1997)—a practice that continued into the 1900s.

Few written records of fire events exist for the period prior to fire suppression; however, modern fire records and studies provide detailed information about the current fire regime, particularly rates of human and lightning ignitions. Since 1979 humans have caused an average of 105 fires per year per 400,000 ha in the Missouri Ozarks (Westin, 1992). In contrast, rates of natural ignitions are among the lowest in the continental U.S. [<1 lightning fire per year per 400,000 ha (Schroeder and Buck, 1970)]. Combined Missouri and Arkansas state agency records indicate that lightning-caused fires accounted for 1–2% of all fires during approximately the last 30 y (Garner, 1989; Jurney *et al.*, 2004). Lightning is not an important source of ignitions partly because: (1) asynchrony exists between the timing of the primary lightning season (summer) and the curing of deciduous fuels (fall and winter) and (2) lightning-producing storms are generally accompanied by rain.

Fire histories can provide much information about fire regimes prior to written documents and records. The objectives of this study were to: (1) reconstruct the fire history of the Lower Buffalo Wilderness Area from tree-ring dated fire scars and (2) test for relationships between both fire frequency and human population density and between historic fire events and droughts.

MATERIALS AND METHODS

Study site.—The study site is located in the northeast portion of the federally designated Lower Buffalo Wilderness Area (LBWA), Marion County, Arkansas (36°9′N, 92°27′W). The 9300 ha wilderness is situated between the confluence of the Buffalo and White Rivers. The study site included the majority of Granite Mountain, a steep and highly dissected east-west ridgeline with more than 350 m of relief from drainage to crest. Forest composition is dominated by oak (*Quercus spp.*), hickory (*Carya spp.*) and shortleaf pine (*Pinus echinata* Mill.). Woodland-savanna-glade complexes cover portions of the study area and surrounding vicinity, though encroaching woody vegetation has resulted in reduced herbaceous diversity (Jenkins *et al.*, 1997). Beginning in 1995 the National Park Service began using prescribed fire at the LBWA in an attempt to restore open-canopy forest structures.

Rivers and river confluences like that of the Buffalo and White Rivers were common locations of historic Native American and Euro-American activities in the region (Stevens, 1991). These rivers were preferred east-west travel corridors through the otherwise highly dissected topography. Prior to Euro-American settlement this area was only seasonally inhabited by the Osage tribe. Permanent Euro-American settlements existed near the Buffalo and White Rivers confluence as early as the 1820s (Schoolcraft, 1821). The confluence of the Buffalo and White Rivers was a particularly active area during the mid- to late-19th Century when Buffalo City, a town now located on the north side of the White River, was located on a peninsula between the two rivers (Rossiter, 1992). The town was a shipping hub, receiving steamboats carrying merchandise up the White River and barges carrying zinc ore down the Buffalo River. The river confluence was also conducive to allowing the propagation of fire into the Granite Mountain site because the distance is relatively short (2 km), there are no physical barriers, and the fire path (*i.e.*, via southeast and northeast drainages) (Fig. 1) is continuously upslope. In even closer proximity existed roads that would have allowed for much easier, and perhaps more frequent, access to the study site.

Fire scars.—We exhaustively searched and sampled the entire Granite Mountain area for shortleaf pines exhibiting external evidence of fire scarring. Shortleaf pine is considered a fire adapted species as it has moderately thick bark, is able to survive multiple fires (*e.g.,* >30), and saplings can resprout following top-kill (Keeley and Zedler, 1998). The species is ideal for use in fire history research due to its longevity and resistance to decay following injury and death. Cross sections were collected from 26 trees, stumps and natural remnants with a two-man crosscut saw. In the laboratory cross sections were surfaced with an electric hand planer and the cellular detail of annual rings and fire scar injuries were revealed by sanding with progressively finer sandpaper (80 to 600 grit). Fire scars were identified by the presence of callus tissue, traumatic resin canals, liquefaction of resin and cambial injury. All samples had charcoal present on the scarred exterior. Fire scar dates were assigned to the first year of response to cambial injury. We used FHX2 software (Grissino-Mayer, 1995) to construct the fire chronology and generate summary statistics. Analysis began with the first year of tree-ring record (AD 1670). Mean fire return intervals and fire frequencies were derived from the composite fire scar chronology and represent the occurrence of fire somewhere in the study area. We compared individual tree fire intervals to composite fire intervals for understanding differences in fire frequency between point locations (individual trees) and the mountain scale.

The initial scarring of shortleaf pine boles requires considerable heat to penetrate the bark (Spalt and Reifsnyder, 1962; Hengst and Dawson, 1994). Lowery (1968), studying cambial injury in shortleaf pine exposed to air temperatures of 532 C, showed that 15 to 20 min was required to kill the cambium under 4 cm of bark. The high temperature variability within a fire suggests that initial scarring of trees can also be highly variable. The majority of the samples collected were taken from landscape positions that are highly sensitive with respect to fire scarring because of upper slope positions, xeric aspects and large fetch (valley bottom to ridge top) distances. Throughout the region, these landscape positions are best for locating fire scar remnants and can overcome some assumptions of the necessary effective sample size. For example, a single shortleaf pine tree can yield over 40 fire scars, with over 10 scars per tree being common.

Dendrochronology.—A radius (pith-to-bark tree-ring series) of the cross-section with the least amount of ring-width variability due to fire injuries was chosen for measurement and crossdating. Ring-width series from each sample were measured and plotted, and the resulting plots were used for visual crossdating (Stokes and Smiley, 1968). Visual matching of ring-width patterns allows for the weighting of important "signature years" over years with low common variability among trees. Plots also aid in identifying errors in measurement and missing and/or false rings that can be associated with injury or drought. Samples were crossdated with other shortleaf pine chronologies from Arkansas and Missouri (Guyette, 1996; Stambaugh and Guyette, 2004) and a master dating chronology was constructed from

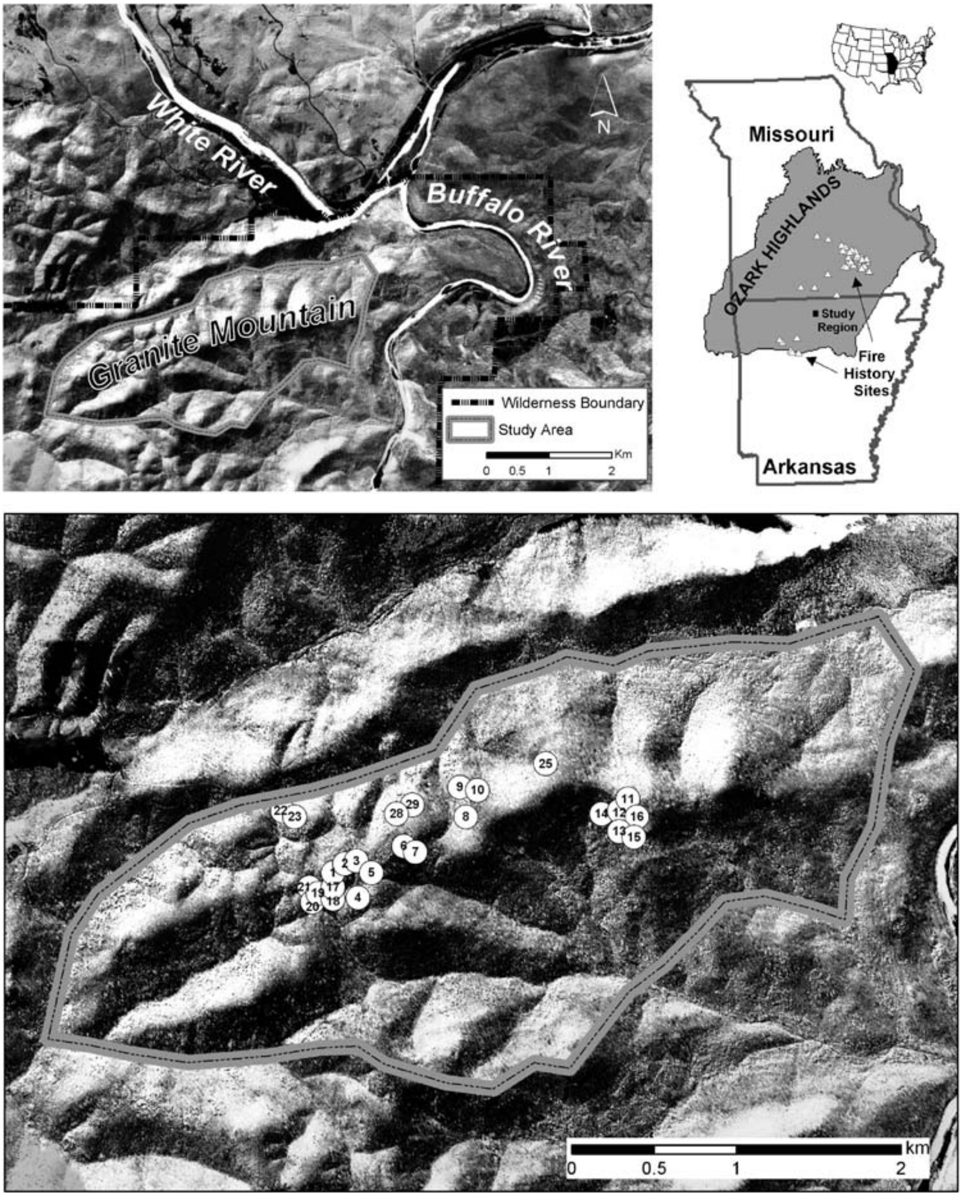

FIG. 1.—Location of the study area (top right) relative to other fire history research sites in the Ozark Highlands province of Arkansas and Missouri, USA. Granite Mountain (top left), part of the Lower Buffalo Wilderness Area, lies at the confluence of the Buffalo and White Rivers. Twenty-six shortleaf pine samples were collected in a 0.8 km^2 area on Granite Mountain. Map with sample locations (bottom) is black and white version of infrared aerial photograph taken in 2000

the tree-ring measurements. The COFECHA program (Holmes, 1983; Grissino-Mayer, 2001) was used to aid in absolute tree-ring dating and measurement quality control.

Fire and drought.—Superposed epoch analysis (SEA) was used to analyze the association between drought and fire occurrence for four separate periods of the fire reconstruction. SEA is commonly used in fire history analyses for determining the degree, strength, and influence of climate prior to and during a fire event (Stephens *et al.*, 2003; Fulé *et al.*, 2005). SEA quantifies the average climate conditions around fire events and determines if they were significantly different (*e.g.,* wetter or drier) than that of all years. The data were bootstrapped for 1000 simulated events in order to derive confidence limits. Fire event data were compared to proxy climate data reconstructed from tree rings to determine if climate was significantly different from average during the 6 y preceding and 4 y succeeding fire events ($n = 92$). We conducted SEA separately for four periods of the fire history (1670–1820, 1821–1880, 1881–1920 and 1920–2001). These periods correspond to cultural periods similar to those used by Guyette *et al.* (2002), with adjustments made for local variation in human population density and fire frequency. The proxy climate data used in the analysis were reconstructed Palmer Drought Severity Indices (PDSI), Grid 202 for north central Arkansas (Cook *et al.*, 2004). In addition to the SEA, we described the association between drought and fire years and used correlation analysis to relate drought to percentage of trees scarred during fire event years.

Human population.—Historic human population data were derived using multiple sources including Marion and Sercey County census records, Arkansas population records, Arkansas state census data (1810–2000) and state population estimates (1686–1999) (Coulson and Joyce, 2003). Decadal Native American population estimates, trends and densities (1520–1820) were derived from multiple sources (Bailey, 1973; Marriott, 1974; Pitcaithley, 1978; Baird, 1980; Stevens, 1991; Hudson, 1995; Rollings, 1995). An average number of humans per square kilometer was estimated by incorporating known Native American settlement locations within the region and their distance from the study site. We divided population estimates by the area of a circle having a radius equal to the distance between the population center and the study site. This method assumes equal distribution of humans throughout the circle area. The area of the circle was considered separately for each cultural group and adjusted each decade to account for temporal changes in territories, and population movements and sizes. Changes in populations and territories documented in the historical literature were used to adjust population density estimates accordingly. We used linear interpolation to derive annual population density from decadal Native American population estimates and Arkansas state census data. One limitation to this method is that linear interpolation causes population changes to occur steadily and may not account for periods of abrupt population change. Population density estimates for the Buffalo River were compared to other estimates for eastern North America (Dobyns, 1983; Ramenofsky, 1987; Thornton, 1987) and occurred within their range of population density estimates (0.07 to 6 humans per km^2). Population density estimates were correlated with the number of fires per decade. The number of fires per decade was calculated for each year using a sliding window approach. This approach involved summing the number of fires in the composite fire chronology for the 10 y preceding each calendar year. For example, the number of fires per decade for 1780 equals the sum of the fire events from 1771 to 1780. This analysis was conducted for the same four periods delineated in the drought analysis using SEA.

RESULTS

Fire scar record.—Nine of the 26 samples were collected from live trees. Remnant and preserved wood was collected primarily from stumps of trees cut around the

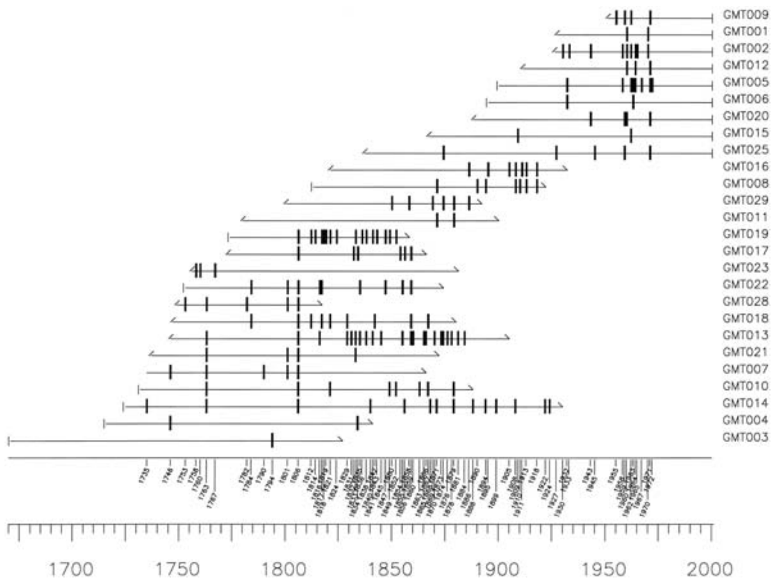

FIG. 2.—Fire chronology of Granite Mountain. Horizontal lines represent a fire scar on a crossdated shortleaf pine tree or remnant. The composite fire scar chronology (all samples combined) is shown at the bottom of the figure. Sample numbers are given on right margin and correspond to locations in Figure 1

beginning of the 20th Century. The total number of years (tree rings) analyzed was 3072 and the mean and maximum number of rings on samples was 118 and 207, respectively. Crossdating of samples showed that no rings were missing from any of the sample ring-width time series. Tree ring-width patterns closely followed shortleaf pine master chronologies despite having considerable variability due to fire injuries and forest stand dynamics.

A total of 165 fire scars and 92 fire years were identified and fire scar dates were compiled into a composite fire scar chronology (Fig. 2) (Guyette and Stambaugh, 2003). The period of record ranged from AD 1670 to 2001 (332 y), but is poorly replicated ($n = 2$) before 1725. The scar dates ranged in calendar year from 1735 to 1972. The percentage of trees that were scarred during fire years ranged from 7 to over 50 (*e.g.,* 1763, 1806 and 1971). The mean number of scars per sample cross section was 6.1 and one sample (GMT013) had 22 fire scars. The majority of fire scars (>90%) were formed at the beginning of a growth ring indicating that these fire events occurred between growing seasons (approximately September to March). More than 90% of the fire scars were located on the uphill side of the bole suggesting upslope fire propagation (Gutsell and Johnson, 1996).

Composite fire intervals.—The frequency of fire intervals decreased exponentially with increasing interval length. Fire return intervals based on the site composite fire chronology were highly variable throughout the period of record and ranged in length from 1 to 28 y (Fig. 3). The mean fire return interval (MFI) for the period 1670–1820, representing predominantly Native American inhabitation, was 7.7 y. Much shorter fire intervals, including periods of annual burning, occurred during Euro-American settlement (1821–1880). Composite MFIs ranged from 1.6 to 7.7 y for the four periods analyzed. In progression, MFIs transitioned from being relatively long (MFI = 7.7 y) during the earliest

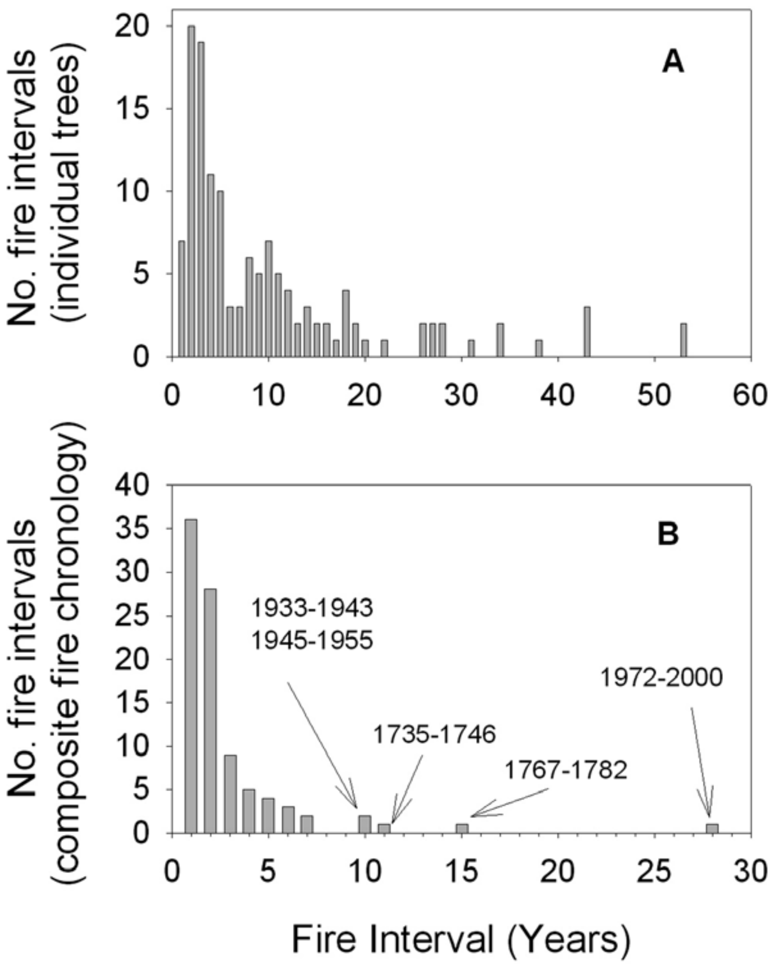

FIG. 3.—Frequency distribution of fire intervals from (A) individual trees and (B) the composite fire chronology. Data are for closed intervals only (*i.e.,* fire events define the beginning and end of each interval)

portion of the record (1670–1820), to significantly shorter (MFI = 1.6 y) during the mid- to late-1800s, to relatively long again during the mid- to late-20th Century. One exception is an abrupt increase in burning for a short time during the mid-20th Century (1955–1972, 12 fires, MFI = 1.55 y). No fires have occurred since 1972.

Individual tree fire intervals.—The distribution of individual tree fire intervals is negatively skewed with intervals that are longer than those of the composite fire interval. It is for this reason that the composite fire chronology (*i.e.,* multiple trees) provides a more accurate estimate of the mean fire return interval at the mountain or landscape scale (Fig. 3). Fire intervals before 1820 were fewer and generally longer than those occurring during the later part of the 19th Century, when 2 and 3-y intervals were most common. Conversely, the longest fire interval began in 1972 and is open-ended until a future fire closes the interval.

TABLE 1.—Stages and characteristics of the fire regime for four distinct cultural periods at Granite Mountain, Lower Buffalo Wilderness Area, Arkansas

Characteristics	Native American period 1670–1820	Euro-American settlement period 1821–1880	Regional development period 1881–1920	Fire suppression period 1921–2001
Economic activities	subsistence and trade	grazing/mining	regional trade/forest resources	industrial forestry/recreation
Mean population density	0.8 humans/km^2	2.4 humans/km^2	9.6 humans/km^2	12.6 humans/km^2
Mean fire return interval (MFI)	7.7 y	1.6 y	2.6 y	4.0 y
% trees scarred (fire events)	17.3%	11.8%	15.7%	21.9%
% trees scarred (all years)	2.3%	7.5%	5.9%	5.5%
r (% scarred × PDSI) (fire events)	−0.29 ($P = 0.01$)*	−0.22 ($P = 0.09$)	−0.18 ($P = 0.27$)	−0.04 ($P = 0.73$)
r (population density × n fires per decade)	0.66 ($P < 0.01$)	0.25 ($P = 0.05$)	0.25 ($P = 0.10$)	−0.65 ($P < 0.01$)

* Correlation is for the well replicated period 1750 to 1820

Fire frequency and human population.—Fire frequency was positively related to human population density up to 1920 when the relationship reversed becoming negatively related at even higher densities (Table 1). The timing of changes in the frequency of burning seemed to coincide with cultural transitions suggesting changes in fire use or values. The most frequent period of burning (1820 to 1880) was a period characterized by a rapidly increasing population that intentionally burned to improve grazing conditions, clear for agriculture and illuminate mining prospects.

Fire occurrence and drought.—Superposed epoch analysis was conducted to determine the association between fire events and drought conditions. Fires occurred in years of drought during the early portion of the record (1670–1820) (Fig. 4). From 1890–1920, however, an opposite relationship existed, with fires occurring when the year prior to the fire event was wet. Fires commonly occurred during the driest years prior to 1820 (*e.g.,* 1735, 1767, 1794, 1806), but were absent during the driest years following 1820 (*e.g.,* 1828, 1861, 1882, 1901) (Fig. 5). The percentage of trees scarred was negatively correlated with Palmer Drought Severity Index (–0.29, $P = 0.01$) for the period 1750 to 1820; however, no significant correlations existed during more recent periods of the record (Table 1).

DISCUSSION

Fire, humans and drought.—Anthropogenic ignitions have an integral role in fire history (Laurance, 1998; Pyne, 1998; Veblen *et al.*, 1999; Vale, 2002). Human life and culture have long been dependent on the frequent use of fire (Sauer, 1950; Pyne, 1982; Hicks, 2000; Delcourt and Delcourt, 2004) making humans a logical predictor of fire frequency particularly in regions with low natural ignition potential such as the Ozark Highlands. The variability in fire frequency at the LBWA over the last three centuries was likely strongly controlled by human ignitions. This is supported by correlations between population

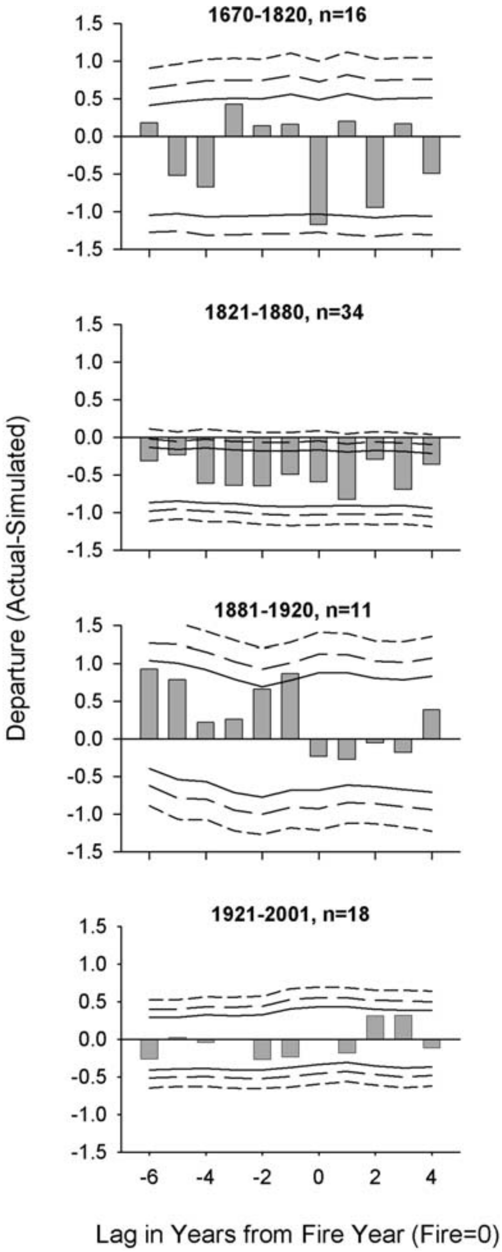

FIG. 4.—Results of superposed epoch analysis for four periods that represent distinct stages in the fire regime. Bars represent deviation from normal drought conditions based on 1000 simulations. Confidence limits are: 90% (solid line), 95% (long dash) and 99% (short dash)

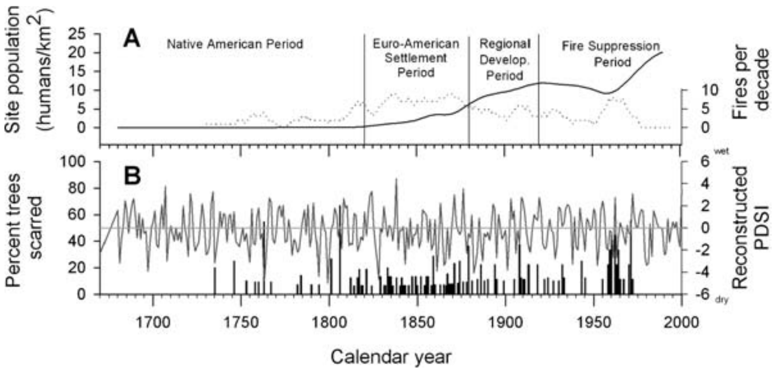

FIG. 5.—A) Estimated annual population density (solid line) from historical documents and census data and the number of fires per decade (dotted line). Four distinct stages of the fire regime were delineated based on changes in regional fire frequency, land use and culture (*see* Guyette *et al.*, 2002). B) Percent trees scarred (bars) and reconstructed Palmer Drought Severity Indices (grey line) (PDSI Grid AR202, Cook *et al.*, 2004) by year

density and fire frequency, high frequency burning, and temporal changes in fire frequency coinciding with changes in culture and land use (Table 1, Fig. 5). The positive to negative change in correlation between population density and fire frequency further supports the importance of human ignitions. The positive correlation, particularly during the Native American and Euro-American settlement periods, reflects a transition from seasonal to permanent human occupation in the region. Later, the negative correlation reflects the increased importance of physical (*e.g.,* fuel discontinuity, land fragmentation, economic risk) and cultural (*e.g.,* fire suppression attitudes) fire-limiting factors that may only become important at higher population densities.

The influence of drought in fire regimes is likely modified by regionally specific conditions such as vegetation and fuels, topography, fire season and ignition sources. In fire regimes with predominantly natural ignitions (*e.g.,* lightning), drought plays an important role in fire frequency. However, in fire regimes with infrequent natural ignitions and abundant human ignitions, such as the LBWA, detecting the effects of drought on fire frequency can be problematic because many drought years occur without fire events and fire events may occur in a range of drought conditions. In this example, frequent human ignitions complicate and potentially mask the influence of drought, or other climate forcing, on fire frequency. From about 1820 to 1880 frequent fire events at the LBWA occurred during a wide range of drought conditions (PDSI –4.7 to 4.5, Fig. 5). The period of high fire frequency beginning circa 1820 suggested strong anthropogenic control on the fire regime and made it difficult to discern a statistical relationship between drought and fire occurrence. No significant relationship between fire events and drought occurred after 1820 (Fig. 4), and no significant correlations existed between the percentage of trees scarred and drought following Euro-American settlement (Table 1). It is interesting that during the period of regional development at LBWA (1881–1920), the years prior to fire events were wet, with the year immediately preceding fire events being significantly wetter than normal (Fig. 4). Increased wetness could have increased fuel accumulation and facilitated the incidence of fire in the following year despite previous frequent burning. In Ozark forests, approximately 50% of the maximum fuel accumulation can occur within 2 y following a fire event (Stambaugh *et al., in press* a).

The advent of active fire suppression is represented in this and other Ozark fire histories (n > 40) by an absence of fire events in the fire chronology beginning around 1940. Before and during the period of fire suppression, the association and correlation between drought and fire occurrence was not significant (Table 1, Figs. 4, 5). During drought in the Ozarks an increased potential exists for ignition of surface fuels (Stambaugh *et al., in press* b). However, we suggest that without human ignitions these drought effects have a small effect on fire frequency. Analyses of climate-fire relationships should consider the potential for anthropogenic influence and attempt to quantify the historic role of humans in the fire regime. Results of this study show variable drought-fire relationships throughout the period of record (1670–2001) (Fig. 4). When populations were relatively low at the LBWA (prior to 1820), a significant relationship between fire occurrence and drought existed. Is this relationship indicative of a climate-fire relationship without or with little human influence? The relative importance of anthropogenic and natural ignitions is debatable and likely regionally variable; nevertheless, drought obviously has important effects regardless of ignition source. Independent evidence, both within and outside of the Ozark region, suggests that drought was important in the presettlement fire regimes across large regions of the Eastern U.S. Guyette *et al.* (*in press*) found that a significant correlation between annual drought indices and fire existed for a large region of Eastern North America and many of the most notable fire events occurred during drought conditions. At the LBWA, two of the most severe fire years occurred in drought years prior to Euro-American settlement (*e.g.,* 1763 and 1806).

No fire events occurred during the driest years of the 1900s (*e.g.,* 1901, 1936, 1952 and 1980) and few (3 of 18 y) occurred between 1900 and 2000 when instrumental PDSI values were less than −2.0. Two of these 3 y occurred during the period of increased fire events circa 1955–1970. Continuation of burning at the study area from 1955–1972 is a unique feature uncommon to other regional fire histories. The causes of these fires are unknown, but explanations include intentional burning by the landowner for management purposes (*e.g.,* forest clearing, improve grazing), or the setting of grudge fires in protest against federal acquisition of the land that is now designated as the Buffalo National River (Pitcaithley, 1978; Rossiter, 1992). The last fire recorded at the site (1972) occurred in the same year that the area was incorporated into the national park system.

Historic fire events.—Fire scars and fire event chronologies provide a host of information about historic fire events. Fire intervals recorded by individual trees are useful for understanding scarring dynamics and the return of fire to a point location, and less useful for describing fire frequency at the landscape scale. Individual tree fire scars can also be used to understand fire behavior, such as whether fires more commonly burned severely over the whole area (high percentage of trees scarred) or if less severe fires (low percentage of trees scarred) that could have resulted from a mosaic burning pattern occurred. The frequency distribution of fire intervals recorded by individual trees conformed to a negative exponential (Fig. 3), showing that trees most commonly had low mean fire return intervals (1–5 y), and individual tree fire intervals greater than approximately 20 y were relatively uncommon. We assume that historic fire severity is synonymous to percentage of trees scarred and that the historic burn area can be determined by looking at the geographic location of trees scarred during any particular year (Shumway *et al.*, 2001). Following this approach and comparing Figures 1 and 2, the fire scar locations also suggest that the site commonly burned in irregular severity or spatial extent, particularly during the periods of Euro-American settlement and regional development (1820–1890) when fire events are characterized by low percentages of trees being scarred and different trees being scarred from one fire event to the next (Fig. 2). Years of likely severe burning, represented by many trees across the entire site being scarred, included 1763, 1806 and 1971. Interestingly, 1806 was a year of widespread drought throughout the northeastern U.S. (Cook *et al.*, 2004) with fires also recorded in the Lower Atoka Hills, Arkansas (Guyette and Spetich, 2003), Big Bay, Michigan (Torretti, 2003) and many sites in Missouri (Guyette and Cutter, 1991; Stambaugh and Guyette, 2005).

Conclusion.—Although little obvious evidence of past burning existed at the site (*e.g.*, charcoal, dominance of fire adapted species), fire scars revealed a highly variable history of burning. This study provides managers with new information about the fire regime such as: the range in historic burning frequency and severity, the effects of drought, the importance of human ignitions, and periods of changes in fire use. One common misconception about many wilderness areas is that they have been minimally altered by humans, but multiple lines of evidence (*e.g.*, historical documents, old roads, tree stumps, and the fire history chronology) show that this is not the case at the LBWA.

Acknowledgments.—The authors thank the Buffalo National River National Park Service personnel and USGS Biological Resources Division for their technical assistance and support of fire history research. Additional thanks to Tom Faust, Matt Struckhoff, Justin Wiles and Thomas Goff for assisting in sample collection and Dan Dey, Erin McMurry and two anonymous reviewers for providing comments on previous versions of the manuscript.

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SUBMITTED 19 JANUARY 2006 ACCEPTED 17 APRIL 2006