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Fire and Human History of a Barren-Forest Mosaic in Southern Indiana

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ABSTRACT.—The purpose of this paper is to provide quantitative fire history information from a historically unique region, the oak barrens of the Interior Low Plateau Ecoregion. We sampled 27 post oak (*Quercus stellata* Wangenh.) trees from the Boone Creek watershed in southern Indiana. The period of tree-ring record ranged in calendar years from 1654 to 1999 and fire scar dates (n = 84) ranged from 1656 to 1992. The mean fire interval for the period 1656 to 1992 was 8.4 y and individual fire intervals ranged from 1 to 129 y. The average percentage of trees scarred at the site was 19% or about 1 in 5 trees sampled. No significant relationship was identified between fire years and drought conditions however, variability in the fire record coincided with Native American migrations and Euro-American settlement periods. Temporal variability in the fire record illustrates not only the dynamic nature of anthropogenic fire regimes but also the importance of humans in culturing presettlement barrens communities.

INTRODUCTION

During the period of Euro-American settlement of the United States the term "barrens" was used by land surveyors and others to describe areas of land that had no or sparse tree cover (Bourne, 1820; Englemann, 1863; Sauer, 1927; Braun, 1950). The term was used loosely for a variety of forest types (*e.g.*, Pine Barrens of New Jersey and northern Lake States, oak barrens of the Midwest) that occurred on a wide range of soils, geology and with variable climate (Tyndall, 1994). Early land descriptions distinguished barrens vegetation from prairies and forests. Botanical manuals and land classification descriptions list barrens as a habitat type that is dominated by drought tolerant plants (Lounsberry, 1900; Gray, 1908; Homoya, 1994), and many of the species that inhabit barrens are representative of the substrate type (*i.e.*, chert, limestone, sandstone, siltstone, gravel, clay and sand) (Bacone *et al.*, 1982; Homoya, 1994).

Oak barrens were common throughout the Eastern United States (Bartgis, 1993; Heikens and Robertson, 1994; Heikens *et al.*, 1994; Homoya, 1994), particularly in the Interior Low Plateau Ecoregion (Bailey, 1995). The "Big Barrens" region, estimated to cover 13,000 to 15,500 km^2 (McInteer, 1944) and located primarily on the Mississippian limestone karst plain of Kentucky and Tennessee (Baskin *et al.*, 1994; DeSelm, 1994), was one of the largest barrens at the time of European settlement. In Indiana, presettlement barren acreage was estimated to be approximately 514,000 ha (Homoya *et al.*, 1985). However, the aerial extent of barrens has decreased dramatically since European settlement because of: (1) conversion to agriculture, (2) urban development (Hutchison, 1994) and (3) reduction in the widespread use of fire (Robertson and Heikens, 1994). In addition, the replacement of the

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term *barrens* with terms such as *glade, savanna* and *woodland* (Baskin *et al.*, 1994; Heikens and Robertson, 1994) has caused problems in assessing the aerial extent of past and present barrens.

Olson (1996) emphasized the importance of fire in maintaining the openness of forests in the Central Hardwood region of the United States based on a synthesis of General Land Office (GLO) surveyor notes, early travelers' descriptions of the vegetation composition and characteristics and accounts of Native American burning practices. Many authors have also concluded that burning was an important factor in creating and maintaining barrens in the Eastern United States (Sauer, 1927; Gleason, 1939; McInteer, 1944; Cottam, 1949; Bielmann and Brenner, 1951; Schroeder, 1981; Anderson and Brown, 1983; Bacone and Post, 1987; Anderson and Schwegman, 1991; Tyndall, 1992, 1994; McClain *et al.*, 1993). It is likely that anthropogenic ignitions were the primary source of fire in the barrens region because of the extremely low frequency of lightning caused fires (Schroeder and Buck, 1970) due largely to heavy rains that accompany storms in this region.

The purpose of this study is to quantify the fire history of an oak barren site in the Interior Low Plateau ecoregion (Fig. 1) and relate the variability in fire frequency to historic periods of drought and changes in anthropogenic ignitions. Knowledge of the fire history of barrens is important for understanding the importance of fire in creating and maintaining barrens communities. Furthermore, understanding the historic fire regime provides an ecological basis for using prescribed fire to mimic historic fire regimes and restore barrens. This study contributes to our understanding of the historical role of fire in the Eastern United States—a region where knowledge of the spatial and temporal dynamics of fire is limited.

MATERIALS AND METHODS

The study site is located in the Boone Creek watershed on the Tell City Ranger District of the Hoosier National Forest (Fig. 1). The Boone Creek watershed is approximately 2 km north of the Ohio River in Perry County, Indiana (38°08′N, 86°28′W). The site is underlain by limestone and characterized by rolling topography with slopes and elevation ranging from 0 to 19° and 168 to 243 m, respectively. Barrens occupy about 6% of the area with barren canopy closure ranging from 0–75%. Currently, the Boone Creek area is largely forested with canopy closure of about 90–95% (USDA, 1992). Oaks and hickories are the most important species in the overstory tree layer, are widely spaced and rarely exceed 15 m in height. Grasses, forbs and small trees dominate the surface and understory vegetation. Comparisons of old (1930s–1940s) with new aerial photographs of the Boone Creek area reveal increases in canopy closure and woody vegetation in previous barren openings; both attributed to fire suppression. Additionally, fire intolerant tree species such as sugar maple (*Acer saccaharum* Marsh.) and American beech (*Fagus grandifolia* Ehrh.) have recently increased in importance in the understory vegetation layer. Several prescribed fires were conducted in the vicinity of the study site during the 1990s including two landscape level burns (approximately 930 ha) and two smaller burns of barren openings (Steven Olson, pers. commu).

Field sampling.—During October of 1999 wedges from 27 post oak (*Quercus stellata* Wangenh.) trees and snags were collected for the purpose of reconstructing the fire history of the site. Wedges were taken exclusively from a 75 ha area in the Boone Creek watershed. Wedges, 2.5 to 5.0 cm thick, were cut from the tree bole within 25 cm of ground level and from the side of the tree that showed external fire scar evidence. We sampled post oaks because the species is long-lived, highly resistant to heart rot, and distributed throughout the study area. Sample trees were selected based on the presence of fire scars, their age and landscape position. The majority of trees were sampled on open southern aspects (barrens)

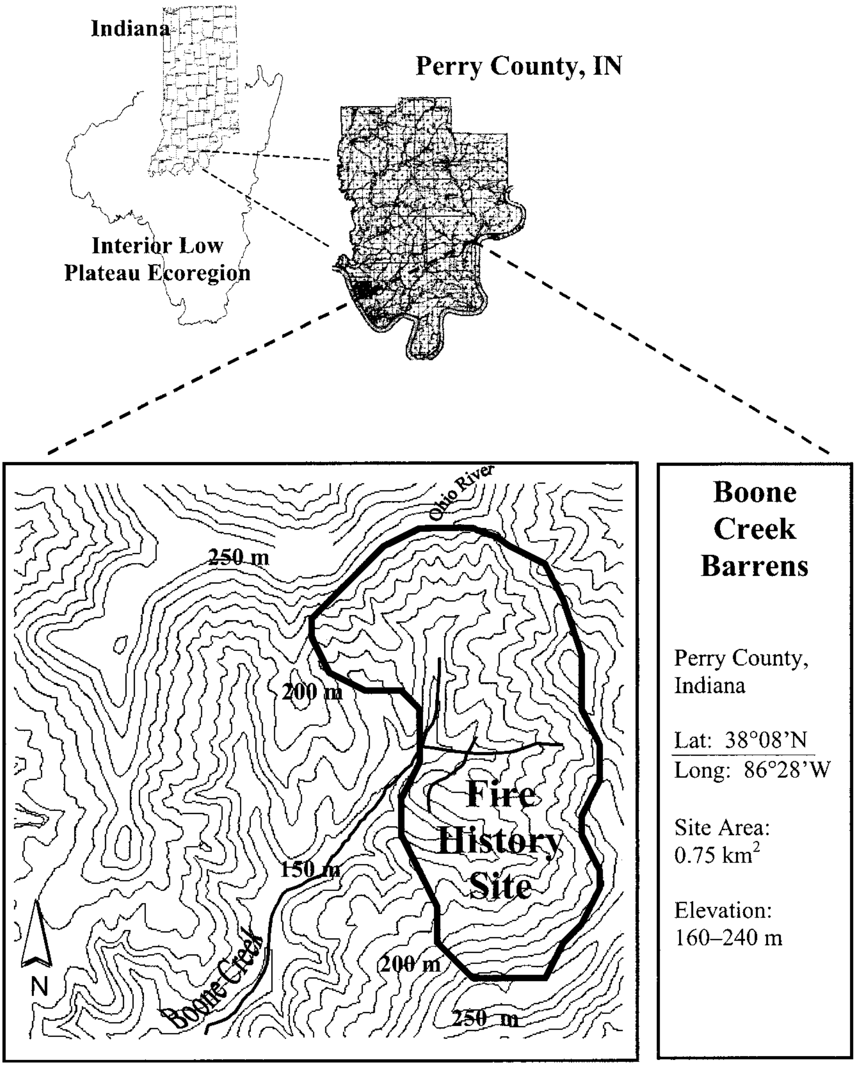

FIG. 1.—Study site is in Perry County on the southern border of Indiana and within the Interior Lowland Plateau. The Boone Creek Barrens area is currently managed by the U.S.D.A. Forest Service, Hoosier National Forest

high on the landscape (*i.e.*, shoulder and upper slope positions), however sample aspect ranged from 70–320° with some representation from lower slope positions. We sampled both young and old trees in order to minimize possible age related scarring biases (due to the effect of tree mass and bark thickness) on the homogeneity of our fire event chronology. Aspect and slope of tree locations were marked on wedges in the field and then transferred to a database. All samples collected were used in creating the fire chronology.

Tree-ring and fire scar dating.—Annual growth increments and fire scars were dated using dendrochronology, a method that uses tree-ring variation caused by climate to date annual growth (Stokes and Smiley, 1968; Guyette and Cutter, 1991). Samples were prepared by sanding their surface to a high polish (*e.g.*, 600 grit sandpaper). Annual rings were measured to an accuracy of 0.01 mm using a moving stage with an electronic transducer and binocular microscope.

Tree-ring measurements were imported into COFECHA (Holmes *et al.*, 1986), a program that checks the accuracy of dating and aids in quality control of measurements. Fire scars were then identified following criteria by Smith and Sutherland (1999) and assigned to the calendar year of the first year of growth response to the fire injury (*e.g.*, callus tissue, cambial death). We determined the diameter of the tree when scarred by measuring the mean radial distance from the scar to pith and multiplying by two. Using FHX2 software (Grissino-Mayer, 1996), we developed the fire chronology and analyzed fire scar years. We computed a mean fire interval and descriptive statistics for both the composite and individual tree mean fire intervals, constructed a composite graph of fire scarring years and tested the actual data frequency distribution using a Kolmogorov-Smirnov goodness-of-fit test and Weibull distribution. Individual tree mean fire intervals were grouped into cultural periods (*e.g.* (1) Native American (pre 1780), (2) Native American and European transition (1780 to 1850), (3) European grazing (1851 to 1930), (4) fire suppression (post 1930)/prescribed fire (1980 to 1999). When intervals spanned multiple cultural periods they were assigned to the period in which the most years of the mean fire interval record represented. The fire intervals and statistical information in this study are based on all fire scars within the 75 ha study area and, therefore, the mean fire interval is defined as the occurrence of fire somewhere in the study site.

Since some fire injuries are not readily distinguishable from injuries caused by other factors (*e.g.*, logging) we used characteristics common to fire scars (*e.g.*, size, shape, orientation, location on tree bole, presence of charcoal, synchrony of scarring among trees and related ring-width response) and fire scar characteristics from known prescribed fires that occurred at the study site during the 1990s to ensure the accurate identification of historic fire scar years. Comparisons and similarities between fire scar characteristics of the prescribed burn and fire scar characteristics before the prescribed burn helped to ensure all scars in our sample were fire-related injuries. In addition, fire scar characteristics were compared to those studied and documented from post oaks in other regions (Guyette and Cutter, 1991; Cutter and Guyette, 1994). Low merchantability and value of barrens trees due to species, bole form, defects and soundness likely inhibited logging therefore, the chance of tree scarring by logging operations is probably low. The lack of stumps and the old age of many of the trees at the study site suggest that logging has been infrequent and has not occurred recently.

Fire scarring biases.—Each tree has a unique fire scarring potential that is based on tree and site characteristics such as species, tree size, bark thickness, previous fire injury, fuel near the bole, thermal xylem characteristics and landscape position (Cutter and Guyette, 1994; Guyette and Cutter, 1991). We sampled young and old post oaks to minimize scarring biases due to tree size and age. Post oak is one of the most fire resistant deciduous tree species in the Midwest, thus making determinations of the historic fire frequency difficult because of the relatively low probability that surface fires have scarred an individual tree. For example, in a study of external scarring from surface fires in the Ozark region of Missouri, Paulsell (1957) found that 10% of post oaks were scarred in annual burns while periodic burns scarred 23%.

Fire and drought event analysis.—Palmer Drought Severity Index (PDSI) reconstructions were used to analyze the potential relationship between fire years and historic drought conditions (Cook *et al.*, 1999). The four nearest PDSI grid points in each of the cardinal directions from the study site were averaged to calculate a mean regional PDSI for the study site. We used PDSI reconstructions from tree-ring records spanning the period of years 1693 to 2000. T-tests were used to determine differences between the mean PDSI for periods in the fire history that were absent of fire and those with frequent fire. Fire years before 1693 were not included in the analysis due to the absence of PDSI reconstruction data.

RESULTS

Composite fire chronology.—The 336-y tree-ring record spanned the period of 1654 to 1999 and fire-scar dates ranged in calendar years from 1656 to 1992 (Fig. 2). Eighty-four fire scars from 27 trees were dated yielding 40 fire intervals (41 fire years). The composite fire chronology was characterized by high variability in fire frequency with a century of no fire and a decade of near annual burning (1896 to 1908, Fig. 2). The mean fire interval for the period 1656 to 1992 was 8.4 y and fire intervals ranged from 1 to 129 y. The mean fire interval for the early half of the fire chronology (1650 to 1820) was 23.0 y with a range in fire intervals from 4 to 129 y. In contrast, fires were more frequent and occurred more regularly in the latter half of the fire chronology (1821 to 1999) where the mean fire interval was 5.3 y and fire intervals ranged from 1 to 40 y. The greatest number of fires scars per year of tree growth occurred from 1650 to 1680; however, our sample size is small in the early period. No fire scars were recorded after this period until the early 1800s.

Years of relatively large fires, calculated as the percentage of trees scarred, were 1821, 1898, 1924 and 1992. With the exception of the 1650 to 1680 period (low sample size, Fig. 3), the highest percentage of sample trees scarred in any fire year was 28% (1898). The average percentage of sampled trees scarred at the site during all fire years was 19.2% or about 1 in 5 post oak trees. We examined the relationship between the number of fire years per decade and the number of sample trees to address the hypothesis that number of fire years is not a function of the number of sample trees and found that the number of sample trees may explain 20% of the variability in fire years per decade. However, this relationship was not statistically significant, likely because of auto correlation in the time series of fire years per decade.

Individual tree fire history.—Fifty-seven individual tree fire intervals resulted from the 27 sample trees (Fig. 4). The mean and mode intervals were 37 and 6 y respectively. Individual tree fire intervals ranged from 1 to 222 y and were positively skewed (skewness = 2.87). A Weibull distribution adequately fit the fire interval data and yielded a median interval of 20.28 y (Fig. 4). Weibull 95% and 5% exceedance probabilities were 0.8 and 129.3 y and intervals <2.5 and >81.4 y were significantly short and long intervals respectively.

Fire scarring.—A histogram of tree basal diameter at the time of fire scarring resulted in a trend of decreasing scarring frequency with increasing tree diameter (Fig. 5). The majority of trees scarred were <15 cm in diameter and ranged from 1.0 to 30.0 cm with a mean of 11.0 cm (SD = 7.1). On average, post oaks ≥ 15 cm showed a lower fire scar frequency than those trees <15 cm. The average number of years from the initial scar to the second scarring event was 42.1 y and ranged from 5 to 180 y.

Drought and fire.—PDSI values were similar for all time periods and categories compared (Table 1). There was no significant difference in PDSI during a 108-y period of no fire (1693 to 1801) and the period of highest fire frequency (1888 to 1929). Few fires occurred during years that were drier than years of recent history (*i.e.*, 1 to 3 y before fire year), particularly in fire years before 1850 (Fig. 6). PDSI values were not statistically different between years of no fire and fire years post-1850. No correlations between lag effects (*e.g.*, t-1, t-2, t-3) of PDSI and fire years (Kaye and Swetnam, 1999) were significant.

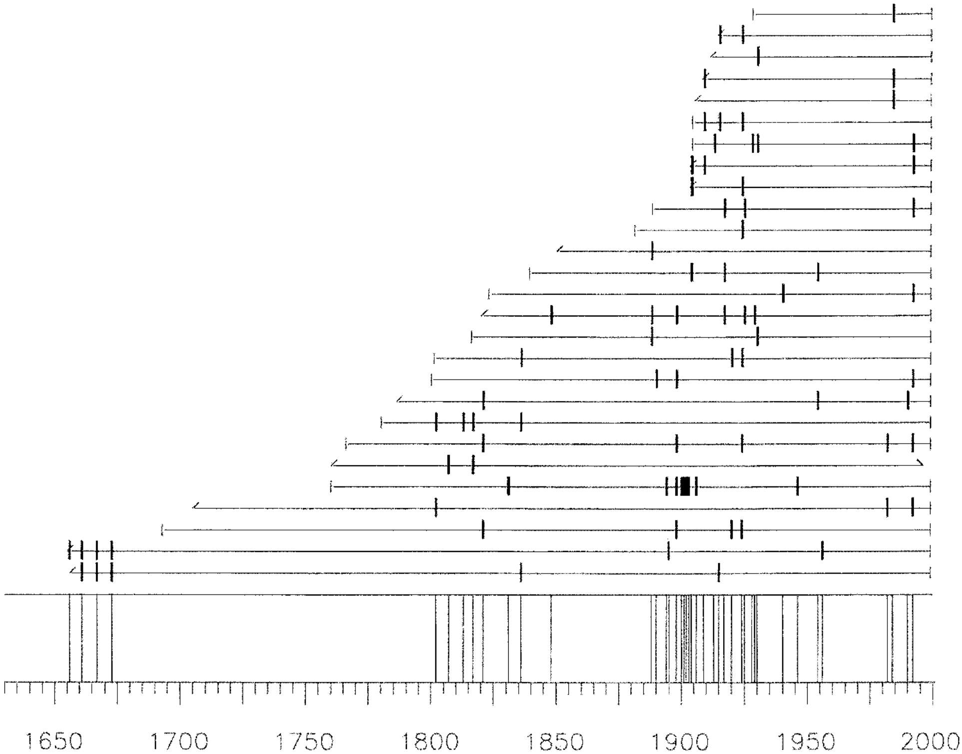

FIG. 2.—A plot of tree samples, their dated fire scars, and a composite fire chronology. The y-axis is calendar years and bold vertical bars represent fire scars. Horizontal lines represent the period of record for each sample tree. Pith dates are represented by short thin vertical lines at the left end of the samples while inside ring dates are represented by diagonal lines. A composite fire scar chronology with all fire years is given at the bottom of the plot

DISCUSSION

Interpretation of the fire scar record.—Woody plant encroachment and succession of barrens to closed-canopy forests was reported as early as the mid-1800s (Chester, 1988). In the absence of fire, succession from barrens to closed canopy forests can occur rapidly (*e.g.*, 40–60 y) (Grimm, 1983, USDA, 1992). Assuming a transition from a barren/open dry upland forest (*e.g.*, historic conditions of the site) to closed canopy forest vegetation (*e.g.*, current conditions of the site) could occur from 50 y of fire suppression, potential for woody encroachment at the Boone Creek study site was high during the 18th Century; a century comprised of a larger 128-y fire free interval (1674 to 1801). Although occurring during a time of low sample size (3 to 9 trees), the 128-y fire free interval is likely an accurate representation of the fire regime. Both small trees and previously scarred post oaks (both likely sensitive to scarring) occurred in this portion of the fire chronology. A second period of succession to forest occurred from 1930 to 1982 (USDA, 1992), a period of low occurrence of fire that allowed fire intolerant woody plants to colonize the site.

There is little evidence that historic fire events corresponded to droughts. This is

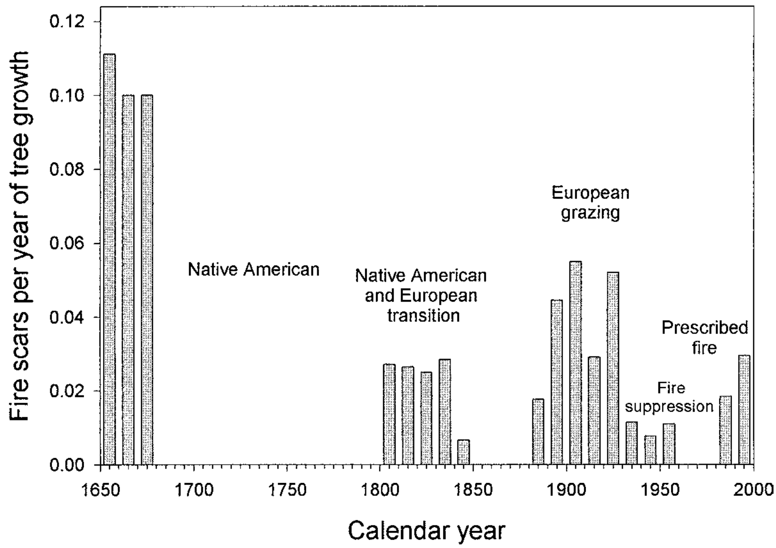

FIG. 3.—A chronology of the influence of fire at the study site. The influence of fire (y axis) is the number of fire scars per decade divided by the number of years of record within a decade on all sample trees. Bars may indicate that either many trees scarred in different years or many trees scarred in a single fire year. Pyro-cultural periods (*see* text) are identified and represent possible changes in human-fire interactions

evidenced by few fire years directly corresponding to drought conditions and significant changes in the fire regime being unrelated to PDSI variability. There is some evidence that fires before 1850 were more strongly correlated with drought conditions, however, this was not statistically significant. Inhabitants of the region may have taken advantage of drought conditions when burning. Regional inhabitants likely used drier than average conditions to modify the landscape with fire as burning during a drought would require less effort in spreading the fire (*e.g.*, number of ignitions) and would likely be more effective in killing woody plants than burning during wetter conditions. As human population and the importance of anthropogenic ignitions decrease it is likely that the correlation between fire and drought would increase.

The lack of evidence supporting a relationship between fire and drought and the presence of a temporal sequence of variability in the fire history suggest that ignitions were largely anthropogenic. The fire history spans five pyro-cultural periods: (1) Native American (pre-1780), (2) Native American and European transition (1780 to 1850), (3) European grazing (1851 to 1930), (4) fire suppression (1931 to 1999) and (5) prescribed fire (1980 to 1999) (Fig. 3). As has been documented elsewhere (Guyette and Dey, 1995, 1997, 2000; Guyette *et al.*, 2002), the sequence and abrupt changes in the frequency of fire at the study site suggest that a strong relationship exists between fire frequency and human population density, settlement and migration.

The temporal variability in fire frequency can be explained by the movement of human populations near the Boone Creek watershed. The long and unusual fire interval in the 1700s (1668 to 1801) at this site may be the result of Native Americans in the Ohio River

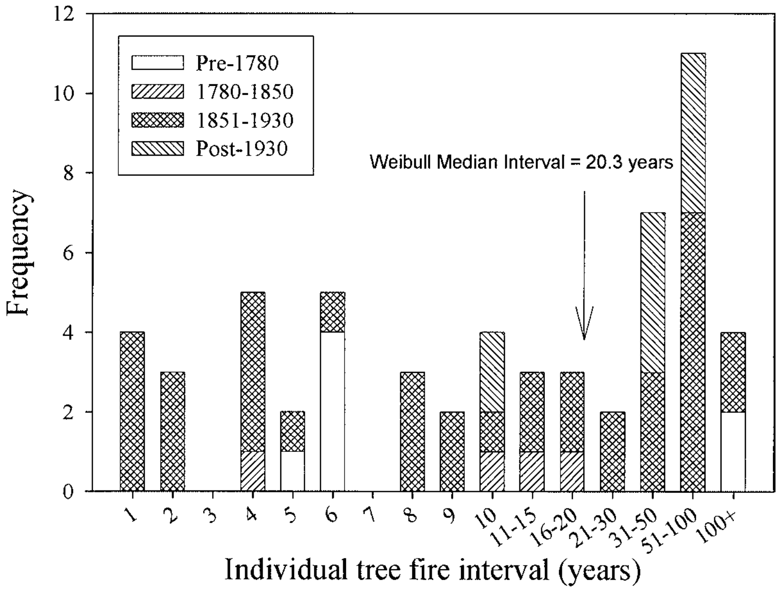

FIG. 4.—Frequency of individual tree fire intervals for important pyro-cultural periods: Native American (pre-1780), Native American and European transition (1780 to 1850), European grazing (1851 to 1930) and Fire suppression/Prescribed fire (post-1930)

Valley migrating into Arkansas and Missouri. Several authors (Hudson, 1995; Obrien and Wood, 1998; Vehik, 1993) point to archeological, linguistic and historic evidence suggesting that the Quapaw and Osage, who lived in Missouri and Arkansas from about 1700 to 1830, had lived in the Ohio River Valley before European arrival. Their migration out of the Ohio River Valley in the latter half of the 1600s may have been a retreat from Iroquois invaders, who had recently acquired European firearms (Baird, 1980). Waldman (1985) reported the Ohio River Valley having the lowest Native American population density in Eastern North America at the time of contact. Nevertheless, considerable archaeological evidence of Native American occupation in the Ohio River Valley and Indiana exists for many periods before contact with Europeans (Kellar, 1973) thus humans cannot be discounted as a potential ignition source during early portions of the fire record.

The return of frequent fire in the early 1800s (1802 to 1848) was likely due to humans. Native Americans ceded parts of Southern Indiana to the United States in the treaties of 1803 and 1804 (Kellar, 1958). Westward migrating tribes, such as the Shawnee and Delaware, moved through southern Indiana (Anson, 1970; Clark, 1993). In the early 19th Century, Europeans settled along the Ohio River in Southern Indiana and population density and fire ignitions began to increase even in topographically rough areas such as the study site (Figs. 1, 2) (Guyette and Dey, 2000; Guyette *et al.*, 2002). Between 1840 and 1930 Indiana population increased from 476,183 to 3,238,503, a more than six-fold increase (Stats Indiana, 2001). Population density reached a maximum of about 18 people/km^2 circa 1900 in Indiana. An abrupt increase in the frequency of fire at the study site occurred between 1888 and 1930 compared to the previous 50 y (Fig. 2). Increases in human population in Indiana between 1820 and 1930 are correlated with increases in fire years per decade (r =

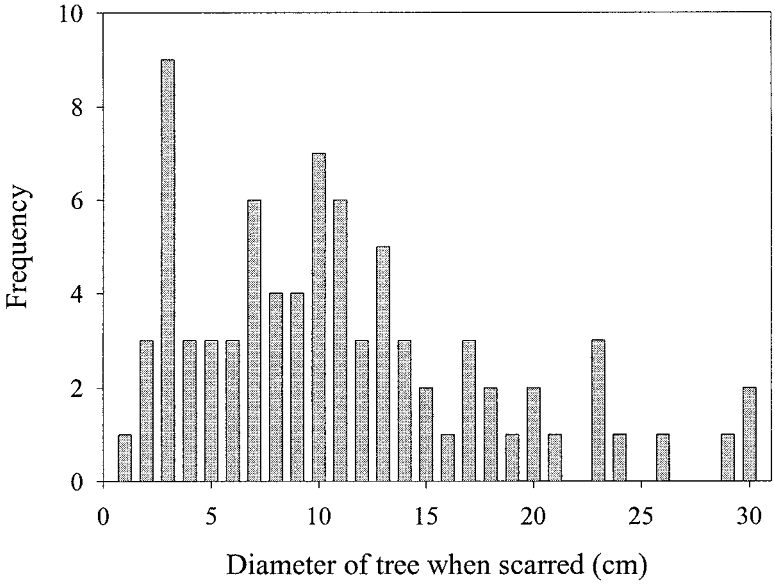

FIG. 5.—Histogram of the diameter of trees when they were fire-scarred indicating the greater likelihood of smaller diameter trees being scarred by a fire

0.63) and the number of fire scars per decade (r = 0.70), however these correlations are not statistically significant because of the short sample length and autocorrelation within the decadal human population data. Landscape level burning in the late 1800s and early 1900s was followed by fire suppression beginning in the mid-1900s.

During the most recent part of the fire event chronology the dates of fire scars are associated with the dates of prescribed fires. Fire scar dates of 1990 and 1992 are associated with prescribed burns conducted in April of 1990 and 1992 by the Hoosier National Forest. Prescribed fires also occurred in 1991 and 1994 in the vicinity of the study site but did not scar the 27 study trees. We do not know if the prescribed fires of 1991 and 1994 actually burned in the study area. The 1992 fire was the first large (152 ha) prescribed burn conducted in the Boone Creek watershed and it scarred 26% of the trees in our sample. Despite our targeting of sample trees, the percentage of trees scarred at the study site in 1992 (26%) is similar to that documented for post oak trees (23%) scarred after prescribed fire in the Ozark region of Missouri (Paulsell, 1957). The average percentage of trees scarred at the Boone Creek study site during all fire years was 19.2% or about 1 in 5 post oak trees. This statistic may overestimate the percentage of trees scarred in a fire because we targeted trees that had external evidence of scarring. However, many trees that were scarred were not sampled because of extensive rot and many fire scarred trees may have died when young and thus were not accounted for in the sample population.

Topographic influences on the fire regime.—Several pyro-topographic features may be relevant to the fire history of this site. Although the site is located approximately 2 km northwest of the Ohio River (Fig. 1), the spread of anthropogenic fire from this major travel corridor to the study site would have been inhibited due to several conditions. No terraces or other potential agricultural sites are located on the side of the river adjacent to the study site,

TABLE 1.—PDSI values for contrasting periods of the fire record showing the similarity in drought conditions. There is no significant difference between the period 1693–1801 and 1888–1923 (T_{crit} = 1.67)

Period	Mean fire interval (y)	Mean regional PDSI	t Stat (df = 54)
1693–1801	no fires	−0.215	
			−1.22
1888–1929	2.1	0.034	
All nonfire years	—	−0.185	
All fire years (n = 37)	—	−0.182	

thereby decreasing the potential for human occupation and agricultural activity as a source of anthropogenic ignitions. Secondly, if a fire were to initiate near the river, the steep step and bluff topography along the river would have inhibited the northward spread of fire because fire does not travel well over steep bluff terrain (Anderson, 1991; Batek *et al.*, 1999). Finally, if a fire were to reach the river's bluff top, it would need to spread down slope to enter the study site, thus further minimizing its potential to spread and scar trees. The highly dissected topography of the surrounding landscape also likely inhibited the spread of fires into the study site, particularly from the north, west and south. Isolation of the site from fire spreading from other areas makes the fire history all that more responsive to changes in local human populations and land uses.

Fire was undoubtedly an important disturbance agent in the maintenance of the Boone Creek barrens site. Fire scars from the period of 1656 to 1999 resulted in a mean fire interval of 8.4 y and we attribute the variability in fire intervals (1 to 129 y) within this period to changes in human populations. Today, many extant barrens (*e.g.*, Boone Creek barrens) are small isolated remnants on xeric sites with rocky, shallow or infertile soils (Bacone *et al.*, 1982; McInteer, 1944). These remnant barrens remnants were probably core areas in what were much larger barrens complexes. Core barrens areas are important in barren restoration because they have relic populations of barren dependent species and they can be used to target areas on the landscape for barrens restoration.

Barrens restoration.—Prescribed burning can be an effective technique for barren restoration (Anderson and Brown, 1983; Bacone and Post, 1987; Wade and Menges, 1987; Stritch, 1990). Where available, land managers should use local fire histories as an ecological basis for developing their fire management plans and prescriptions. Fire managers should recognize that results of mean fire intervals from composite fire chronologies were produced by stochastic presettlement fire events and prescribed burns may not produce similar fire scarring and other fire effects. Prescribed burning practices that mimic presettlement fires might include landscape-scale fires started from point ignitions, fires that only burn portions of the landscape, low to moderate intensity fires (*i.e.*, $<25\%$ trees scarred during a fire event) and variability in burning intervals. Prescribed burning practices such as repeated ignitions to ensure an area is burned homogeneously and static fire intervals are not congruent with the presettlement fire regime we observed in the Boone Creek watershed.

This empirical evidence supports fire as a key disturbance to maintain barren communities and it provides managers with information for understanding the nature of presettlement fire regimes, how dynamic fire regimes can be and how humans have modified the landscape with five centuries of burning. Historic fire frequencies vary greatly between areas due to three and one half factors such as fuel, vegetation, weather and

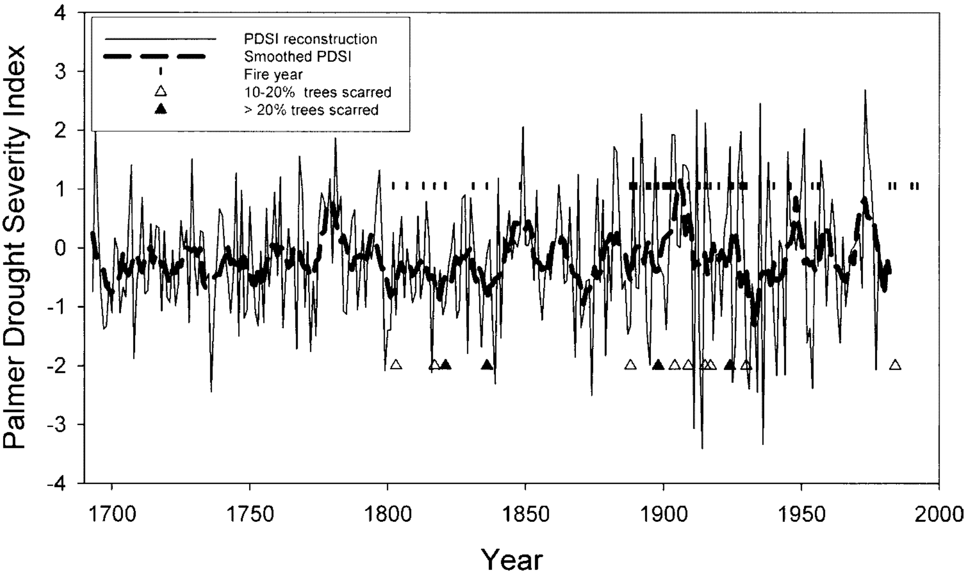

FIG. 6.—Regional Palmer Drought Severity Index (PDSI) reconstructed from tree-rings (Cook *et al.*, 1995) and a smoothed PDSI utilizing a 7-y moving average for the purpose of displaying droughts with longer term influence

climate, topographic roughness and pyro-cultural influence. Therefore, fire histories are typically applicable only to the area surrounding the study site. Additional fire histories are needed from other historic barrens before variability in fire regimes in barrens communities throughout southern Indiana and the larger Interior Low Plateau can be fully characterized.

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LITERATURE CITED

ANDERSON, R. C. 1991. Presettlement forest of Illinois, p. 9–19. *In:* Proc. of the Oak Woods Management Workshop. Eastern Illinois University, Charleston.

——— AND L. E. BROWN. 1983. Comparative effects of fire on trees in a mid-western savanna and an adjacent forest. *Bull. Torr. Bot. Club,* **110**:87–90.

——— AND J. E. SCHWEGMAN. 1991. Twenty years of vegetational change on a southern Illinois barren. *Nat. Areas J.,* **11**:100–107.

ANSON, B. 1970. The Miami Indians. University of Oklahoma Press, Norman, Oklahoma. 329 p.

BACONE, J. A. AND T. W. POST. 1987. Effects of prescribed burning on woody and herbaceous vegetation in black oak sand savannas at Hoosier Prairie Nature Preserve, Lake County, Indiana. *Indiana Acad. Sci. Proc.,* **96**:205–208.

———, L. A. CASEBERE AND M. D. HUTCHISON. 1982. Glades and barrens of Crawford and Perry Counties, Indiana. *Indiana Acad. Sci. Proc.,* **92**:367–373.

BAILEY, R. G. 1995. Description of the ecoregions of the United States, 2nd ed. Misc. Pub. No. 1391, USDA For. Serv. 108 p.

BAIRD, W. D. 1980. The Quapaw Indians: a history of the Downstream People. Univ. of Oklahoma Press, Norman Oklahoma. 290 p.

BAKER, W. L. AND D. EHLE. 2001. Uncertainty in surface-fire history: the case of ponderosa pine forests in the western United States. *Can. J. For. Res.,* **31**:1205–1226.

BARTGIS, R. L. 1993. The limestone glades and barrens of West Virginia. *Castanea,* **58**:69–89.

BASKIN, J. M., C. C. BASKIN AND E. W. CHESTER. 1994. The Big Barrens region of Kentucky and Tennessee: further observations and considerations. *Castanea,* **59**:226–254.

BATEK, M. J., A. J. REBERTUS, W. A. SCHROEDER, T. L. HAITHCOAT, E. COMPAS AND R. P. GUYETTE. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. *J. Biogeog.,* **26**:397–412.

BIELMANN, A. P. AND L. G. BRENNER. 1951. The recent intrusion of forests in the Ozarks. *Ann. Missouri Bot. Garden,* **38**:261–282.

BOURNE, A. 1820. On the prairies and barrens of the West. *Amer. J. Sci. Art, Series 1,* **2**:30–34.

BRAUN, E. L. 1950. Deciduous forests of eastern North America. Blakiston Co., Philadelphia. 482 p.

CHESTER, E. W. 1988. The Kentucky barrens of northwestern middle Tennessee: an historical and floristic perspective, p 145–163. *In:* Proc. 1st Annual Symp. On Nat. Hist. of Lower Tennessee and Cumberland River Valleys. The Center for Field Biology of Land Between the Lakes, Clarksville, Tennessee.

CLARK, J. E. 1993. The Shawnee. Univ. Press of Kentucky, Lexington, Kentucky. 105 p.

COOK, E. R., D. M. MEKO, D. W. STAHLE AND M. K. CLEAVELAND. 1999. Drought reconstructions for the continental United States. *J. Climate,* **12**:1145–1162.

COTTAM, G. 1949. The phytosociology of an oak woods in southwest Wisconsin. *Ecology,* **30**:271–287.

CUTTER, B. E. AND R. P. GUYETTE. 1994. Fire frequency of an oak-hickory ridgetop in the Missouri Ozarks. *Am. Midl. Nat.,* **132**:393–398.

DESELM, H. R. 1994. Tennessee Barrens. *Castanea,* **59**:214–225.

ENGELMANN, H. A. 1863. Remarks upon the causes producing the different characters of vegetation known as prairies, flats, and barrens in southern Illinois with specific reference to observation made in Perry and Jackson counties. *Am. J. Sci. Art,* Series 2, **36**:384–396.

GLEASON, H. A. 1939. The individualistic concept of the plant association. *Am. Midl. Nat.,* **21**:92–110.

GRAY, A. 1908. Gray's new manual of botany, 7th ed. American Book Company, New York. 926 p.

GRIMM, E. C. 1983. Chronology and dynamics of vegetation change in the prairie-woodland region of southern Minnesota, U.S.A. *New Phyt.,* **93**:311–350.

GRISSINO-MAYER, H. D. 1996. Users manual FHX2. Laboratory of tree-ring research, University of Arizona, Tuscon. 117 p.

GUYETTE, R. P. AND B. E. CUTTER. 1991. Tree-ring analysis of fire history of a post oak savanna in the Missouri Ozarks. *Nat. Areas J.,* **11**:93–99.

——— AND ———. 1997. Fire history, population, and calcium cycling in the Current River watershed, p. 354–372. *In:* Proc. 11th Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. NC-188.

——— AND D. C. DEY. 1995. A dendrochronological fire history of Opeongo Lookout in Algonquin Park, Ontario, p. 4. *In:* Ontario For. Res. Inst. For. Res. Rep. No. 134. Sault Ste Marie, Ontario.

——— AND ———. 1997. Fire and logging history at Huckleberry Hollow, Shannon County, Missouri. Forestry Research Paper No. 1. Missouri Dept. Cons. Jefferson City, Missouri. 10 p.

——— AND ———. 2000. Humans, topography, and wildland fire: the ingredients for long-term patterns in ecosystems, p. 28–35. *In:* Proc. Workshop on Fire, People, and the Central Hardwoods Landscape. USDA For. Serv. Gen. Tech. Rep. NE-274.

——— R. MUZIKA AND D. C. DEY. 2002. The dynamics of anthropogenic fire regimes. *Ecosystems,* **5**:472–486.

HEIKENS, A. L. AND P. A. ROBERTSON. 1994. Barrens of the Midwest: a review of the literature. *Castanea,* **59**:184–194.

———, K. A. WEST AND P. A. ROBERTSON. 1994. Short-term response of chert and shale barrens vegetation to fire in southwestern Illinois. *Castanea,* **59**:274–285.

HOLMES, R. L., H. R. K. ADAMS AND H. FRITTS. 1986. Quality control of crossdating and measuring: a users manual for program COFECHA, p. 41–49. *In:* Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin. Laboratory of Tree Ring Research, University of Arizona, Tuscon.

HOMOYA, M. A. 1994. Indiana barrens: classification and description. *Castanea,* **59**:204–213.

———, D. B. ABRELL, J. R. ALDRICH AND T. W. POST. 1985. The natural regions of Indiana. *Proc. Indiana Acad. Sci.,* **94**:245–268.

HUDSON, C. 1995. Introduction, p. 208. *In:* Cultural encounters in the early south. Univ. of Arkansas Press, Fayetteville.

HUTCHISON, M. D. 1994. The barrens of the Midwest: an historical perspective. *Castanea,* **59**:195–203.

KAYE, M. W. AND T. W. SWETNAM. 1999. An assessment of fire, climate, and apache history in the Sacramento Mountains, New Mexico. *Physic. Geog.,* **20**:305–330.

KELLAR, J. H. 1958. An archaelological survey of Perry County. Indiana Historical Bureau, Indianapolis. 40 p.

———. 1973. An introduction to the prehistory of Indiana. Indiana Hist. Soc., Indianapolis. 76 p.

LOUNSBERRY, A. 1900. A guide to the trees. Frederick A. Stokes Co., New York. 313 p.

MCCLAIN, W. E., M. A. JENKINS, S. E. JENKINS AND J. E. EBINGER. 1993. Changes in the woody vegetation of a bur oak savanna remnant in central Illinois. *Nat. Areas J.,* **13**:108–114.

MCINTEER, B. B. 1944. A change from grassland to forest vegetation in the "Big Barrens" of Kentucky. *Am. Midl. Nat.,* **36**:276–282.

OBRIEN, M. J. AND W. R. WOOD. 1998. The prehistory of Missouri. Univ. of Missouri Press. Columbia. 417 p.

OLSON, S. D. 1996. The historical occurrence of fire in the Central Hardwoods, with emphasis on southcentral Indiana. *Nat. Areas J.,* **16**:248–256.

PAULSELL, L. K. 1957. Effects of burning on Ozark hardwood timberlands. Univ. of Missouri Agric. Exper. Stat. Bull. No. 640. 24 p.

RICKETTS, T. H., E. DINERSTEIN, D. M. OLSON AND C. J. LOUCKS. 1999. Terrestrial ecoregions of North America. Island Press, Washington D.C. 485 p.

ROBERTSON, P. A. AND A. L. HEIKENS. 1994. Fire frequency in oak-hickory forests of southern Illinois. *Castanea,* **59**:286–291.

SAS INSTITUTE INC. 1987. SAS/STAT guide for personal computers, version 6. SAS Institute Inc., Cary, North Carolina.

SAUER, C. O. 1927. Geography of the Pennyroyal of Kentucky, the barrens. *Kentucky Geolog. Survey, Series* 6, **25**:123–130.

SCHROEDER, W. A. 1981. Presettlement prairie of Missouri. Natural History Series, No. 2, Missouri Dept. Cons. 37 p.

SCHROEDER, M. J. AND C. C. BUCK. 1970. Fire weather. USDA For. Serv., Ag. Handbook No. 360. 288 p.

SMITH, K. T. AND E. K. SUTHERLAND. 1999. Fire-scar formation and compartmentalization in oak. *Can. J. For. Res.,* **29**:166–171.

STATS INDIANA. 2001. Indiana Business Research Center, Indiana University, Bloomington.

STOKES, M. A. AND T. L. SMILEY. 1968. Introduction to tree-ring dating. Univ. of Chicago Press, Illinois. 73 p.

STRITCH, L. R. 1990. Landscape-scale restoration of barrens-woodland within the oak-hickory forest mosaic. *Rest. Mngmt. Notes,* **8**:73–77.

TYNDALL, R. W. 1992. Historical considerations of conifer expansion in Maryland serpentine "barrens". *Castanea,* **57**:123–131.

———. 1994. Contributions of the Barrens Symposium: Preface. *Castanea,* **59**:182–184.

USDA, Forest Service, Hoosier National Forest. 1992. Environmental assessment: ecological restoration in the Boone Creek watershed. Tell City Ranger District, Perry County, Indiana. March 13.

VEHIK, S. C. 1993. Dhegia origins and plains archaeology. *Plains Anthr.,* **38**:231–252.

WADE, K. A. AND E. S. MENGES. 1987. Effects of fire on invasion and community structure of a southern Indiana cedar barrens. *Indiana Acad. Sci.,* **96**:273–286.
WALDMAN, C. 1985. Atlas of the North American Indian. Facts on File. New York. 276 p.

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