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Research Note

Fire History of a Relict Oak Woodland in Northeast Texas

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Abstract

Empirical data generated from fire scars are a foundation for understanding fire regimes, designing land-management objectives, and addressing long-term land-use and climate-change effects. We derived precise dates of historic fires from fire-scar injuries occurring on trees growing in a relict post oak woodland in northeastern Texas. The fire-event chronology shows the last three centuries were marked with human influence, with an overall trend of decreasing fire occurrence through time. Thirty different fire events occurred between 1690 and 2007, of which 26 occurred prior to 1856. All fires occurred while trees were dormant. From 1690 to 1820, the mean fire interval was 6.7 yr. A 50-yr period without fire occurred in the latter 19th century (1855–1905) and coincided with the establishment of an oak cohort. A second extended period (80 yr) without fire characterized most of the 20th century. We hypothesize that the absence of fire during much of the last century has resulted in increased tree density and canopy closure, the establishment of fire-intolerant vines, shrubs, and trees, and likely the decline of fire-dependent plant species. Information describing long-term changes of fire regimes in oak woodlands in this region could aid in determining fire-management objectives with respect to prescribed fire implementation and community restoration.

Resumen

Los datos empíricos procedentes de cicatrices de fuego son la base para la comprensión de los regímenes de fuego y para diseñar objetivos del manejo de la tierra. De la misma manera, sirven para diseñar el uso a largo plazo de la tierra y los efectos del cambio climático. Fechas específicas de incendios forestales se obtuvieron a partir de cicatrices de fuego en una arboleda de robles remanente en el noroeste de Texas. La cronología de incendios demuestra la influencia humana en la tendencia a disminuir estos eventos en los últimos tres siglos. Treinta incendios forestales diferentes ocurrieron entre 1690 y 2007 de los cuales veintiséis se dieron antes de 1856. Todos los incendios ocurrieron mientras los árboles estaban en estado latente. El intervalo de incendios entre 1690 y 1820 fue de 6.7 años. Se detectó un periodo de 50 años sin incendios forestales entre 1855 y 1905 que coincide con el establecimiento de una cohorte de robles. Un segundo periodo (80 años) sin fuegos caracterizó la mayor parte del siglo 20. Planteamos la hipótesis que la ausencia de incendios durante el último siglo ha causado un incremento en la densidad de árboles y un cerramiento de sus copas, así como el establecimiento de especies de lianas, arbustos y árboles que no toleran al fuego con una disminución en especies dependientes de la incidencia de incendios forestales. Información que describa los efectos a largo plazo en cambios de los regímenes de incendios en arboledas de roble en la región puede ayudar a determinar los objetivos de manejo de incendios con relación a la implementación de fuegos prescritos y restauración de la comunidad.

Key Words: Caddo, dendrochronology, fire frequency, fire regime, fire scars, fire suppression

INTRODUCTION

Dendrochronological (tree-ring)-based records of fire occurrence are widely used for characterizing historic fire regimes throughout the world. Their precision and accuracy make them well suited for applications combining other high-precision data such as vegetation, climate, or historical records. In Texas, historic fire regimes have gone largely unquantified and are currently limited to conifer forests in mountainous regions located on the western border of the state (> 700 km from our study site; Moir 1982; Sakulich and Taylor 2007; Poulos et al. 2009). In the southern Great Plains only a few fire scar records are available (Clark et al. 2007; Stambaugh et al. 2009; DeSantis 2010) and all describe a somewhat frequent fire regime (5–7 yr) occurring in oak–grassland ecosystems prior to Euro-American settlement. The value of these records pertains not just to describing fire regimes, but also toward understanding long-term vegetation change, drought–fire interactions, and the historical context for wildland and prescribed fire use in present-day natural resource management. The objective of this study was to reconstruct the long-term changes in fire occurrence from fire-scar injuries on trees at a relict oak woodland located in northeastern Texas.

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METHODS

Study Site

The study site was located at Purtis Creek State Park (lat 32°21′N, long 96°00′W) in Henderson and Van Zandt

Counties, Texas. Land for the 640-ha park began to be acquired in the late 1970s and the park opened in 1988. The park lies in the Oak Woodlands Natural Subregion of northeastern Texas (Arnold 1978) where the terrain is flat to rolling and elevation is approximately 100 m above sea level. The park is surrounded by private lands that consist of primarily grasslands interspersed with forests. No major fire barriers (e.g., large rivers, rugged topography, barren soils) exist nearby. Potential major fire barriers include the Trinity River and Cedar Creek drainages located approximately 25 and 15 km to the southwest, respectively. Climate is considered humid subtropical (Peel et al. 2007), and average annual precipitation is 106 cm (National Climate Data Center 2002).

The study site consists of an approximately 0.5-km^2 area of rare old-growth post oak (*Quercus stellata* Wangenh.) and sand post oak (*Quercus margaretta* Ashe ex Small) woodland that has recently experienced extensive mortality from undetermined causes. Younger trees have become established among the older dominant oaks and include black hickory (*Carya texana* Buckl.), blackjack oak (*Quercus marilandica* Münchh.), winged elm (*Ulmus alata* Michx.), and eastern redcedar (*Juniperus virginiana* L). Herbaceous and understory vegetation ranges from sparse grass and sedge growth under dense canopy cover to thick woody shrub and vine growth under more open canopy conditions (Keith 2009). The abundance, presence, and sizes of fire-sensitive species and a lack of external fire scars on trees suggest that no fires have occurred at the site for at least several decades.

The location of the study site at the western edge of the Oak Woodlands and nearly adjacent to the Blackland Prairie subregion provides a unique opportunity to describe the fire history in a grassland–woodland transition zone at the southern periphery of the tallgrass prairie ecosystem. Some information (based on expert opinions) regarding the natural role of fire is available for the Blackland Prairie subregion, though no quantitative fire-history descriptions exist. The pre–Euro-American settlement period fire frequency of the Blackland Prairie was probably comparable to more northern tallgrass prairie regions (~ 3–5 yr; Wright and Bailey 1982), though higher temperatures and a longer growing season may have led to some climate-induced differences (Smeins 1972).

Field and Laboratory Methods

In February 2009, fire-scarred trees were located by surveying the entire study area. Prior to cutting the boles of trees were "sounded" with a hammer to assess the degree of solid–hollow wood. Forty-nine cross sections were cut from near the ground level of only dead oaks. All sample locations were recorded with the use of a GPS. Slope, aspect, and orientation were written on each cross section. In the laboratory, cross sections were surfaced with an electric hand planer and sanded to reveal the annual rings and fire scars. We measured the radius (pith-to-bark ring series) of each cross section that had the least amount of ring-width variability due to reaction wood, injury, or callus tissue. The radius-measurement location was also chosen to maximize the number of rings measured. Ring-width plots were used for visual cross matching of ring-width signature years. Visual matching of ring-width patterns allows the weighing of important "signature years" over years with low common variability among trees. Plots and matching of known frost ring years (Stahle 1999) aided in ensuring accurate dating. COFECHA, software for quality control and cross dating of tree-ring measurements (Holmes et al. 1986), was also used to ensure the accuracy of both relative and absolute dating of the samples by correlation analysis. Absolute dating was accomplished by cross dating with cores collected from live trees. The master ring-width chronology was compared with other nearby oak chronologies (Stahle et al. 1982).

Fire scars were identified by the presence of callus tissue, charcoal, barrier zones, and cambial injury. Fire scar dates were assigned to the year of first cambial response. If possible to view, the season of the fire event was recorded based on the position of the injury either within the ring (early to late growing season) or between rings (dormant season; Kaye and Swetnam 1999). Fire-scar data were summarized from the composite fire chronology—a compilation of all fire years recorded at the site. Fire-scar data-analysis software, FHX2 (Grissino-Mayer 2001) was used to plot the fire-scar data and for performing statistical analysis of fire events. Composite fire chronologies are commonly used to describe fire regimes because statistics describing events are based on many samples, leading to a more accurate representation of the presence of fire at a particular site than would be obtained from single trees. Not all trees may be scarred in a fire because of the variation in fire behavior, fuels, and tree characteristics (e.g., size, bark thickness); thus several trees at a site are combined to give a better estimate of fire frequency. Furthermore, it should be noted that very low intensity fires may not leave scars on trees; therefore fire intervals represent maximum intervals for the period of record.

RESULTS

The post oak tree-ring record spanned the period 1681 to 2007 (327 yr; Fig. 1). Post oak tree ages ranged from 66 to 321 yr. Ages of trees suggested a bimodal age distribution with trees of approximately 315 and 140 yr in age. The older cohort of trees established circa 1690 and lived through a century of repeated and likely low-severity fires. The younger cohort of trees established at the beginning of a 50-yr period without fire that began in 1855 (Fig. 1).

Eighty-three fire scars were identified and dated between 1690 and 1924, resulting in 30 different fire events. Based on the timing of cambial response to fire injuries, all fire scars with a determinable seasonality were shown to have occurred during the dormant growth season. Based on the percentage of trees scarred in a given year, the most severe fire occurred in 1704, when 7 of 19 trees were fire scarred (37%). Fire intervals ranged from 2 to more than 50 yr. The full period (1690–1924) mean fire interval was 8.1 yr (SD = 8.1) and median fire interval was 6.0 years. Prior to 1820 (estimated beginning of major Euro-American influence; McNatt et al. 1998), the mean fire interval was 6.7 yr. A 50-yr period without fire occurred in the second half of the 19th century (1855–1905). The longest period without fire occurred from 1924 to 2007 (the end year of the tree growth record). Immediately after the study site was sampled, however, the area was treated with prescribed fire.

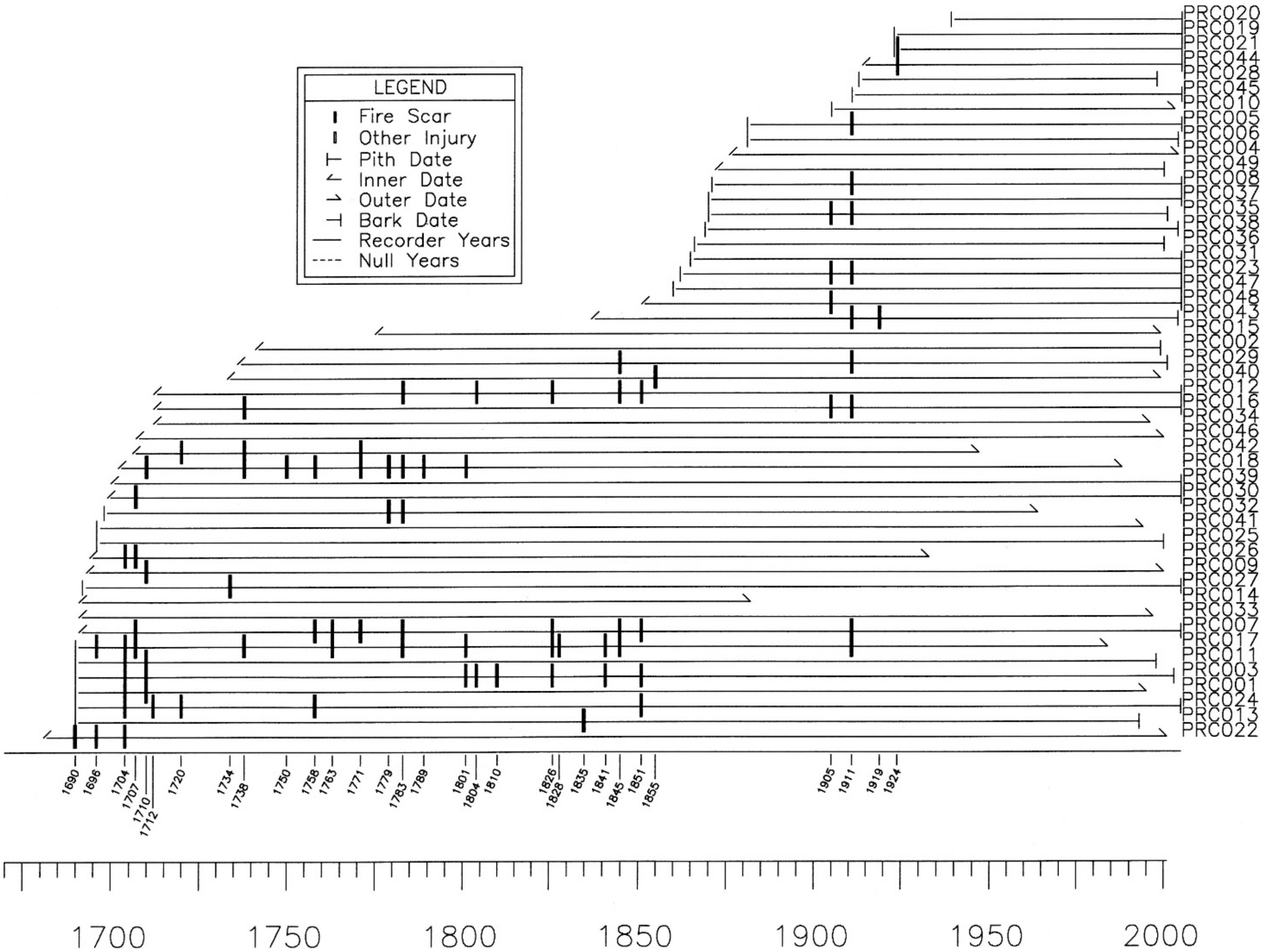

Figure 1. Fire-scar history chart of Purtis Creek State Park, Texas. Each horizontal line indicates the tree-ring record of an individual tree. The left ends of horizontal lines are capped with either a vertical line that indicates the pith of tree or a diagonal line that indicates the innermost ring (in case where tree center is hollow or rotten). The right ends of horizontal lines are capped with either a vertical line that indicates the bark year or a diagonal line that indicates the outermost ring (in case where outer wood is rotten or removed). Bold vertical ticks along horizontal lines represent fire years based on fire scars. All fire-scar dates are included in the x-axis composite (bottom of chart).

DISCUSSION

It is nearly impossible to positively identify causes of prehistoric fire events (natural vs. anthropogenic). Often the relative importance of ignition sources from modern observations and information on historic cultural fire use are used to infer importance of past ignition sources. From long-term fire-scar history studies of oak woodlands in the Ozarks and Cross Timbers, temporal changes of fire events (e.g., frequency, severity, seasonality) have been shown to coincide with changes in culture and population (Guyette et al. 2002; Clark et al. 2007; Stambaugh et al. 2009). Perhaps less well known is the historic importance of lightning ignitions. Specifically, an estimate is needed of the numbers of lightning ignitions that would be required to maintain historic burning frequencies considering the vegetation conditions, potential of fire sizes, and fire compartment sizes in the plains.

The majority of historic fires recorded at Purtis Creek occurred during the Historic Caddoan period (AD 1680–1860), a period of increasing trade and cultural exchange between Hasinai Caddo and Europeans in the region (Perttula 1992). The use of fire by Caddo groups is relatively unknown. Pollen evidence from nearby Upshur County, Texas has been used to suggest that the Caddo manipulated their environment through burning (Albert 2007). Fire scars from central Louisiana also associates Caddo occupation with very frequently burned longleaf pine (*Pinus palustris*; Stambaugh et al. in review). In addition to the Caddo, eastern Native American tribes (Cherokee, Shawnee, Delaware, and Kickapoo) migrated to the northeastern Texas region circa 1820 until they were forced further west in 1839. These eastern Native American tribes have a more well-documented history of intentional burning of land (Pyne 1983; DeVivo 1991; Guyette et al. 2002; Guyette et al. 2006b), and likely influenced the rate of ignitions during this period. Concerning the fire-history record prior to settlement at Purtis Creek, though it may be impossible to decipher more closely the degree to which fires were of natural or anthropogenic origin, the overall decrease in fire post-1850s compared to before strongly implicates cultural changes as a significant influence on the fire regime.

Following the earliest Euro-American settlement in the area in 1839, a period of about 15 yr occurred when fires still burned at regular intervals. Not much information is available about these earliest years of settlement, though settlement occurred relatively slowly in the beginning. The four original land grantees of the current Purtis Creek State Park lands were most likely absentee landowners and never actually lived on or cultivated their lands (McNatt et al. 1998). Beginning in the 1850s expansion of agriculture and population centers began in earnest, synchronous with the beginning of the 50-yr fire-free period at Purtis Creek. This period without fire appears to correspond to the period of greatest economic and agricultural expansion. Roads were constructed in the 1850s, the last Caddo were relocated in 1859, and the arrival of railroads by 1880 caused an immediate increase in population and settlements (McNatt et al. 1998).

The topography and surrounding landscape of the study site also likely influenced fire occurrence throughout the period of record. The area is bounded to the south and east by a perennial creek and bottomland forest, which may have acted as a break for fires approaching from the south. Some time after settlement the land immediately north of the study area was used as agricultural field and, depending on land use and season, could have restricted fires from reaching the study site.

Four fire events occurred in the early 20th century and, despite being relatively recent, no records have been found that indicate the origin or extent of these fires. Changes in land-management practices may be one possible explanation for this cluster of fire events.

Overall, the fire frequency at Purtis Creek prior to Euro-American settlement was very close to previously published fire frequency estimates for the region. Frost (1998) suggested historic fire frequency ranged from 4 to 6 years based on fire-history studies, landforms, and vegetation characteristics. Guyette et al. (2006a) estimated a fire frequency of 4–5 yr based on coarse-scale climate conditions and human population-density estimates. Despite both of these sources being coarse-scale estimates, our fire-scar evidence supports that their ranges of estimates are plausible for this region.

MANAGEMENT IMPLICATIONS

Quantitative fire-history information, such as fire frequency, seasonality, and severity can guide prescribed burning programs and help managers develop specific fire effects goals. The fire history of Purtis Creek may also provide insight to the potential fire-regime characteristics of other oak savanna–woodland communities in Texas and southern Great Plains—a region where relatively frequent fire was likely a significant ecological influence. Purtis Creek State Park is representative of many public lands where managers face challenges in restoring or maintaining natural communities following decades of fire suppression. As a result of decades without fire invasive fire-sensitive plant populations (e.g., eastern redcedar, *Smilax* sp., yaupon [*Ilex vomitoria* Ait.], American beautyberry [*Callicarpa americana* L.]) have expanded while populations of fire-dependent plant species (e.g., *Yucca freemanii*) are increasingly rare (Keith 2009). Accumulations of fine fuel loads and dense woody understories have increased the risk of wildfires and prescribed fires having relatively severe effects. Prescribed fire-management goals at Purtis Creek are to decrease fuel loads, encourage herbaceous species (grasses and forbs) richness and diversity, reduce invasive understory brush species such as yaupon, eastern redcedar, and winged elm, and proceed along the long-term objective of natural community restoration and maintenance. In addition, park managers seek to convert old fields to savannahs or woodlands and restore native forb and grass diversity (Keith 2009).

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