Working toward a fire-scar network for the Cumberland Plateau—Fire history results from Bridgestone Nature Reserve at Chestnut Mountain, Tennessee1

Authors: Abadir, Erin R., Marschall, Joseph M., and Stambaugh, Michael C.

Source: The Journal of the Torrey Botanical Society, 149(2) : 159-165

Published By: Torrey Botanical Society

URL: https://doi.org/10.3159/TORREY-D-21-00032.1

Journal of the Torrey Botanical Society 149(2): 159–165, 2022.

Working toward a fire-scar network for the Cumberland Plateau—Fire history results from Bridgestone Nature Reserve at Chestnut Mountain, Tennessee[1]

Erin R. Abadir, Joseph M. Marschall, and Michael C. Stambaugh[2]
Center for Tree-Ring Science, School of Natural Resources, University of Missouri, Columbia, MO 65211

Abstract. We reconstructed historical fire regime characteristics at the Bridgestone Nature Reserve at Chestnut Mountain using tree-ring dated fire scars on live and dead shortleaf pine (*Pinus echinata* Mill.) trees. Fire-scar records described the historical fire frequency and seasonality from the mid-18th century to present. Overall, we found historical fires occurred relatively frequently, predominantly in the dormant season, and were likely low-severity events. Mean fire intervals (MFIs) were slightly longer in the pre-Euro-American period (1744–1834; MFI = 9.6 yrs) versus the post-Euro-American period (1834–1935; MFI = 5.6 yrs). No fires were recorded after 1940, which in combination with past logging and land uses, is likely a major contributor to the ongoing decline of shortleaf pine and pyrophytic oak species observed here. Surprisingly, the majority of fire event years after 1834 were also recorded at Savage Gulf State Natural Area (52 km to the south), raising questions about potential historical fire sizes, patterns, and driving factors across the Cumberland Plateau landscape. In a landscape where fire-scarred remnants are present but relatively scarce and rapidly disappearing, these data are important for evidencing historical fire regimes and developing a more comprehensive regional network of fire history sites that could reveal valuable historical ecological information for the Cumberland Plateau.

Key words: dendrochronology, fire frequency, fire seasonality, Chestnut Mountain, shortleaf pine, drought, management

Across large portions of the eastern US, over 200 years of forest resource extraction and widespread burning followed by fire exclusion has led to forests greatly departed from their presumed historical vegetation and fire regime conditions (Guyette *et al.* 2012, LANDFIRE 2014). Where remnant fire-adapted and fire-dependent species are present, natural community restoration efforts commonly rely on restoring fire to the landscape. In many areas, there is a great need to identify historical evidence for fire regimes and to document historical fire frequency, intensity, extent, and seasonality to better understand historical ecology and restoration goals (Greenberg and Collins 2021). The Cumberland Plateau, in the southern portion of the broader Appalachian Plateau physiographic region, is one area where historical fire regime information is particularly lacking.

Multiple lines of evidence—including paleoecological, ethnobotanical, and archaeological studies (Delcourt and Delcourt 1998, 2004; Ison 2000), fire-scarred trees, and numerous descriptions by early European explorers and settlers of fire-maintained landscapes (Michaux 1805, Ramsey 1860, Ison 2000)—have provided a baseline understanding that this was once a landscape of frequent fire strongly influenced by humans (Ison 2000, Clatterbuck *et al*. 2006). However, physical evidence and quantitative measures of past fire frequency and other fire regime characteristics remain unclear and difficult to obtain. When available, fire-scarred trees can provide detailed fire history information and a strong scientific basis for applied historical ecology—the use of historical information to inform modern-day land management (Swetnam *et al*. 1999, Harley *et al*. 2018).

Based on regional historical documentary accounts, including descriptions of vegetation communities, we believe that relatively frequent historical fire regimes must have been extensive

[1] We thank The Nature Conservancy–Tennessee Chapter for providing funding and field support for this research. In particular, we thank Katherine Medlock and Alex Wyss for coordinating project logistics and fieldwork activities. Additional support was provided on-site by Trisha Johnson and Brittney Townsend. Sample preparation and laboratory analysis was supported by Eli Gaffney and Victoria Marshall at the University of Missouri. In-kind support was provided by the Center for Tree-Ring Science at the University of Missouri.

[2] Author for correspondence: stambaughm@missouri.edu

doi: 10.3159/TORREY-D-21-00032.1

Received for publication September 28, 2021, and in revised form January 12, 2022; first published March 24, 2022.

across the Cumberland Plateau. Currently, scant evidence exists with only three fire-scar history studies published to date (McEwan *et al*. 2014, Hutchinson *et al*. 2019, Stambaugh *et al*. 2020) in this region. In this study, we report on a field survey for fire-scarred shortleaf pine trees at a site on the Cumberland Plateau, and subsequent analyses of fire scars contained therein. With this information, we sought to increase understanding of regional fire ecology, provide land managers with reference conditions about historical fire frequency and seasonality, and continue to further develop a network of study sites that will contribute to a broader landscape-scale understanding of the fire ecology of the Cumberland Plateau region.

Methods. Study Site. The study was conducted at Bridgestone Nature Reserve at Chestnut Mountain (BNR) in southeastern White County, Tennessee, USA (longitude: –85.32°; latitude: 35.87°; elevation ∼550 m) in the Mid-Cumberland Plateau physiographic region (Smalley 1982). Situated along the western escarpment of the Cumberland Plateau, the 2,332-ha preserve is owned and managed by The Nature Conservancy. In the vicinity exists an extensive area of undeveloped forestland including more than 24,000 ha of additional public ownerships.

Topography at BNR is a combination of relatively flat plateau, rugged sandstone cliffs, and deeply dissected ravines. Forests grade from mixed-mesophytic composition on lower and side slopes and along drainages to oak-hickory-pine forests on drier, upland sites (Hinkle 1989). Generally, these forest types are considered highly productive hardwood forests. The climate is humid subtropical, with a mean annual precipitation of 141 cm (Tennessee Climate Division 2, Period: 1901–2021; NOAA 2022).

Field Methods. In March 2021, we extensively surveyed most upland and plateau rim locations of BNR for the presence of fire-scarred living, recently dead trees, and remnant stumps/snags suitable for dendrochronological dating and fire history reconstruction. To determine the general abundance and spatial distribution of historical fire evidence at BNR, we did not limit collection of samples to a defined spatial extent as is often done in fire history reconstructions (typically 1 km^2), but instead we collected across the entire BNR area (∼23.3 km^2). We observed evidence of fire scarring on multiple species (Fig. 1), but limited our collections to shortleaf pine (*Pinus echinata* Mill.) as wood from this species is often well preserved and can extend multiple centuries back in time. For this wood, we cut cross-sections (10 to 30 cm thick) from the basal portion of trees using a chainsaw. For each tree sampled, we recorded slope, aspect, height above ground, and a GPS location. In addition, we collected increment cores from living pine trees.

Laboratory Methods. Cross-sections were dried and then sanded with progressively finer sandpaper (80 to 1,200 grit) to reveal cellular details of annual rings and fire scars. We measured tree-ring widths in sequence (bark-to-pith) to 0.01-mm precision using a microscope, a Velmex TA measuring system (Velmex, Inc., Bloomfield, New York, USA), and Measure J2X software (ProjectJ2X; VoorTech Consulting, Holderness, NH). Ring-width series for all trees were plotted and visually crossdated using standard dendrochronological methods (Stokes and Smiley 1968) and statistically verified with the COFECHA computer program (Holmes *et al*. 1986). Fire scars were identified by the presence of callus tissue, traumatic resin canals, liquefaction of resin, and/or cambial injury (Smith and Sutherland 1999). Charcoal was often associated with fire-scar injuries on the outside of the tree. Fire scars were dated to the exact calendar year of formation and, when possible, the season of cambial response to injury based on the position within or between rings (Kaye and Swetnam 1999). Dormant season fire scars occurred between rings and thus were assigned to the subsequent calendar year (*i.e.,* the year of cambial response to the injury).

Data Analysis. We compiled, summarized, and statistically analyzed fire-scar data using FHAES v. 2.0.2 fire history analysis software (Brewer *et al*. 2016). Fire frequency at the site (composite) level was described using mean fire intervals (MFIs, the average number of years between fire events), interval ranges, and Weibull median intervals (WMI) when Kolmogorov-Smirnov goodness-of-fit tests indicated that the Weibull distribution modeled the interval data better than a normal distribution. We also calculated fire interval ranges and means for individual sample trees.

Fire intervals were calculated for the entire period of record (minimum of three sample trees) and also for two subperiods representing changes

Fig. 1. Left: A dead remnant shortleaf pine tree with multiple fire scars and charcoal at its base persists at the edge of the Cumberland Plateau escarpment at Bridgestone Nature Reserve (BNR) at Chestnut Mountain, Tennessee. Right: Mature and dominant oak with a partially healed over injury at its base likely caused by past repeated and frequent fires.

in human occupation and culture associated with Euro-American settlement (EAS). While acknowledging that Euro-American settlers were present and impacting indigenous populations from an earlier time, we selected the year 1834 as the approximate beginning of the EAS period based on the Indian Removal Act of 1830. This also allowed for direct comparisons with previously published fire history data in the Cumberland Plateau and Eastern Highland Rim ecoregions (Stambaugh *et al*. 2020). The EAS period included only fire events that occurred prior to the beginning of effective fire suppression activities circa 1935.

We tested for associations between fire events and drought conditions using Superposed Epoch Analysis (SEA) in FHAES. For this, reconstructed summer season Palmer Drought Severity Indices (PDSI; grid point 220; Cook *et al*. 2004) were compared to all fire event years and a subset of fire years that were shared with a nearby (~52 km SSW) fire history study site at Savage Gulf State Natural Area (SAV), Tennessee (Stambaugh *et al*. 2020). In SEA, PDSI data were bootstrapped for 1,000 simulated events to derive confidence limits that were then used to test whether drought conditions of fire event years were significantly wetter or dryer than expected. SEA tests were repeated for the six years preceding and four years succeeding fire events to account for potential lagged effects.

Results. Samples were collected from 19 dead shortleaf pines across the BNR property. Of these, 11 were successfully crossdated and had fire scars included in the analysis. Inability to date some samples related to such factors as: too few rings, advanced wood decay prohibiting viewing of rings, and anomalous ring-width variability due to scarring and abrupt growth releases. The 11 samples that were successfully crossdated were located in a relatively small area (0.2 km^2). For these, the number of tree rings per sample ranged from 110 to 224, and the resulting chronology spanned the calendar years of 1711 to 2020 (309 years). Fire scars were identified on nine of the dated samples, and the number of scars per tree ranged from one to eight. Fire scar dates ranged from years 1715 to 1940 (Fig. 2). All identifiable

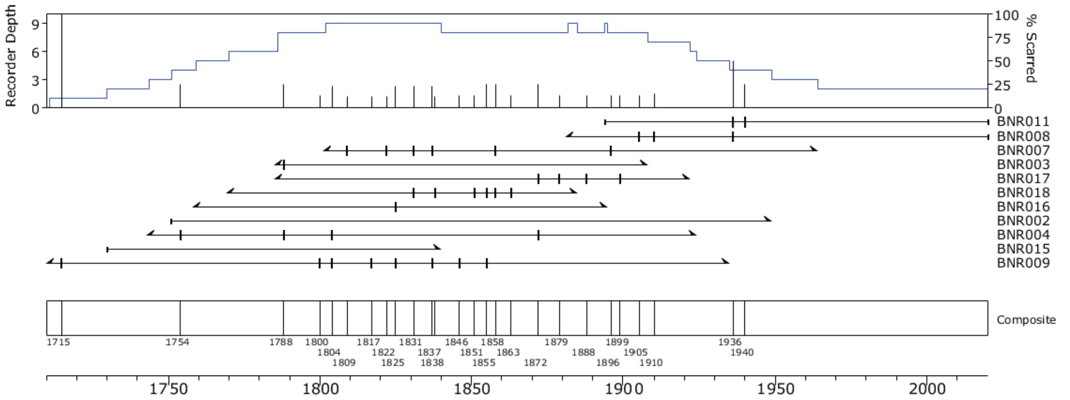

FIG. 2. Fire history chart for Bridgestone Nature Reserve (BNR) at Chestnut Mountain, Tennessee. Each horizontal line represents the lifespan of an individual tree (sample number on right). Slanted or vertical lines at the left terminus of horizontal lines indicate the inner-most ring or pith date, respectively. Slanted or vertical lines at the right terminus of horizontal lines indicate the outer-most ring present or bark, respectively. Vertical ticks on horizontal lines indicate fire scars. At top, the blue line shows sample depth through time, and vertical bars show the percentage of sample trees scarred in each fire year. At bottom, a composite of all fire events recorded at the site is shown.

scars occurred in the dormant season ring position. Growing season scars ($n = 3$) were observed, but on samples that did not crossdate, so the years of these events are unknown and unaccounted for in the fire chronology.

Based on all dated fire scars on all trees, fire intervals ranged in length from 1 to 34 yr, and fires occurred on average every 7.8 yr (Table 1). In the period before widespread influence of Euro-American settlement (1744–1834), fires appeared to occur less frequently (MFI = 9.6 yr) than they did following settlement (MFI = 5.6 yr). Fire intervals on individual trees ranged from 3 to 85 yr. Across all periods of time, the mean fire interval recorded on an individual tree was 16.9 yr.

When all fire event years were considered, SEA showed a statistically significant association between fire occurrence and dry conditions in the fire year. When only fire years that were shared with the fire history site at SAV, the level of signficance was higher.

Discussion. This study highlights both the immense value and potential of fire-scar studies in the Cumberland Plateau region and the limitations to interpretation when fire-scarred remnants are not abundant. The fire frequencies indicated here are likely very conservative due to the small sample size and because some fire scars occurred on undated samples and were not included in the fire-scar record. Despite our exhaustive search of the entire BNR area, relatively few datable fire-scarred remnants were found. Those that were found were commonly near cliffs and escarpments and near drainages—sites that may be considered marginally representative of the broader landscape from a fire spread perspective. Fire-scarred remnants may be scarce at BNR, due not to a lack of historical fires, but rather to a loss of remnants over time to fire, decay, and land-use practices (*e.g.,* the extensive removal of pine wood to fuel tar kilns in this region [pers. comm. Steve Simon, The Nature Conservancy]). Though remnant fire-scarred trees were limited in abundance, their presence across nearly the entire BNR property confirms that this site was once

Table 1. Fire scar history results for Bridgestone Nature Reserve (BNR) at Chestnut Mountain on the Cumberland Plateau, Tennessee. Fire interval results are provided for all years of record (min. 3 samples) and the pre-Euro-American settlement (EAS) and post-EAS time periods. MFI = mean fire interval; SD = standard deviation; WMI = Weibull median interval.

	All years (1744–1963)	Pre-EAS (1744–1834)	Post-EAS (1834–1935)
Fire scars (*n*)	35	13	18
Fire years (*n*)	25	9	14
MFI	7.8	9.6	5.6
SD	7.4	10.2	2.5
Range	1 to 34	3 to 34	1 to 9
WMI	6.4	7.7	5.5

Table 2. Fire scar history results for study sites located throughout the Cumberland Plateau ecoregion. Years represents the time span covered by the tree-ring record. Mean fire intervals (MFI) are provided for each site in the pre-Euro-American settlement (EAS) and post-EAS time periods. Number of samples and number of fire scars are also summarized. The present study site is abbreviated as BNR.

Study site (state)	Years	Pre-EAS MFI	Post-EAS MFI	No. Samples	No. Scars
HTN (KY)[1]	1748–2004	6.6	3.5	31	75
ANG (KY)[2]	1740–2017	5	3.8	25	98
BEH (KY)[3]	1669–2009	9.3 (all years)		35	33
BNR (TN)	1711–2020	9.6	5.6	11	35
SAV (TN)[2]	1659–2018	4.4	2.4	26	144
JMT (GA)[2]	1673–1979	7.1	2.3	20	130

[1] Hutchinson *et al*. 2019.
[2] Stambaugh *et al*. 2020.
[3] McEwan *et al*. 2014.

more influenced by fire disturbance than current vegetation conditions would imply.

Fire scar history studies in the Cumberland Plateau and broader Appalachian Plateau region (McEwan *et al*. 2007, Hutchinson *et al*. 2019, Flatley *et al*. 2013, Stambaugh *et al*. 2016, Stambaugh *et al*. 2020) have consistently reported historical fire regimes characterized by relatively frequent, low- or mixed-severity fires occurring primarily in the dormant season. This characterization of Cumberland Plateau fire regimes is consistent with what we found at BNR. Compared to the other Cumberland Plateau fire history studies (Table 2), mean fire return intervals were slightly longer at BNR. With the limited number of suitable scarred samples at BNR, however, it is unclear if this is an artifact of small sample size or if there are site-specific factors at BNR that limited fire occurrence and spread (*e.g.,* topographic roughness, natural fire breaks, human population density).

Fire appeared to be less frequent in the pre-EAS period as compared to after EAS. While the small sample size prevents meaningful statistical evaluation of this observation, it is a characteristic that has been observed in other fire-scar history studies in the Cumberland Plateau and southern Appalachian regions (*e.g.,* McEwan *et al*. 2014, Stambaugh *et al*. 2020). Also in agreement with other fire history studies in the region (Brose *et al*. 2014, Lafon *et al*. 2017), the majority of identifiable scars were formed in the dormant season. In the southern Appalachians, dormant season (fall, winter, early spring) fires are associated with anthropogenic ignitions when fuel and climate conditions are favorable for fire spread, while growing season fires are associated with late-spring and summer months, when lightning strikes are most frequent (Lafon *et al*. 2017, Stambaugh *et al*. 2017, Tippett et al. 2019). With seemingly fewer fires during the pre-EAS period and a majority of fires in the dormant season, the historical fire regime at BNR exhibits the hallmark traits of a primarily anthropogenically driven fire regime. Further research is needed to improve confidence and understanding of these dynamics.

One of the most surprising findings from this study was the high number of shared fire years with SAV. All of these shared fire years were in the post-EAS period, and most (82%) occurred in years with summer season PDSI drier than normal ($\bar{x} = -1.17$). This raises the question of what is driving the high level of correspondence and whether the correspondence results from single, extensive landscape fire events, multiple individual fires, or mixed proportions of each. Increasing the coverage of fire scar sampling between BNR and SAV could further elucidate the drivers of historical fire extents and patterning. These data may provide further context to understanding potential modern day fire risk or fire compartments under drought conditions.

Although additional samples are not likely to be found at BNR, we think it is likely that more fire history evidence exists on the similar land types on adjacent properties, which includes an extensive complex of public lands in the Caney Fork River watershed. Expanded fire history studies within this complex would inform landscape-scale management planning, prioritization of prescribed burning efforts, and fire implementation (Kelly 2020). Such information is relevant to management that deals with altered fire regimes, changing land use, and potential future climate change impacts. Conditions of upland forests at BNR exhibit evidence of forest mesophication and densification, successional trends occurring throughout the eastern U.S. broadleaf forest (Nowacki and Abrams 2008, Hanberry *et al*. 2020, Alexander *et al*. 2021). In addition, the restoration of early successional vegetation states (open structured forests and habitats), including management to promote shortleaf pine and shortleaf pine-oak forest types, is a major emphasis in this portion of the Cumberland Plateau.

The fire scar history presented here provides land managers at BNR and other similar Cumberland Plateau sites with baseline reference points on the historical fire regime before widespread fire exclusion. Although we document recurring fires in historical time periods, an expanded regional fire-scar network is needed to improve confidence in these findings and draw more meaningful conclusions about the past fire regime of the broader Cumberland Plateau. BNR is described by The Nature Conservancy as a "living laboratory," and research goals include restoring fire to the landscape to improve oak-pine habitat and increase forest resiliency in the face of changing climate. Altered forest composition and structure in fire-adapted ecosystems due to suppression leads to reduced forest resiliency and impaired ecological function (Greenberg *et al*. 2021). Often, prescribed fire is the best method available for restoring forest composition and structure, and increasing function and resiliency in these systems. Information on site-specific historical fire frequency and seasonality, in conjunction with considerations of current forest and climatic conditions, can provide a solid foundation for management prescriptions aimed at conserving or restoring imperiled shortleaf pine-oak woodlands and forests in the Cumberland Plateau.

Literature Cited

Alexander, H. D., C. Siegert, J. S. Brewer, J. Kreye, M. A. Lashley, J. K. McDaniel, A. K. Paulson, H. J. Renninger, and J. M. Varner. 2021. Mesophication of oak landscapes: Evidence, knowledge gaps, and future research. BioScience 71: 531–542. doi:10.1093/biosci/biaa169.

Brewer, P., M. Velásquez, E. Sutherland, and D. Falk. 2016. Fire History Analysis and Exploration System (FHAES) version 2.0.2. Available online at http://www.frames.gov/fhaes/home.

Brose, P. H., D. C. Dey, and T. A. Waldrop. 2014. The fire-oak literature of eastern North America: Synthesis and guidelines. General Technical Report NR-135. United States Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA, USA. 106 pp.

Clatterbuck, W. K., G. W. Smalley, J. A. Turner, and A. Travis. 2006. Natural History and Land Use History of Cumberland Plateau Forests in Tennessee, Special Report No. 06–01. National Council for Air and Stream Improvement, Inc. (NCASI), Research Triangle Park, NC, USA. 37 pp.

Cook, E. R., D. M. Meko, D. W. Stahle, and M. K. Cleaveland. 2004. North American summer PDSI reconstructions. World Data Center for Paleoclimatology Data Contribution Series No. 2004-045. http://www.ncdc.noaa.gov/paleo/newpdsi.html. Retrieved Jan. 10, 2022.

Delcourt, P. A. and H. R. Delcourt. 1998. The influence of prehistoric human-set fires on oak-chestnut forests in the southern Appalachains. Castanea 63: 337–345. https://www.jstor.org/stable/4033982.

Delcourt, H. R. and P. A. Delcourt. 2004. Prehistoric Native Americans and Ecological Change: Human Ecosystems in Eastern North America Since the Pleistocene. Cambridge University Press, Cambridge. 204 pp.

Flatley, W. T., C. W. Lafon, H. D. Grissino-Mayer, and L. B. LaForest. 2013. Fire history, related to climate and land use in three southern Appalachian landscapes in the eastern United States. Ecological Applications 23: 1250–1266. https://doi.org/10.1890/12-1752.1.

Greenberg, K. and B. Collins. 2021. Fire Ecology and Management: Past, Present, and Future of US Forested Ecosystems. Springer-Verlag, NY. 519 pp.

Greenberg, C. H., B. S. Collins, S. Goodrick, M. C. Stambaugh, and G. R. Wein. 2021. Introduction to fire ecology across USA forested ecosystems: Past, present, and future, pp. 1–30. *In* C. H. Greenberg and B. S. Collins, eds., Fire Ecology and Management: Past, Present, and Future of US Forested Ecosystems, Springer.

Guyette, R. P., M. C. Stambaugh, D. C. Dey, and R. Muzika. 2012. Predicting fire frequency with chemistry and climate. Ecosystems 15: 322–335. doi:10.1007/s10021-011-9512-0.

Hanberry, B. B., Abrams, M. D., Arthur, M. A., and Varner, J. M. 2020. Reviewing fire, climate, deer, and foundation species as drivers of historically open oak and pine forests and transition to closed forests. Frontiers in Forests and Global Change 3. https://doi.org/10.3389/ffgc.2020.00056.

Harley, G. L., C. H. Baisan, P. M. Brown, H. D. Grissino-Mayer, D. A. Falk, W. T. Flatley, A. Hessl, E. K. Heyerdahl, M. W. Kaye, C. W. Lafon, E. Q. Margolis, R. S. Maxwell, A. T. Naito, W. J. Platt, M. T. Rother, T. Saladyga, R. L. Sherriff, L. A. Stachowiak, M. C. Stambaugh, E. K. Sutherland, and A. H. Taylor. 2018. Advancing dendrochronological studies of fire in the United States. Fire 1. doi:10.3390/fire1010011.

Hinkle, C. R. 1989. Forest communities of the Cumberland Plateau of Tennessee. Journal of the Tennessee Academy of Science 64: 123–129.

Holmes, R. L., R. K. Adams, and H. C. Fritts. 1986. Tree-ring chronologies of Western North Americas: California, Eastern Oregon, and northern Great Basin with procedures used in the chronology development work including user's manuals for computer programs

COFECHA and ARSTAN, Chronology Series VI. Tucson, AZ: University of Arizona, Laboratory of Tree-Ring Research. 182 pp.

Hutchinson, T. F., M. C. Stambaugh, J. M. Marschall, and R. P. Guyette. 2019. Historical fire in the Appalachian Plateau of Ohio and Kentucky, USA, from remnant yellow pines. Fire Ecology 15: 33. https://doi.org/10.1186/s42408-019-0052-x.

Ison, C. R. 2000. Fire on the edge: Prehistoric fire along the escarpment zone of the Cumberland Plateau, pp. 36–45. *In* D. A. Yaussy (comp.) Proceedings: Workshop on fire, people, and the central hardwood landscape. General Technical Report NE-274. United States Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA. USA. 129 pp.

Kaye, M. W. and T. W. Swetnam. 1999. An assessment of fire, climate, and Apache history in the Sacramento Mountains, New Mexico. Physical Geography 20: 305–330. https://doi.org/10.1080/02723646.1999.10642681.

Kelly, J. 2020. Ecomath for the Cumberland Plateau and Mountains of TN: A randomized approach determining ecoregional fire priorities based on ecological factors. A report prepared by Mountain True, Asheville, NC, USA. 17 pp.

Lafon, C. W., A. T. Naito, H. D. Grissino-Mayer, S. P. Horn, and T. A. Waldrop. 2017. Fire history of the Appalachian region: A review and synthesis. General Technical Report SRS-219, United States Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, USA. 97 pp. https://doi.org/10.2737/SRS-GTR-219.

LANDFIRE. 2014. LANDFIRE Project. United States Department of Agriculture, Forest Service; United States Department of the Interior. Retrieved Jan 10, 2022. http://www.landfire.gov/index.php.

McEwan, R. W., T. F. Hutchinson, R. P. Long, D. R. Ford, and B. C. McCarthy. 2007. Temporal and spatial patterns in fire occurrence during the establishment of mixed-oak forests in eastern North America. Journal of Vegetation Science 18: 655–664.

McEwan, R. W., N. Pederson, A. Cooper, J. Taylor, R. Watts, and A. Hruska. 2014. Fire and gap dynamics over 300 years in an old-growth temperate forest. Applied Vegetation Science 17: 312–322. https://doi.org/10.1111/avsc.12060.

Michaux, F. A. 1805. Travels to the Westward of the Allegheny Mountains, in the States of Ohio, Kentucky, and Tennessee, in the Year 1802. Richard Phillips, London, UK. 110 pp.

NOAA, National Centers for Environmental Information (NCEI). 2022., Climate at a Glance: Divisional Time Series. Retrieved January 10, 2022, https://www.ncdc.noaa.gov/cag/.

Nowacki, G. J. and M. D. Abrams. 2008. The demise of fire and mesophication of forests in the eastern United States. BioScience 58(2): 123–138. https://doi.org/10.1641/B580207.

Ramsey, J. G. M. 1860. The annals of Tennessee to the end of the eighteenth century. Lippincott, Philadelphia, PA, USA.

Smalley, G. W. 1982. Classification and evaluation for forest sites on the Mid-Cumberland Plateau. General Technical Report SO-38. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA, USA. https://doi.org/10.2737/SO-GTR-38.

Smith K. T. and E. K. Sutherland. 1999. Fire-scar formation and compartmentalization in oak. Canadian Journal of Forest Research 29: 166–171. https://doi.org/10.1139/x98-194.

Stambaugh, M. C., R. P. Guyette, J. M. Marschall, and D. C. Dey. 2016. Scale dependence of oak woodland historical fire intervals: Contrasting The Barrens of Tennessee and Cross Timbers of Oklahoma, USA. Fire Ecology 12: 65–84. https://doi.org/10.4996/fireecology.1202065.

Stambaugh, M. C., J. M. Marschall, and E. R. Abadir. 2020. Remnant shortleaf pine (*Pinus echinata* Mill.) forests and their historical fire regimes on the Cumberland Plateau. Fire Ecology 16. https://doi.org/10.1186/s42408-020-00084-y.

Stambaugh, M. C., J. M. Varner, and S. T. Jackson. 2017. Biogeography: An interweave of climate, fire, and humans. pp. 17–38 *In* K. Kirkman and S. Jack, eds. Ecological Restoration and Management of Longleaf Pine Forests. CRC Press, Boca Raton, FL. https://doi.org/10.1201/9781315152141-2.

Stokes, M. A. and T. L. Smiley. 1968. Introduction to Tree-Ring Dating. University of Chicago Press, Chicago, IL. 73 pp.

Swetnam, T. W., C. D. Allen, and J. L. Betancourt. 1999. Applied historical ecology: Using the past to manage for the future. Ecological Applications 9: 1189–1206. https://doi.org/10.1890/1051-0761.

Tippett, M. K., C. Lepore, W. J. Koshak, T. Chronis, and B. Vant-Hult. 2019. Performance of a simple reanalysis proxy for U.S. cloud-to-ground lightning. International Journal of Climatology 39: 3932–3946.