THREE CENTURIES OF APPALACHIAN FIRE HISTORY FROM TREE RINGS

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Abstract—Many researchers and resource managers advocate an increase in fire use to restore fire regimes similar to those under which the vegetation of the Appalachian Mountains developed. Restoring fire implies a need to establish historical reference conditions. We have developed dendroecological reconstructions of fire history and forest dynamics for a network of sites in the Appalachian Mountains of Virginia, North Carolina, and Tennessee. Estimates of fire frequency for these sites indicate that fire typically returned at intervals of 2–19 years. Burning occurred at a relatively steady level under varying land uses until the early twentieth century. Fire activity thereafter plummeted with the onset of organized fire prevention and suppression. Our results suggest fire return intervals that managers might target for restoring communities that developed under the aboriginal and European land uses that preceded widespread logging and fire exclusion.

INTRODUCTION

Over the past two decades, it has become apparent that many ecological communities in the Appalachian Mountains require periodic burning if they are to be maintained (e.g., Brose and others 2001, Williams 1998). Most prominent are those communities in which Table Mountain (*Pinus pungens*) and pitch pine (*Pinus rigida*) dominate. These species exhibit traits, such as cone serotiny, early development of sexual maturity, and thick bark, which enable their populations to persist under periodic burning. These yellow pine stands are widely distributed on dry south- and west-facing slopes at middle and low elevations across the Blue Ridge and the Ridge and Valley provinces between Pennsylvania and Georgia. They are interspersed with hardwood-dominated forests, which predominate on the adjacent slope facets. Various oak (*Quercus*) species are particularly abundant in this hardwood forest matrix (Stephenson and others 1993). Oaks and some of their associates, e.g., hickories (*Carya*) and the once-common American chestnut (*Castanea dentata*), appear to thrive under frequent surface fires, which thwart the establishment of mesophytic trees that have few traits that would enable them to endure frequent burning (Nowacki and Abrams 2008).

Appalachian forests burn infrequently today, a consequence of the effective fire prevention and suppression tactics that have been implemented by State and Federal resource management agencies since the early twentieth century (Lafon 2010). These protection efforts were adopted in response to the widespread, destructive conflagrations that accompanied the commercial logging operations during ca. 1880–1930. At that time, many researchers and managers feared that fire would preclude the development of young forest stands to replace the logged forests. The protection efforts have been so successful, however, that Appalachian forests have developed largely without fire over the past 60–100 years. Today, following this prolonged absence of fire, many fire-associated species and communities are declining in abundance and extent, and appear to be following a successional trajectory toward denser stands abounding in mesophytic, fire-intolerant plant species (Nowacki and Abrams 2008). This situation has led many resource managers to use controlled burning to restore the fire-deprived ecosystems (Waldrop and others 2008).

Restoring fire implies a need to establish historical reference conditions, but the dramatic forest changes of the past century—logging and burning followed by fire exclusion—impede our understanding of how the forests functioned prior to the great logging episode. How frequently did fire occur in the Appalachian forests previously? We have established a network of dendroecological sites to investigate fire history in the Appalachian Mountains of Virginia, Tennessee, and North Carolina. We searched for yellow pine stands that contained old, fire-scarred trees—living and dead—that would document the longest possible record of fire history in the tree-ring record (fig. 1). Pines are especially useful

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for such work because the resin with which they saturate the fire-injured wood helps preserve the wood from decay, even in dead trees. Many hardwood trees also bear fire scars, but they decay more readily and generally do not preserve as useful a fire history record as do the pines.

METHODS

The study sites are located at several locations within the George Washington National Forest, Jefferson National Forest, and The Nature Conservancy's Narrows Preserve in Virginia; Great Smoky Mountains National Park and House Mountain State Natural Area in Tennessee; and Pisgah National Forest in North Carolina (fig. 2). These sites represent a wide range of the variations in climate and land use history that exist across the Appalachian Mountains. Each site comprises multiple neighboring pine stands (generally four stands) separated by intervening hardwood forest (fig. 3). The spatial configuration of this network enables the most reliable possible estimates of historic fire frequency at the level of the individual stand while also permitting insights into broader (multi-stand and multi-site) patterns of burning. We used standard dendroecological techniques to sample and analyze the fire-scar data. Tree rings were crossdated to permit accurate determinations of the year in which each fire event occurred, and the fire history analyses were conducted using FHX2 software and standard statistical analyses. Details of the study sites, sampling strategies, and analyses performed can be found in Aldrich and others (2010), DeWeese (2007), Flatley and others (2013), Hoss and others (2008), and LaForest (2012).

RESULTS AND DISCUSSION

Analyzing the intervals between successive fires reveals that fires burned often, at intervals typically ranging between about 2 and 19 years (Aldrich and others 2010, DeWeese 2007, Flatley and others 2013, Hoss and others 2008, LaForest 2012) throughout the period of record (generally the 1700s through the early 1900s). For a fire chart that graphically depicts the history of burning at one of the study sites, see Figure 4. The 2–19 year range in fire intervals reflects the differences among sites and between different filtering techniques used for estimating fire return interval. Shorter intervals reflect less conservative estimates obtained on the basis of including all fires recorded at a study site; some of these may have been minor fires that burned only one or two trees in a single stand. Longer intervals reflect more conservative estimates, such as filtering the fires to include only the "major" fires that scarred at least 25 percent of the trees, or only the "area-wide" fires that burned all the neighboring pine stands at a given site during a single year. Regardless of which filtering method is used, a picture of frequent burning emerges.

The results presented here demonstrate that the montane pine stands distributed across the study area burned at short intervals before fire prevention and suppression were implemented during the early twentieth century. Additionally, the short intervals that emerge even for the area-wide fires suggest that the intervening hardwood forests also burned often: for an area-wide fire to occur, it would have had to spread through the hardwood forest to propagate from one pine stand to another (Flatley and others 2013). In fact, we noted numerous hardwood trees that exhibited one or more fire scars (fig. 5). Therefore, our results apply not only to the pine stands but also to the broader mountain slopes across which the pine stands are scattered.

Analyzing temporal variations in fire frequency reveals no long-term trends prior to the era of fire exclusion (Hoss and others 2008, Aldrich and others 2010, Flatley and others 2013, e.g., fig. 6). The fire chronologies that we developed for all the study sites extend back to the period of early European settlement, and for a few of the sites the chronologies reach back further to the period of aboriginal depopulation that preceded European settlement in Virginia, or to the period of Cherokee occupancy that preceded European settlement in Tennessee and North Carolina. Fire appears to have burned these landscapes on a regular basis from the pre-European period through subsequent settlement and agricultural expansion, and also during the episodes of mining and/or logging, which affected each study site in a different manner. The only pronounced change in burning coincided with the advent of active fire prevention and protection in the early twentieth century. We detail our analyses and interpretations more thoroughly elsewhere (Aldrich and others 2010, DeWeese 2007, Flatley and others 2013, Hoss and others 2008, LaForest 2012).

As a basis for restoration, our results suggest that burning at relatively short intervals, similar to the estimates presented here and detailed in our other publications (Aldrich and others 2010, DeWeese 2007, Flatley and others 2013, Hoss and others 2008, LaForest 2012), could be appropriate for maintaining conditions similar to those under which the communities developed during aboriginal and European land uses of the eighteenth and nineteenth centuries. Whether the reintroduction of fire would quickly restore pre-exclusion vegetation properties is an important question. Following several decades of forest development in a nearly fire-free environment, some communities may require intensive management (e.g., multiple/severe fires, mechanical treatment) to initiate a vegetation composition and structure that could be maintained thereafter by regular burning.

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Figure 1—Fire-scarred dead pine in the George Washington National Forest. Multiple fires have injured the tree, as evidenced by the ridges that formed as wood grew over each new fire scar.

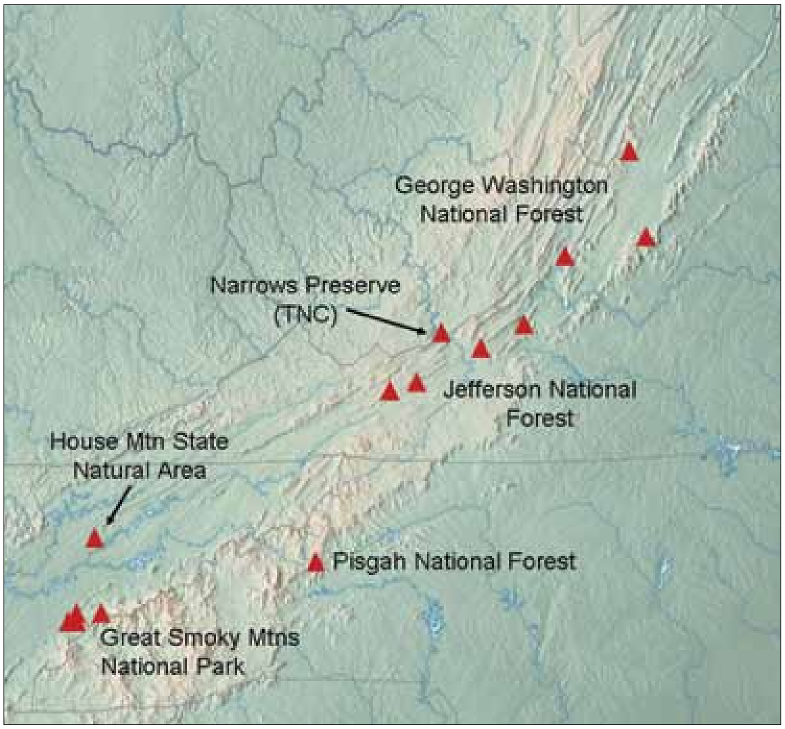

Figure 2—The distribution of fire history study sites (triangles) across the Appalachian Mountains of Virginia, Tennessee, and North Carolina.

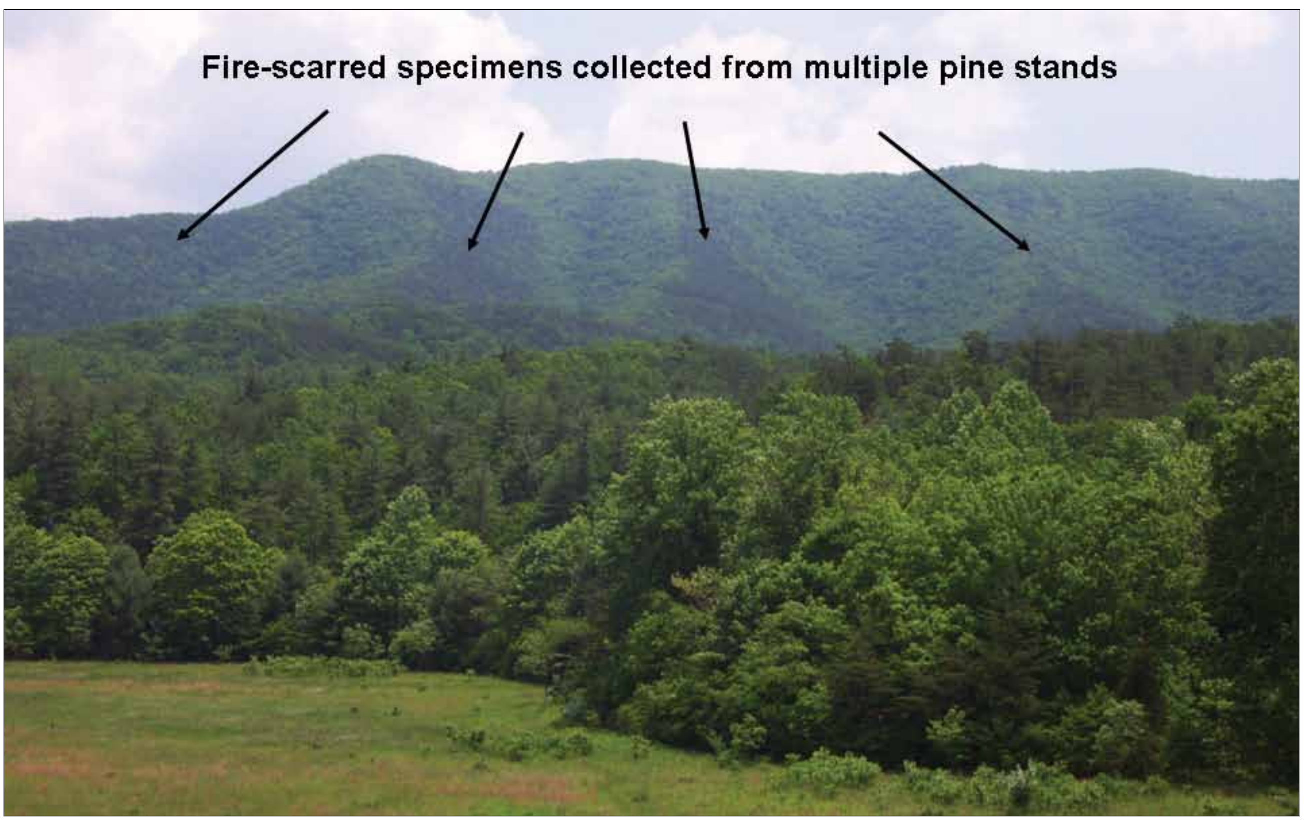

Figure 3—A view of the north slope of Brush Mountain, on the Jefferson National Forest. Pine stands occupy the west face (right side in this photograph) of each spur on the dissected mountain slope. The pines in this photograph are evident as darker patches surrounded by the lighter-colored hardwood forests. We collected fire-scarred trees from multiple pine stands at each study site. Many of the fires burned multiple pine stands, suggesting that fires spread across the whole mountain slope, including the hardwood stands that form the forest matrix between pine stands.

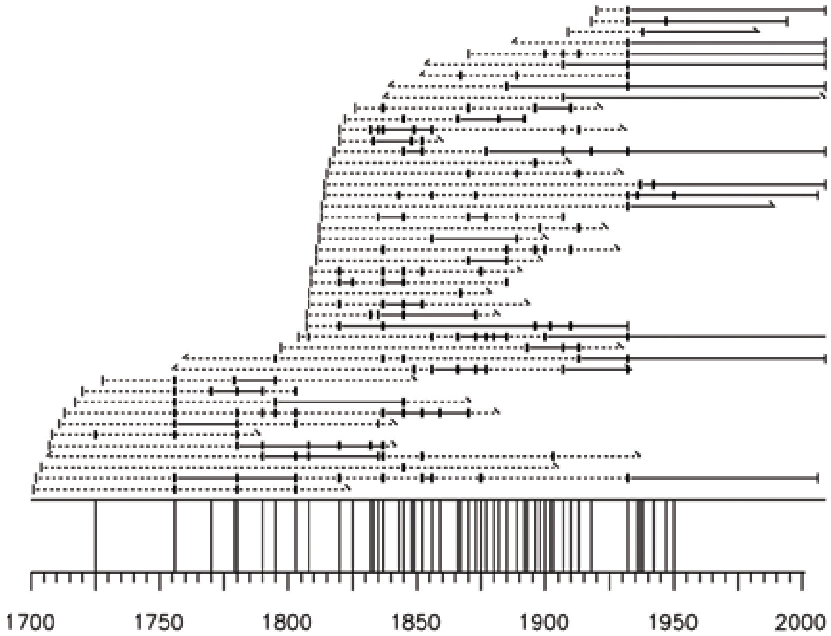

Figure 4—Fire chart from the Linville Mountain study site in the Pisgah National Forest. The timeline at the bottom indicates the period of record, while each horizontal line above it represents the period covered by each of the scarred trees we dated. The vertical tics along each line indicate dated fire scars for each tree, and the longer vertical lines at the bottom of the chart represent the composite fire-scar record for all the trees combined.

Figure 5—A hardwood tree located at Little Mountain in the Jefferson National Forest that exhibited the typical calous wood that formed over an injury caused by a wildfire event at some point in the past. Such fire-scarred hardwoods were found in nearly all sites we examined, but hardwoods decay more rapidly than pines, making them less useful for analyzing fire scars to determine fire history.

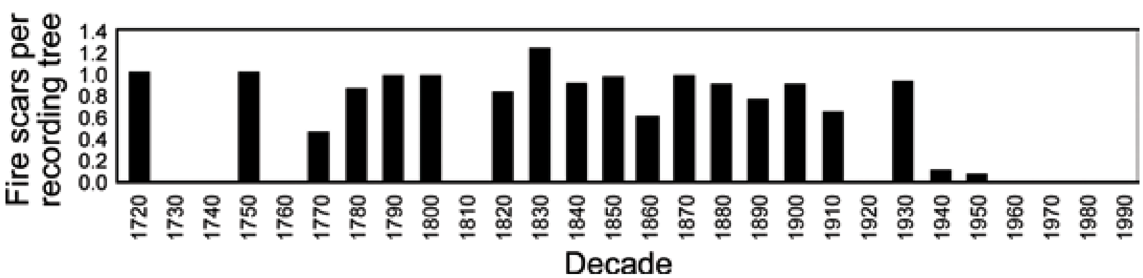

Figure 6—Temporal pattern of fire at the Linville Mountain site, indicated as the mean number of fire scars recorded per tree for each decade. This calculation standardizes the fire record across decades with varying sample sizes, enabling a depiction of temporal trends in fire occurrence. This graph for Linville Mountain reveals little variation in fire frequency from the beginning of the record until the 1930s, after which fire activity declined.