TWO CENTURIES OF FIRE IN A SOUTHWESTERN VIRGINIA PINUS PUNGENS COMMUNITY

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ABSTRACT: Fire exclusion in fire-dependent forest communities can alter stand structure and composition. The objective was to construct a fire history of two Pinus pungens Lamb. communities growing in southwestern Virgina. Tree- ring analysis of fire-scarred P. pungens specimens and a tree survey were used to determine species composition and age distributions. From 1798-1944, fires burned approximately every 10 years. After acquisition by the United States Department of Agriculture Forest Service (ca. 1935) the study area burned only once (1944). Most of the population derives from two large cohorts established in the 1850's and the 1930's, but some trees established during nearly every decade before 1950. Few, if any, trees have established since then. There appears to be a linkage between tree establishment and major fire occurrence. Recent regeneration failure appears to be coincident with fire exclusion. Continuing fire exclusion will probably result in decline in the P. pungens communities, as they succeed to Quercus-dominated communities.

INTRODUCTION

The exclusion of fire from fire-adapted communities eventually results in catastrophic, highly destructive fires (Mutch, 1970). Management of fire-adapted communities requires an understanding of the role fire plays in the community, and characterization of the fire regime. Age structure analysis is a common method of determining fire frequency in long fire-return interval communities where high-intensity stand-replacing fires occur (e.g., Arno et al, 1993). However, in communities with short fire-return intervals where fires are low in intensity, few trees are killed and some trees may develop fire scars. In these systems, tree-ring analysis of the scars is the appropriate method to determine fire history (Baisan and Swetnam, 1990). Combining both these approaches would reveal the relationship between age structure and historical fire patterns.

The purpose of this study was to reconstruct the historical relationship between fire and community structure using both the age and species composition approach in combination with tree-ring fire history analysis. The fire-adapted community chosen to study is Pinus pungens Lamb., commonly called Table Mountain pine and sometimes hickory pine, mountain pine, or prickly pine. P. pungens is endemic to the central and southern Appalachian Mountains. It occupies dry, steep, exposed ridge tops and slopes throughout its range, although it will occupy more mesic sites following fire (Zobel, 1969).

The regeneration and maintenance of Pinus pungens depends on stand and site disturbance that exposes mineral soil to light and warmth (Della-Bianca, 1990). McCune (1988) classified P.

pungens as a fire-resilient species. Fire appears most effectively to promote regeneration (Zobel, 1969; Harmon, 1982) although Whittaker (1956) hypothesized that populations are maintained in the absence of fire in dry pine-oak forests, as components of a topographic or edaphic climax (extremely dry and sterile rock outcrops and steep shale slopes), or both. Barden (1977) examined age structures of stands near Brevard, North Carolina, and concluded that populations there have maintained themselves since the last fire, which had occurred nearly a century earlier (1889). However, on Brush Mountain in southwestern Virginia, Williams and Johnson (1990) found an under-representation of P. pungens seedlings and small trees and concluded that maintenance of the populations in this area was "unlikely under current disturbance regimes." Williams and Johnson (1990) hypothesized that the populations of P. pungens that they studied originated from seed trees left on the sites following heavy logging and fires at the turn of the century.

Pinus pungens has many physical adaptations to fire (Della-Bianca, 1990); interestingly, these adaptations are consistent with both long- and short- interval fire regimes. For example, trees that are adapted to catastrophic, stand-replacing fire often have serotinous cones that open when heated. P. pungens has serotinous cones throughout much of its range (McIntyre, 1929; Zobel, 1969; Barden, 1979), particularly on western and southern exposures, which tend to be dry and steep and are prone to burning. Seeds are medium to heavy in weight compared to other Pinus species, and not adapted to carriage by wind, but rather are adapted to regeneration in situ and to the typically dry conditions. While P. pungens does shed seeds each year, viable seeds on serotinous cones can persist for up to 11 years (Barden, 1979). P. pungens also can reproduce vegetatively after fire from basal bud sprouts, which allows recovery of saplings after injury (Zobel, 1969). However, P. pungens also has characteristics of trees that are adapted to frequent ground fires, such as medium-thick bark, a deep rooting habit, self-pruning limbs, and pitch production to seal wounds. Zobel (1969) noted healing ridges and charcoal on many trees, evidence typical of fire scars. On the study sites, living trees and dead snags with multiple fire scars frequently were encountered.

STUDY AREA

The study area was on the northern flank of Brush Mountain, a strike-ridge mountain in the Valley and Ridge Province in the Appalachian Mountains of southwestern Virginia (USA), north of Blacksburg, and apparently near those studied by Williams and Johnson (1990, 1992). The sites selected were on the upper west- and southwest-facing slopes of the many hollows that dissect Brush Mountain. Elevations within the sample areas range from approximately 750-840 meters.

Regionalized climatic data for southwestern Virginia are displayed in **Figure 1**. The climate is strongly seasonal, with summer months the warmest and wettest. The autumn (September to November) is the driest season, and February and April are dry compared to preceding months.

Williams and Johnson (1990) found age distributions on Brush Mountain to be bimodal at three sites, with 10-, 50-, 75- and 80-year age classes at each site, and few trees over 100 years old. They interpreted these results to mean that the populations either were not self-maintaining or were episodically recruited. They found that regeneration was limited by thick litter, because P. pungens requires mineral soil exposure for successful seedling establishment. They asserted that the P. pungens communities on Brush Mountain probably originated at the end of the 19th century during a period of heavy logging and fire, and presently are succeeding to Quercus communities dominated Q. prinus and Q. coccinea. Pinus pungens seedlings and saplings were uncommon. They further noted copious evidence of fire in the form of fire-scarred trees and charcoal in the soils. The species composition of the communities we encountered were nearly identical to those described by Williams and Johnson (1990). The entire north face of Brush Mountain is steep and difficult for logging equipment to reach, and has been designated as unsuitable for timber by the U.S. Department of Agriculture Forest Service. Besides fire suppression, there is no active forest management in this management unit, and the area is little disturbed except some fuelwood cutting (Personal communication, 5/28/93, E. Leonard, USDA Forest Service, Jefferson National Forest, Blacksburg Ranger District).

METHODS AND RESULTS

We visually examined three of the dissected sideslopes to locate fire- scarred trees. On Sites 1 and 3, we found several size classes of P. pungens and many fire-scarred living and standing dead trees. On Site 2, the P. pungens trees were all small and there was little fire-scarred material, indicating that the site had experienced a stand-replacing fire that consumed overstory trees and dead material. Due to time constraints, we concentrated only on Sites 1 and 3.

Development of a Master Chronology

We developed a master chronology of common ring-width variation for the area (Stokes and Smiley, 1968; Fritts, 1976; Swetnam et al., 1985) using two cores from each of 11 dominant trees on Site 1 and from 15 dominant trees on Site 3. Diameter at breast height (1.45 m; dbh) of each tree was recorded. The patterns were easily discernable, and the master chronolgy readily matched most of the cores.

Fire History Development

We located fire-scarred living and dead P. pungens trees at Sites 1 and 3, cutting down living trees only if they had at least three fire scars. Small wedges were taken from the fire-scarred face of living trees that were too large to sample (Arno and Sneck, 1977). Dead material included standing snags and downed logs. The cross-sections wre collected as outlined by Arno and Sneck (1977) and Baisan and Swetnam (1990). We first applied calendar-year dates to the living trees using the master dating chronology developed from increment cores (Dieterich, 1980; Swetnam and Dieterich, 1985) to determine the year of occurrence for the most recent fires. The season of fire occurrence was learned by noting the intra-annual position of the fire scar within the annual ring (Baisan and Swetnam, 1990). These seasonal designations included dormant season fires (scars between the latewood of one year and the earlywood of the following year) and fires occurring in the early, middle, and late portion of the growing season. We expected the majority of fires to be classified as dormant season scars because fires are historically known to occur predominantly during the months of February, March, and April (personal communication, 6/1/93, S. B. Stephenson, Fairmont College, West Virginia).

All fire information was analyzed using the FIRE2 fire history analysis program (Grissino-Mayer, Henri. 1993. FIRE 2: Unpublished computer program developed at the Laboratory of Tree-Ring Research, University of Arizona, Tucson). This program provided information on fire frequency, Mean Fire Intervals (MFI), and the dominant seasonality of fire for various percentage- scarred classes, and helped to identify temporal and spatial changes in fire occcurrence at the Brush Mountain sites.

The fire scar record is displayed in **Figure 2**. We found that major fires (over 50 percent of trees scarred) occurred at the Brush Mountain sites during the years 1882, 1883, 1893, 1900, 1910, 1926, and 1934. These fires occurred exclusively during the dormant season. Other, perhaps minor, fire years were noted for 1885, 1907, 1911, 1914, and 1944. In **Figure 3**, we compare major and minor fire years to the Palmer Drought Severity Index (PSDI), an index of drought intensity (Palmer, 1965). Negative PSDI values indicate drought conditions relative to regional norms and positive values indicate relatively wet conditions. Although major fire years do not necessarily coincide with the most intense drought years, all have negative PDSI values. Notably, no major fires occurred after Forest Service fire suppression policy was enforced in the late 1930's, even though droughts occurred after 1940 of intensity equal to or greater than those of the major fire years before 1940.

We found that the majority of trees collected, both living and dead, germinated during the interval 1855 to 1865, perhaps indicating the occurrence of a stand-initiating fire some time before 1855. Only one sample (BR1-01) extended before 1855, and contained fire dates for 1847 and 1853. We believe that the 1853 fire is most likely the stand-initiating fire because it occurred during the latter portion of the growing season unlike all the other fires, which occurred during the dormant season.

Fires were synchronous between both Brush Mountain sites for all major fires. Fires in 1882 and 1883 are classified as minor and were asynchronous; Site 1 burned in 1882 and Site 3 burned in 1883. In **Figure 3**, all major fires that occurred during the period of climate record happened during relative dry periods (negative PDSI, usually < -2). Synchrony of fire events probably requires a combination of climate and fuel conditions that promotes fire spread.

Sample BR1-01 is the only scarred specimen that pre-dates the 1855 to 1865 cohort establishment. However, many other samples were collected from dead material, and possibly some of these samples will verify the fire dates obtained from BR1-01. Fires are indicated on this sample during the years 1798, 1805, 1810, 1819, 1847, and 1853.

Age Distribution analysis

To determine species composition and size distribution of the community on Site 1, we ran a 5 m-wide belt transect from the top of a spur ridge down the slope for a distance of 100 meters to the point where there were no more P. pungens. At the end of this transect we turned and ran a 60-meter transect parallel to the contour. Measurements were recorded in blocks, 5 m by 5 m. We recorded d.b.h. of all trees. The frequency of encountered species (**Figure 4**) indicates that Quercus coccinea and Q. prinus dominate the community in numbers. Only one each of Q. alba, Pinus strobus, and Acer rubrum were encountered. However, the size structure of the community with respect to species in **Figure 4** clearly is apparent. Most of the Quercus sp. trees are
very small; in the 0 category (trees under 1.45 m height, d.b.h. not measured), there are many Q. coccinea, and size classes less than 20 cm d.b.h. are dominated by Q. prinus. However, all the size classes larger than 20 cm d.b.h. are dominated by P. pungens. Note that there are few small P. pungens.

We determined the age structure of the P. pungens trees by coring trees > 10 cm and < 20 cm as they were encountered by chance along the slope. Cores were taken at breast height and parallel to the slope contour. The cores were brought to the laboratory where the number of rings at d.b.h. was determined. To examine the age structure of larger trees, we used the cores taken for master chronology development. In cores that did not intersect the pith, we estimated the number of rings to the inside by visually interpolating from the curvature of the rings. The age structure of the sampled P. pungens reveals a bimodal age distribution, with only three trees established before 1851 (**Figure 5**). Clearly recruitment was episodic with a significant recruitment event in the 1850's, and another important event in the 1930's and 1940's, with minor recruitment occurring at other periods and little or no establishment in recent years.

DISCUSSION AND CONCLUSIONS

We have established from the fire scar chronology that fire occurred frequently (every 9-11 years) in the community, at least through the 19th and mid-20th century. Most fires occurred during the dormant season, probably in early spring. Those fire dates were consistent on Site 1 and Site 3, indicating that fires probably were large and widespread on at least that portion of the mountainside. During the period of climatic record, PDSI values indicate dry conditions during major fire years in the fire seasons before active fire suppression. Except for the minor 1944 fire, the Brush Mountain fire regime abruptly ends after the 1934 fire. We believe this cessation of fires is due to the incorporation of the Brush Mountain site into the Jefferson National Forest by the USDA Forest Service beginning in 1935. Fire suppression is known to have begun somethime in the late 1930's.

Our species and age structure results are similar to those of Williams and Johnson (1990) on Brush Mountain. They found abundant oak regeneration (primarily Quercus prinus and Q. coccinea) and a bimodal distribution of Pinus pungens establishment that they interpreted as likely to be associated with some type of disturbance. Given the fire scar analysis results, this disturbance was almost certainly fire. Our age structure analysis shows that unusually severe fires may have occurred at least twice, resulting in two important recruitment events. For example, scar placement of the 1853 fire during active cambial growth indicates that fire occurred during the growing season. These fires during the warm period of the year may have been hotter, more intense, and damaging to existing trees than dormant season fires, and resulted in the 1850's recruitment event. Many other fires occurred, and while they too probably promoted some recruitment, the fires probably functioned by reducing competition from less fire-adapted vegetation, thus maintaining P. pungens dominance.

Our results are consistent with the acknowledged dependence of P. pungens upon fire for regeneration and maintenance (Della-Bianca, 1990). Fire suppression is most likely the cause of a dramatic change in the composition of the Brush Mountain communities during the last 60 years (Williams and Johnson, 1990). In the past, fire clearly promoted integrity of the Pinus pungens community on Brush Mountain. Only by understanding the spatial and temporal variation of fire in Table Mountain pine landscapes can forests be managed to ensure the viability of P. pungens communities.

The sum of information from the age structure analysis and fire scar analysis was more than these analyses would have revealed separately. For example, the age structure analysis would have led the researcher to conclude that two or three fires burned through the sites. Fire history alone revealed the frequency and seasonality of fires. However, taken in combination, we can infer that the cohorts originated from fire events, and that those fires were probably higher intensity than most other fires. This approach is highly informative and is recommended to understand the function and frequency of fires in fire-adapted plant communities.

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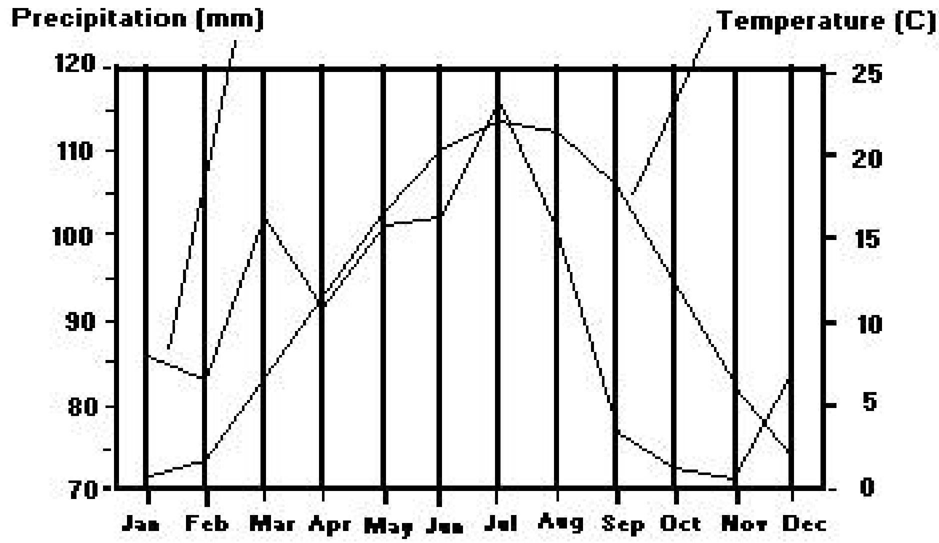

Figure 1. Southwestern Virginia monthly temperature (C) and precipitation (mm), 1895-1897 (Regionalized data from the National Climate Data Center).

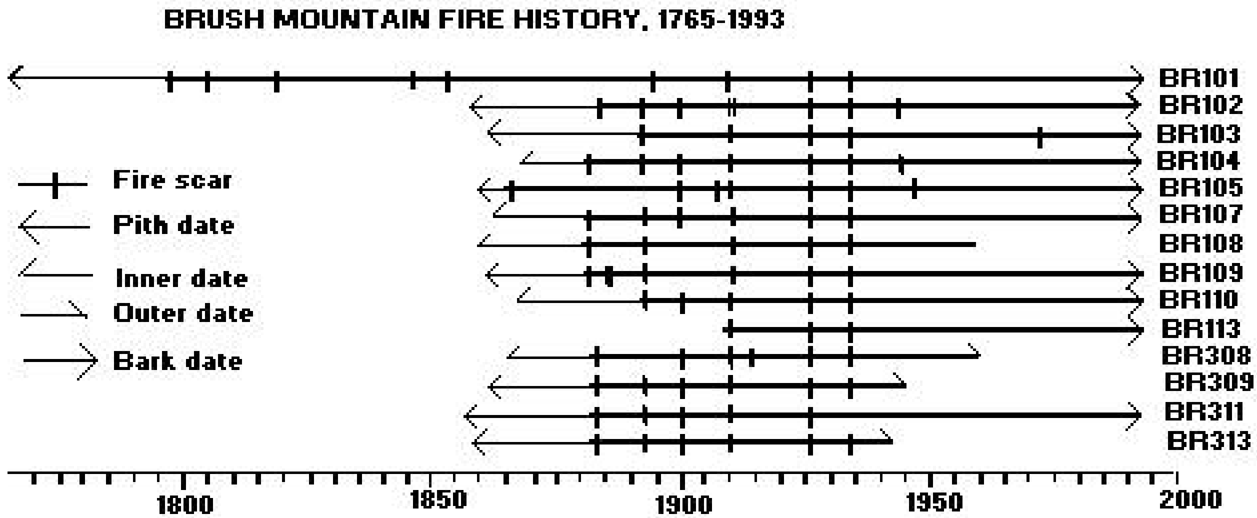

Figure 2. Fire scar records for materials collected at sites 1 and 3, Brush Mountain, Virginia. Each line represents the fire chronology for individual trees sampled. The identification code indicates whether the sample originated from site 1 (BR1) or site 3 (BR3).

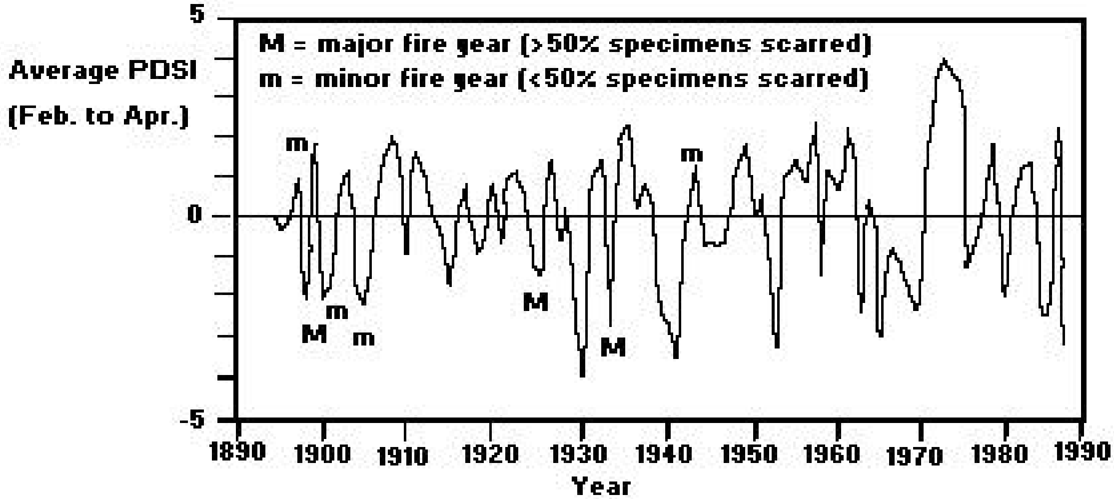

Figure 3. Fire season (average of February to April) Palmer Drought Severity Index, 1895-1988, southwestern Virginia region.

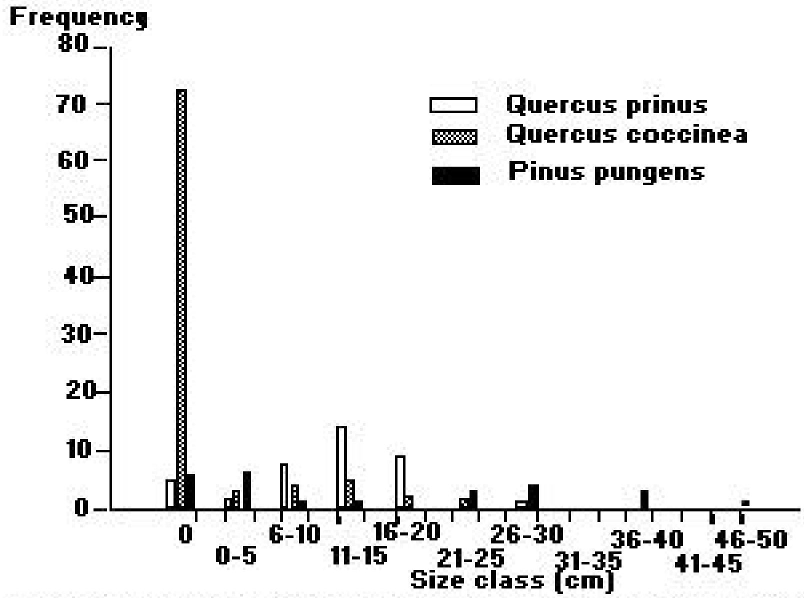

Figure 4. Frequency of individuals in predominant overstory species by size classes. (Not shown one each individual Q. alba, P. strobus, and A. rubrum).

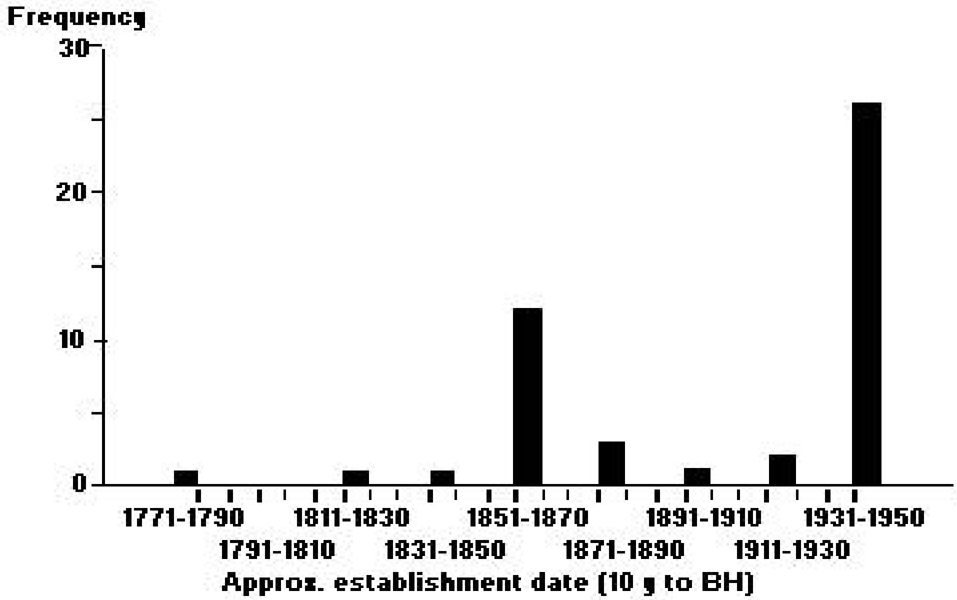

Figure 5. Number of Pinus pungens trees established by 20-year period. (Assuming here approximately 10 years to reach breast height.)