Giant Sequoia Fire History in Mariposa Grove, Yosemite National Park

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Abstract

We reconstructed a 1,438-year history of wildfire in the Mariposa Grove of giant sequoias (Sequoiadendron giganteum). Partial cross sections were taken from 18 dead fire-scarred trees, and the tree rings and fire scars were dated. The resulting master fire chronology shows that fires recurred at intervals ranging from 1 to 15 years. Changes in fire frequency on time scales of centuries are also apparent. This fire history documents the long-term importance of fire in sequoia-mixed conifer ecosystems and illustrates the temporal variability of fire regimes.

INTRODUCTION

Episodic surface fires have swept through giant sequoia groves for many centuries. Nearly all of the largest and oldest sequoias have huge basal fire scars that bear witness to these ancient flames. Although park naturalists have 1ong accepted that fire was a frequent visitor to sequoia groves before arrival of Anglo-American settlers around 1850, real concern about negative effects of suppressed natural fire regimes did not arise until the early 1960s. Ecologists noticed that there were few sequoia seedlings or saplings within the groves, while the density of other shade-tolerant tree species was increasing. Research suggested that elimination of episodic fires during the past century had also eliminated necessary conditions for sequoia regeneration; sequoia seeds germinate and establish best in mineral soils exposed by surface burns (Harvey et al. 1980). Concern about changes in the structure of sequoia-mixed conifer forests was an important stimulus to reintroducing fire to some groves as early as 1968. Many prescribed burn areas within the groves now have abundant sequoia seedlings and saplings.

Although managers generally embraced the concept of reintroducing natural fire regimes, programs with the Sierran national parks have proceeded slowly (Parsons et al. in press, Underwood, this volume). This caution is due to the obvious hazards of ”escaped” fires and limited specific knowledge about giant sequoia fire ecology and effects. A key information base that was identified as necessary for improving the design and long-term objectives of fire management plans was fire history that encompassed the very long life spans of sequoias (Christensen et al. 1987).

Early tree-ring investigations of fire history in Mariposa Grove were conducted by Clifford Presnall (1933a, 1933b), a park naturalist. Presnall took increment cores from basal scars of sequoia trees and counted the rings from bark into the wound. He observed that some fires were very ancient; his earliest approximate fire date was 450 A.D. Presnall observed that intervals between fires were as short as 15 years, but his data were too incomplete to provide a definitive assessment of fire frequencies in the Mariposa Grove. The most informative fire history work in the sequoia and mixed-conifer type was carried out by Kilgore and Taylor (1979). They collected fire scar specimens from nonsequoia species and estimated fire frequencies in two watersheds near Kings Canyon National Park. Their history extended back to approximately 1478 A.D. They found mean fire intervals varied between about 8 and 18 years.

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This paper describes a fire history study conducted within the Mariposa Grove of giant sequoias in Yosemite National Park. This work is part of a larger project that includes development of fire histories for five sequoia groves (Mariposa, Big Stump, Giant Forest, Atwell Mill, and Mountain Home). Our aim is to reconstruct temporal and spatial variability of fire frequencies, areal extent, and intensities in different sequoia groves. Results from the Mariposa Grove are described here and used to illustrate several implications for management of fire regimes within protected sequoia groves.

Partial cross-section samples were obtained from 18 dead trees. A chain saw with an approximately 1-meter-long bar was used to excise the sections from fire-caused basal wounds. Parallel cuts were made through the basal wounds and sections were extracted with dimensions of about 5- to 10-cm thickness and up to approximately 2 meters on a side. Large sequoias often have deep fire scar cavities at multiple locations around the stem. Quantity and quality of fire scar infor tion preserved within a cavity is highly variable. Thus, the sampling procedure usually required cutting in several different cavities around the tree bole. A maximum of eight partial sections were removed from a single log. We found that optimum sampling included (1) selection of trees with maximum numbers of visible scars on outer surfaces and (2) sampling close to the original ground level of the tree (estimated from butt flare and location of the root crown). When removing partial sections from the dead stems, we often observed many fire scars completely buried within the tree bole.

The ring-width patterns of the specimens were crossdated with the 3,200-year giant sequoia chronology originally developed by A. E. Douglass (1945) and updated sequoia chronologies (Hughes et al. 1990). This procedure involved plotting the relative ring widths of an undated specimen and comparing this plot with a similar plot from one of the absolutely dated sequoia chronologies. Points of synchrony between the plots were used to establish correct dating in the specimen (Douglass 1919, Stokes and Smiley 1968). Once the annual rings were exactly dated, then the dates of fire scars recorded within the rings were noted.

In addition to fire scars, we observed other ring features that appear to indicate past fire occurrence. We call these features ”other indicators.” The other indicators are (1) expanded latewood – a characteristic band of latewood-type cells often observed following a fire scar (it appears as a second layer of latewood cells overlapping a fire scar that is within or on the boundary of an earlier for band of latewood); (2) growth release – an obvious positive change in ring growth rate; and (3) traumatic resin ducts – a proliferation of resin ducts within a ring (this is probably a physiological response to an injury).

These indicators, especially types 1 and 2, are consistently associated with fire dates determined from actual fire scars on the same or other sampled trees. For example, it is possible to observe a ring with expanded latewood or abundant resin ducts on one part of a partial cross section and to follow the affected ring(s) around the section and locate a fire scar in the same year. In general, we believe that fire frequencies based on combined fire dates from both fire scars and other indicators provide a more complete estimate of past fire occurrence within the groves. All fire dates were compiled into a master fire chronology, and fire frequencies for different time periods were computed.

RESULTS

The Mariposa Master Fire Chronology is shown in figure 1. Individual sequoia trees contain very long and detailed records of past fires, A maximum of 47 fire scar dates was recorded on a single tree (MPU 6). Including both fire scars and other indicators, a total of 104 fire dates were recorded on another tree (MPU 9). The oldest fire scar date was A.D. 553 (MPU 8), while the oldest exact annual ring date was A.D. 262 (MPU 9). Due to declining sample depth at the beginning and end of the chronology, the fire history from about A,D. 850 to 1900 is best represented and most reliable for comparing relative changes in fire frequency.

Changes in frequency of past fires can be seen in the composite bar graph shown at the bottom of figure 1. Periods of highest frequency show close spacing of fires, while lower fire frequency periods show longer intervals between fires. The longest period between fires was 15 years. Between A.D. 850 and 1900, three 15-year fire-free intervals were recorded (979 to 994, 1185 to 1200, and 1637 to 1652). One-year intervals between fires were recorded about 50 times, but these fires were apparently very patchy; the consecutive-year fires were usually recorded by different trees in different parts of the grove.

Figure 2 shows a summary of temporal changes in fire frequency. Maximum frequencies were observed from about A.D. 1000 to 1400. A decline in fire frequency was observed from about 1400 to 1700. Fire frequencies increased to another maxima during the 1700s, then declined again. The end of episodic fires in the late 1800s has been observed in many other sites in the western United States. This was probably initially due to grazing by domestic livestock, which removed the fine fuels important to fire spread, and subsequently due to organized fire-fighting efforts by government agencies.

DISCUSSION AND CONCLUSION

Fire scar chronologies from giant sequoia groves are the longest precisely dated disturbance histories ever developed for any forest ecosystem. The Mariposa chronology clearly shows repeated fires for many centuries before settlement of this area by Anglo-Americans. Because of high fire frequency, the intensity of fires in most areas was probably limited to surface burns. It is also possible that locally intense burning created gaps in the forest canopy, leading to establishment of groups of sequoias (Parsons et al. in press; Stephenson et al. 1990). These fire-created gaps may also partly explain the observed fire-related growth releases. Reduced competition from killed trees would probably result in increased ring growth of surviving trees, Thus, localized tree mortality within prescribed burn areas, which has generated considerable criticism and public controversy (Christensen et al. 1987; Bonnicksen; this volume) may well be within the range of conditions created by pre-settlement fires. We plan to further investigate the association of growth releases and fires of different intensity by analyzing tree- growth response in areas of recent prescribed burns and wildfires.

Although the Mariposa fire history shows that fires were frequent throughout the past 1,000 years (until 1864), changes in fire frequency between centuries were also observed (fig. 2). This variability may have important implications for understanding the dynamics of sequoia groves. Did more sequoia seedlings establish during the higher or lower fire frequency periods? Investigation of sequoia age structure is under way in the same areas where we are reconstructing fire histories, including the Mariposa grove (Stephenson et al. 1990). This research should provide some of the needed information. Knowledge of this response will be cri tical for managers faced with the daunting task of designing and implementing prescribed fire programs whose fundamental goal is to reintroduce natural process.

Other pressing questions about fire management in sequoia groves are raised by these data. Do we want to reintroduce fire regimes that would have persisted in the sequoia groves had not Anglo-Americans arrived on the scene in the 1800s? What would the 20th-century fire regime have been without our interference? This leads us to ask what were the sources and mechanisms of fire in presettlement sequoia groves? Were the changes we observe in fire frequency during presettlement times largely driven by climate and fuel dynamics, or did Native Americans also contribute by setting fires? We may never obtain satisfactory answers to these questions. However, we expect that this puzzle will slowly be pieced together in coming years. The millennial-scale history of giant sequoias will become richer as we pull together information from fire scars, tree-ring-based climate reconstructions (Graumlich 1990, Hughes et al. 1990), sequoia age structure (Stephenson et al. 1990), and sedimentary records (Anderson 1990).

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REFERENCES

Anderson, R. S. 1990. Holocene forest development and paleoclimates within the central Sierra Nevada, California. *Journal of Ecology* 78:470-489.

Christensen, N. L., L. Cotton, T. F. Harvey, R. Martin, J. McBride, P. Rundel, and R. Wakimoto. 1987. Review of fire management program for sequoia-mixed conifer forest of Yosemite, Sequoia and Kings Canyon National Parks. Final Report to U.S. Department of Interior, National Park Service. Unpublished Report.

Douglass, A. E. 1945. Survey of sequoia studies. *Tree-Ring Bulletin* 12(2):10-16.

Graumlich, L. J. 1990. Interactions between climatic variables controlling subalpine tree growth: Implications for climatic history of the Sierra Nevada, California. In Betancourt, J. L. and A. MacKay (eds.), Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989, California Dept. of Water Resources, *Interagency Ecological Studies Program Technical Report* 23:115-118.

Harvey, H. T., H. S. Shellhammer, and R. E. Stecker. 1980. Giant Sequoia Ecology: Fire and Reproduction. USDI National Park Service, *Scientific Monograph* No. 12, Washington, DC.

Hughes, M. K., B. J. Richards, T. W. Swetnam, and C. H. Baisan. 1990. Can a climate record be extracted from giant sequoia tree rings? In Betancourt, J. L. and A. MacKay (eds.), *Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989,* California Dept. of Water Resources, Interagency Ecological Studies Program Technical Report 23:111-114.

Kilgore, B. M. and D. L. Taylor. 1979. Fire history of a sequoia-mixed conifer forest. *Ecology* 60(1):129-142.

Parsons, D. J., N. L. Stephenson, and T. W. Swetnam. In press. "Restoring natural fire to the sequoia-mixed conifer forest: Should intense fire play a role?" In *Proceedings of 17th Tall Timbers Fire Ecology Conference,* Tallahassee, Florida, May 18-21, 1989.

Presnall, C. C. 1933a. Translating the autobiography of a big tree. *Yosemite Nature Notes* 12(1):5-6.

Presnall, C. C. 1933b. Fire studies in the Mariposa Grove. *Yosemite Nature Notes* 12(3):23-24.

Stephenson, N. L., D. J. Parsons, and T. W. Swetnam. 1990. Effects of fire history on forest age structure in sequoia-mixed conifer forests. *Bulletin of the Ecological Society of America* 71(2):336.

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

Swetnam, T. W., C. H. Baisan, P. M. Brown, A. C. Caprio, and R. Touchan. 1990. Late holocene fire and climate variability in giant sequoia groves. *Bulletin of the Ecological Society of America* 71(2):342.

Swetnam, Touchan, Baisan, Caprio & Brown. 1990. Giant Sequoia Fire History in Mariposa Grove. Yosemite Centennial Symposium Proceeding-Natural Areas and Yosemite: Prospects for the Future.

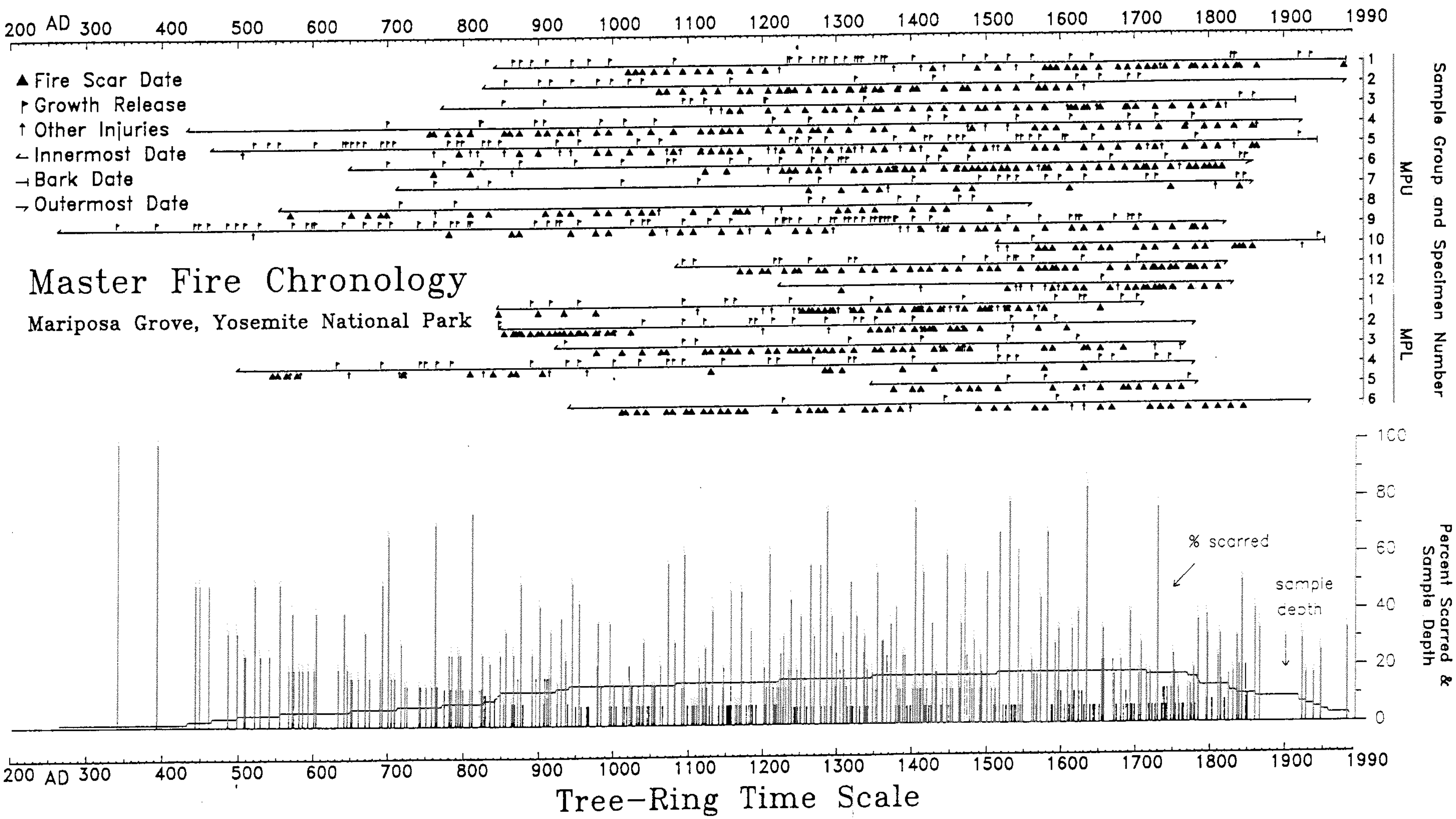

Figure 1. Master Fire Chronology, Mariposa Grove, Yosemite National Park. The horizontal lines represent sampled life spans of individual trees, and symbols on the lines indicate fire dates determined from fire scars and other indicators. The bar graph at the bottom shows percent- age of trees recording fire dates. The horizontal line running through the bar graph shows the number of trees included in the chronology.

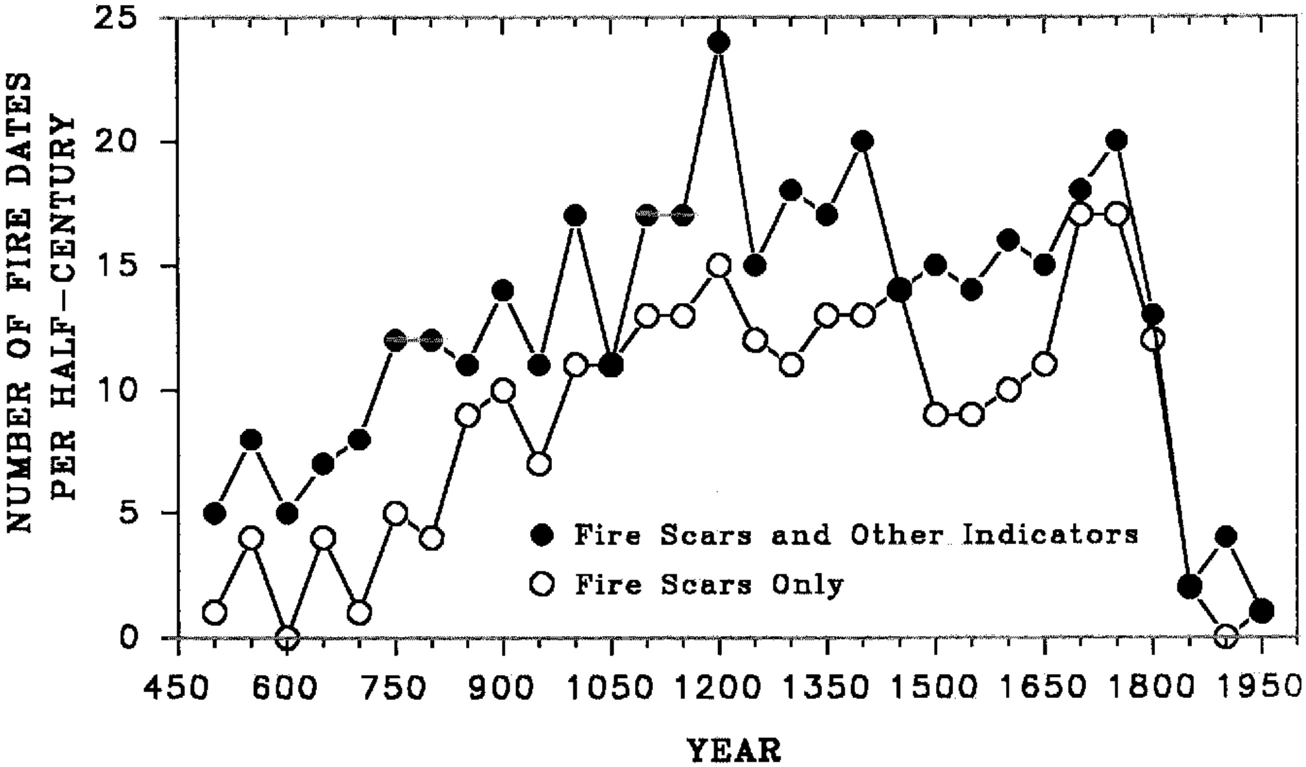

Figure 2. Estimated fire frequency in Mariposa Grove. Numbers of fire dates are shown per half century, estimated from fire scars plus other indicators, and fire scars alone. Selection of the 50-year periods was arbitrary. The data points represent the 50-year period from the indicated date and the subsequent 49 years. For example, the number of fire dates shown at 1200 represent numbers of fires recorded from 1200 to 1249 A.D. Estimated fire frequencies before about 800 are of lower confidence because sample depth is low before this point.