Fire History in a Mexican Oak-Pine Woodland and Adjacent Montane Conifer Gallery Forest in Southeastern Arizona[1]

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Fire-scarred logs, snags, and trees were sampled within an oak-pine woodland and adjacent conifer-dominated gallery forest in Rhyolite Canyon, Chiricahua National Monument. Dendrochronological analysis of these fire-scarred samples documents a fire regime characterized by episodic surface fires that occurred at intervals of 1 to 38 years. The mean fire interval (MFI) for the entire study area was 3.9 years for fires scarring any tree and 13.2 years for fires scarring at least 25% of the sampled trees for the period A.D. 1620 to 1890. Based on the position of fire injuries within tree-rings and recent studies of cambial phenology, these fires occurred primarily between May and late July. Lower canyon areas dominated by woodland type vegetation sustained a reduced MFI (more frequent fires) during the latter portion of the 19th century. This reduced MFI may have been caused by shifts in Apache burning practices. Virtually no fire activity occurred in the conifer dominated central portion of the canyon during the 50-year period 1801-1851. We hypothesize that this 50-year hiatus in fire activity resulted from changes in fuel continuity due to flood and/or debris-flow events. Cessation of the episodic fire regime after 1890 is attributed to livestock grazing and associated reduction in the amount and continuity of surface fuels.

Based on modern patterns of lightning fire ignitions and the fire scar record, the oak-pine gallery forest in Rhyolite Canyon appears to have served as a conduit that allowed fire to spread across elevation gradients. We conclude that important sources of fire were the high elevation pine forests in the uplands above the head of the canyon and the low elevation grassland and woodland communities at and below the mouth of the canyon. Elimination of episodic fires has resulted in significant changes in community composition and structure as well as the amount and distribution of live and dead fuel. These changes, in addition to the existence of artificial management boundaries, will complicate planning and implementation of fire management programs. Nevertheless, the historical perspective offered by this study provides a baseline for assessing patterns of change and, perhaps, a model for desired future conditions.[3]

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[3] For a more complete presentation and analysis of this data please refer to Swetnam et. al. 1989 and Swetnam et. al. 1991.

INTRODUCTION

Knowledge of fire regimes, including the frequency, areal extent, and intensity of past fires, is needed to evaluate and plan prescribed burning programs in wilderness and parks. There is widespread agreement among most forest scientists and land managers that fire is essential for the healthy functioning of forest and woodland ecosystems, and that this process should be reintroduced in wilderness and parks where it has been artificially excluded by humans. Fire regimes are, however, highly variable both spatially and temporally, even within forest types. Documentation of past fire regimes is therefore one of the first and most basic scientific inventories that is necessary to improve understanding of the fire process within specific management units (Kilgore 1987).

Few studies of fire history or fire effects in Madrean evergreen woodland have been conducted, but the presence and importance of fire within the various woodland community types has been noted (Leopold 1924; LeSueur 1945; Wallmo 1955; Marshall 1957, 1963; Moir 1980, 1982; Niering and Lowe 1984). Marshall (1963), surveying birds in the Mexican pine-oak woodlands, compared woodlands of Mexico to those in the United States and felt fire played a different role due to the differences in fire suppression policies at the time of his study. In Mexico, where fire suppression was minimal, he found the woodlands to be open with a dense grass understory. Across the border in the United States where fire suppression was sophisticated and generally effective, Marshall observed that woodlands were stunted, have heavy fuel accumulations, and little grass understory. Fires that do occur are often severe and may kill most of the overstory trees and understory plants.

This study documents more than three centuries of fire regime variations along an elevation gradient. The study area is of particular interest because of the transition along this gradient, from an open oak-pine woodland at the lower end through mixed-conifer forest to open pine forest at its upper terminus. We were able to reconstruct the fire regime along this gradient by sampling and dendrochronologically dating fire-scarred pines.

DESCRIPTION OF THE STUDY AREA

Chiricahua National Monument is located in southeastern Arizona, occupying a relatively low area at the north end of the Chiricahua Mountains. Elevations within the Monument range between 1,579 and 2,229 m (5,180 and 7,313 feet). Terrain is extremely rugged and is dissected by several large, steep-walled, canyons (Bonita, Rhyolite, and Jesse James) which drain to the west.

The study area includes Rhyolite Canyon, several side canyons, and the upland area between the head of Rhyolite and the adjacent watershed to the south. A few samples were also collected near the mouth of Surprise Canyon, a small watershed immediately to the north of Rhyolite Canyon. Rhyolite is the largest canyon within the monument and drains westward into the Sulfur Springs Valley. Streamflow is intermittent and the channel is well developed with a relatively broad, gravelly, boulder-strewn bottom at the monument headquarters.

Soils are shallow on the uplands, but relatively deep and stable in canyon bottoms. They are generally gravelly to moderately coarse and are derived from a substrate of rhyolitic tuff (Reeves 1976). Slopes are of varying degree and exposure, but aspects are predominately north or south. Aspects is especially important in determining species composition through the effects of insolation and evapotranspiration.

Vegetation of the study area is diverse, a consequence of a broad range of elevation, precipitation, temperature, topography, soil, and fire regimes. Plant species composition is strongly influenced by distinct regional plant communities located to the north, east, and south, leading to a high degree of biotic complexity not found at higher latitudes. Higher elevation, mesic montane conifer forests found within protected habitats in Chiricahua National Monument have northern affinities while lower elevation semi-desert grasslands have affinities to the east. Madrean evergreen oak woodland, comprising 60% to 65% of the vegetation cover in the monument, is strongly influenced by the Sierra Madre where the distributional center of oak woodland is located. The type within Rhyolite Canyon also has some affinities with more northern and western interior chaparral (Reeves 1976, Murray 1982).

Major tree species occurring in the study area are: *Pseudotsuga menziesii* (Douglas-fir), *Pinus ponderosa* (ponderosa pine), *P. leiophylla* var *chihuahuana* (chihuahua pine), *P. engelmannii* (apache pine), *P. discolor* (border pinon), *Cupressus arizonica* (Arizona cypress), *Quercus chrysolepis* var *palmeri* (canyon live oak), *Q. rugosa* (netleaf oak), *Q. hypoleucoides* (silver-leaf oak), *Q. emoryi* (emory oak), *Q. arizonica* (Arizona white oak), *Arbutus arizonica* (Arizona madrone), and *Juniperus deppeana* (alligator-bark juniper). Detailed descriptions of the vegetation within the monument can be found in Roseberry and Dole (1939), Moir (1975), Reeves (1976), and Murray (1982). Major plant associations are interior chaparral, semi-desert grassland, montane conifer forest, relict conifer forest, and Madrean evergreen woodland.

Climate of southeastern Arizona is semi-arid, characterized by low rainfall, relatively high temperature and evaporation, and low humidity. Precipitation is distinctly bimodal with wet winters and summers and a pronounced foresummer drought (April-June) and a less predictable fall drought. Summer rains in the form of thunderstorms occur from July to September with moist air usually flowing from the southeast. Winter storms from December to March are usually derived from frontal systems from the northwest (Sellers et al. 1985). Average temperatures for oak woodland stations in southeast Arizona are highest in late June and early July and lowest during January. Average minimum temperature for January is -0.2°C (31 °F) while average maximum is 14.7°C (56 °F). In July the average minimum and maximum temperatures are 17.4 and 32.8°C respectively (63 and 91 °F).

The fire season in southeastern Arizona occurs mainly in the late spring and early summer, prior to the inception of the "Arizona monsoon", and occasionally extends throughout the summer into October (Barrows 1978). The pre-monsoon season is a period of high temperature, low humidity, and dry vegetation. Weak storm cells sometimes develop in which virga and lightning are common. Lightning during this period often results in isolated or clustered ignitions that are associated with specific storm systems (Bock et al. 1976; Murray 1982).

METHODS

A chain saw was used to fell snags, section logs and stumps, and remove samples from living trees. Where possible, as an alternative to felling snags, wedge sections were removed from the face of the scar as described by Arno and Sneck (1977). Fifty-six cross sections or wedges were collected in this manner. Forty-five of these samples were from remnants (dead trees and logs) and eleven were from living trees. One additional sample, which had been previously collected, was obtained from Chiricahua National Monument.

Samples were sectioned with a band saw and sanded with a series of progressively finer sanding belts (40 to 320/400 grit) to prepare the surface. Cross sections were examined with a binocular microscope, and cross-dated as described by Stokes and Smiley (1968). Once the specimens had been successfully cross-dated, fire dates (determined from the fire scars) were recorded. The position of the scars within the rings, when discernable, was also noted to provide an estimate of the season of occurrence (Ahlstrand 1980; Barrett 1981; Dieterich and Swetnam 1984; Baisan and Swetnam 1990).

The fire scars were identified as one of the following types based on observations of relative positions within annual rings:

D - Dormant season. Fire scar occurred on the boundary of two rings, with latewood cells of the prior year on one side of the scar and earlywood cells of the next year on the other side of the scar. Because the fire season begins in the spring in southern Arizona, these scars were dated to the later year (that is, as spring rather than fall fires).

E - Earlywood. Fire scar occurred within earlywood cells of one annual ring. These types of scars were further sub-classified when possible into categories of **EE**, early-earlywood, occurring within the first one-third of the earlywood portion of the ring; **ME**, mid-earlywood, occurring in the second one-third of the earlywood; **LE**, late-earlywood, occurring in the last one-third of the earlywood. Earlywood scars that could not be sub-classified were simply given the generic classification of **E**, earlywood. Earlywood type scars were probably formed by fires occurring between May and July or early August.

L - Latewood. Fire scar occurred within the latewood cells of the ring. Latewood type fire scars were probably formed by fires occurring between July and the end of September.

Interpretations of the probable period when the different scar-types were produced are based on observations of cambial growth in the Santa Catalina Mountains (Fritts 1976) and current studies of cambial phenology in Rhyolite Canyon (Baisan and Swetnam in preparation).

RESULTS AND DISCUSSION

The use of dendrochronological dating methods allowed us to sample primarily logs and snags. Sampling of this remnant material might be considered a "salvage" of scientific information, since this material is continually decaying, and thus information on past forest ecosystems is becoming less available. Much of this dead woody material is present only because of fire suppression activity during the current century; under pre-settlement fire regimes it would have burned long ago. This material will be consumed and historic information irretrievably lost as prescription burning becomes more common.

Modern fire data

Chiricahua National Monument fire records document a dispersed ignition pattern and rather low overall ignition rate (1.5/yr.) (Jandrey 1975). Twenty six percent of recorded fires occurred within the Rhyolite watershed. Almost no ignitions in the modern record occurred within the canyon proper, leading to the conclusion that the majority of historic fires were ignited elsewhere and were able to spread into and within the drainage.

Comparison of recent versus past fire regimes and ignition sites must be interpreted in light of associated vegetation changes which may have occurred in the last 100 years. Changes have been noted in most vegetation types of southeastern Arizona (Leopold 1924; Marshall 1957, 1963; Hastings and Turner 1965; Reeves 1976; Bahre 1991) and are very apparent in oak woodlands, desert grasslands, and pine forest. General patterns are increased dominance of woody plants and a corresponding decrease in dominance of herb species. Alteration in the fuel matrix would certainly affect ignitions and spread of fire through the various vegetation types.

The fire-scar record

Analysis of the fire scarred samples provided a five-century long record of fire activity in this watershed from the earliest fire date in 1476 to the last in 1983. The mean fire interval (MFI) for fires that burned through extensive portions of Rhyolite Canyon was 13.2 years with a range of 1 to 31 years. In general, for the 1620 to 1801 period, the MFI estimates did not differ appreciably from the upper to the lower reaches of the canyon. After 1801, however, this pattern of episodic, canyon-wide fire changed dramatically. At this point a 50-year fire-free interval occurred in the mid and upper part of the main canyon (Fig. 1). Trees in the lower canyon continued to record fire activity with a MFI similar to the period prior to 1801.

After 1851, fires were recorded again by trees in the upper and middle portions of the canyon until 1886 when the last widespread fire was recorded. During this period the lower canyon continued under a largely separate fire regime characterized by a pronounced increase in fire frequency. Lower canyon trees recorded fires in 1852, 1856, 1859, 1867, 1873, and 1882 for a much reduced MFI of 6.0 years. Of these fires, only the fire of 1859 was recorded by trees sampled in other areas of the canyon. After the late 1880s few fires were recorded anywhere in the drainage.

The general synchrony of pre-1801 fire-scar dates within the canyon suggests that regardless of where a fire began, once in the canyon it tended to spread throughout large portions of the drainage. It is possible that some scars were caused by fires ignited separately at different points along the canyon, although the low ignition rate during the historic period suggests this was unlikely. Modern fire records indicate ridges and upland areas have been a source of lightning ignition in the recent past. It is probable that lightning fires from the higher elevations occasionally were able to burn downslope into the main canyon. Another ignition source may have been fires burning up from the grassland at the base of the mountains. Slightly higher fire frequencies

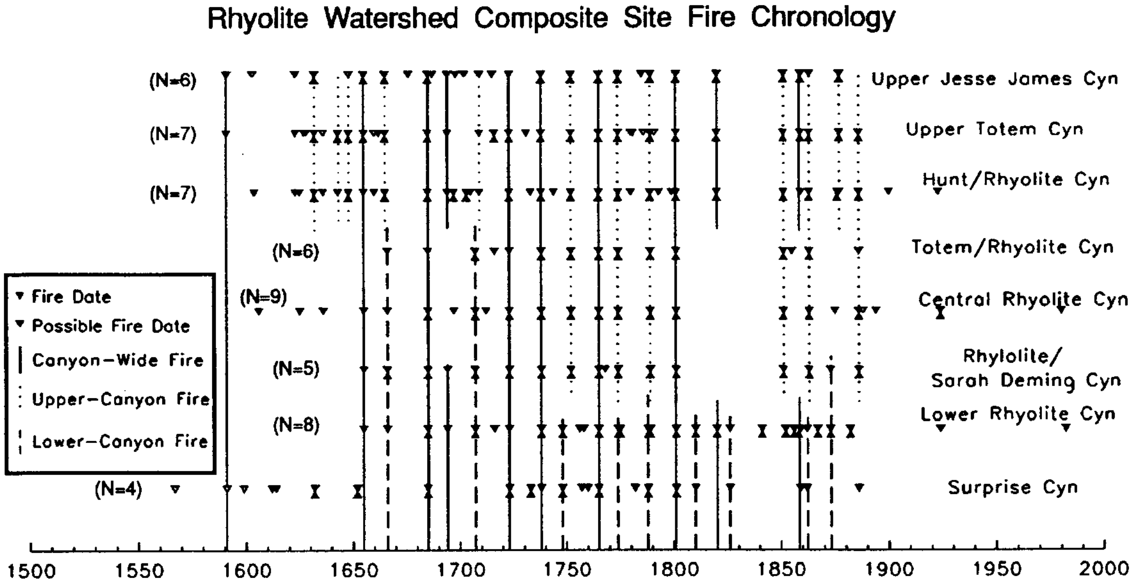

Figure 1. Fire chronology chart for the entire study area including Surprise Canyon and the upland area (upper Jesse James Canyon and upper Totem Canyon). Data are organized by groups of trees in relatively close proximity with the number of samples in each group shown in parenthesis. Canyon-wide fires as well as those affecting just the mouth of Rhyolite Canyon and the upland area are noted with a solid line, those which affected the upper watershed with a dotted line, while those affecting the lower canyon are shown with a dashed line.

recorded in both the upper and lower groups of trees as compared to the middle group suggest these were closer to areas of ignition and that not all fires were able to spread the length of the canyon system.

After 1801 this pattern changed. The subsequent 50-year hiatus in the scar record for trees in the upper and middle groups has not been observed in any other fire chronology from the southwest during the pre-1900 period. A possible explanation for this change in the fire regime may be related to a change in fuel continuity within the canyon. Before 1801, when fires were canyon-wide events, fuel continuity probably allowed fires to spread throughout the drainage. Fires recorded by trees at the mouth of the canyon after 1801 were not recorded on trees higher in the drainage and vice versa. Also, assuming fires were still ignited in the uplands, none appear to have been able to burn into the canyon bottom.

We hypothesize that a flood and/or debris flow event disrupted fire spread patterns after 1801. We have observed that large floods can almost completely scour vegetation from canyon bottoms in southeastern Arizona. For example, an October 1983 flood stripped vegetation from some riparian corridors in the Galiuro Mountains. Such an event could produce the fire regime changes we documented in Rhyolite Canyon. We are currently investigating pre 1900 flood history in Rhyolite Canyon through the analysis of flood-scarred trees (McCord 1990). Although 1866 is currently the oldest flood date documented in this manner, more thorough sampling may reveal additional, earlier, dates.

Increased fire frequency in the lower portion of Rhyolite Canyon after 1851 is especially suggestive of human influence. Bonita Canyon, the next major canyon north of Rhyolite, was historically used as a route of travel through the mountains by the Apache. In 1885, the Army established a camp close to the mouth of Bonita and Rhyolite specifically to control Apache use of this area (Baumler 1984). It is possible, therefore, that the increased Apache presence sometime in the mid to late 1800s may be related to with the increase in fire frequency. Similarly, the end of the fire regime in the late 1880s could be linked to the establishment of the Army camp, removal of the Apache and the advent of intensive grazing in the area. Pre-settlement episodic fire regimes in southwestern forests were usually eliminated at the time of intensive grazing, and one to several decades before effective fire suppression (Swetnam 1990; Baisan and Swetnam 1990; Savage and Swetnam 1990).

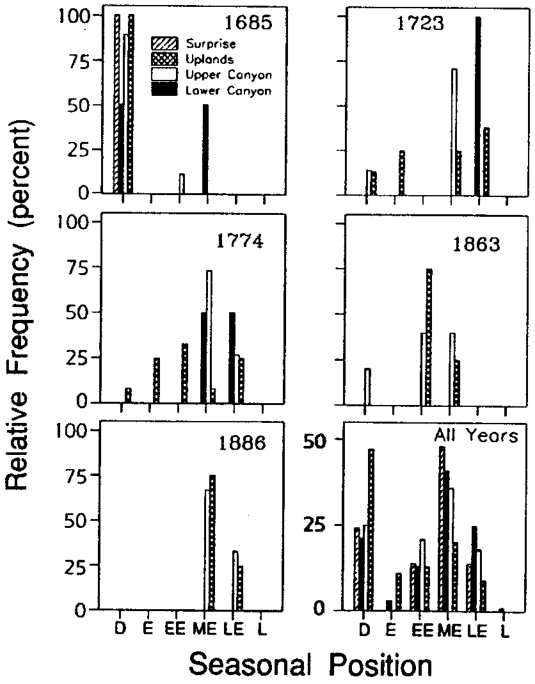

Figure 2. Histograms of the seasonal position of fire scars for various dates. Fires were predominantly early season with only occasional late season fires.

Intra-annual (seasonal) data were sorted by fire date and a series of histograms constructed for six major fire years between 1685 and 1886 (fig. 2). Most fires occurred within some portion of the earlywood, indicating that growing season fires from approximately May to August were most typical of pre-settlement fires. Distributions of scar position for some fires suggested specific seasonal timing for these events. For example, the fires of 1685, 1707, 1765, and 1801 appear to have occurred early in the growing season, perhaps during the month of May or June. The fires of 1723, 1789, 1851, 1863, and 1886 appear to have occurred well into the growing season, possibly as late as August or September.

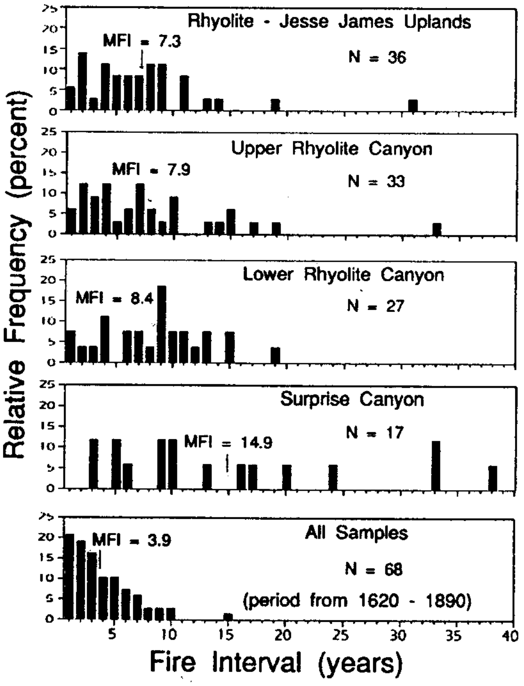

Figure 3. The distribution of fire intervals, all fires included, in various portions of the canyon system. *N* is the number of intervals. Note the general variability in relation to the mean interval. Such variability appears to have characterized pre-settlement fire regimes in the southwest.

Although MFI is often used to characterize fire regimes, it can be seen from figure three that a simple reporting of the mean interval masks the inherent variability of this disturbance process. Variability, itself, should also be recognized as an important characteristic. Additionally, when the area considered exceeds the average fire size the MFI ceases to have relevance for a specific point. Rather, it becomes a measure of the frequency of fire occurrence within an area.

SUMMARY

- Spreading fires, recurring at intervals of 1 to 19 years, were an integral component of the dynamics shaping the vegetation within Rhyolite Canyon and adjacent forested areas over at least the past five centuries.
- Fires occurred predominantly during the spring and early summer months.
- Many fires appear to have been large by today's standards, some burning throughout the drainage.
- Geomorphic processes (floods and debris flows) probably interacted with the fire regime within the Canyon.
- The fire regime influenced a variety of plant associations along an elevational gradient from grassland, oak-conifer woodland, montane conifer gallery forest, to upland pine forest.

CONCLUSIONS

Fire played a key role in shaping the diverse plant communities within the Rhyolite Canyon watershed of Chiricahua National Monument. Although three distinctly different community types occur along this drainage, the mean and range of fire intervals differed little among them. Given the evidence of frequent surface fires during pre-settlement times, the virtual cessation of these fires around the turn of the century, and the obvious accumulation of live and dead fuels in the canyon over the last 90 years, it is clear that profound changes in ecosystem composition and structure have occurred. Additionally, we hypothesize that floods and debris flows interacted with the fire regime by altering the fuel distribution.

These results provide a baseline and justification for management policy that acknowledges disturbance processes as fundamental attributes of natural communities, and seeks to reintroduce that process. Knowledge of fire seasonality and typical fire recurrence intervals, coupled with information derived from other studies on the response of species to fire, will aid in developing reconstructions of the pre-settlement composition and structure of these communities. These reconstructions may then be used to assess both the amount of change that occurred during the past century and to predict the probable effects of management actions.

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