FIRE HISTORY OF PONDEROSA PINE FORESTS IN THE GILA WILDERNESS, NEW MEXICO

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ABSTRACT: Crossdating of tree-rings and fire scars on 44 cross sections of ponderosa pine *(Pinus ponderosa)* trees revealed that extensive surface fires were a common occurrence before 1900. Mean fire intervals from 1633 to 1900 were approximately 4 to 8 years, and fire intervals ranged from 1 to 26 years.

INTRODUCTION

In 1924 approximately 750,000 acres (303 500 ha) of the Gila National Forest were designated as the Nation's first Wilderness and Primitive Area within the National Forest System. Today, the Gila Wilderness, the nearby Aldo Leopold Wilderness, and adjoining primitive areas comprise one of the largest areas under wilderness protection in the United States. The Gila contains some of the most extensive stands of virgin ponderosa pine remaining anywhere within the widespread range of this species.

It is fitting that pioneer efforts to reintroduce fire in wilderness have occurred in the Nation's first wilderness area. Since 1975 approximately 12,000 acres (4 856 ha) have been burned by lightning-ignited, prescribed fires (see Webb, elsewhere in this volume). Although burning prescriptions and fuel models have been refined and monitoring techniques improved, the availability of basic information on the importance of fire to specific ecosystems within the Gila Wilderness has been lacking.

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In the summer of 1980 we began a fire history research study to provide data for future wilderness fire management planning and to answer several pertinent questions within the framework of the Prescribed Natural Fire (PNF) Program (Swetnam 1983). We posed the following questions:

1. How often did fires burn within ponderosa pine areas of the Gila Wilderness before livestock grazing and fire suppression efforts began?

2. How large were presettlement fires?

3. Are prescribed natural fires frequent and large enough to simulate the presettlement fire regime?

To obtain information about the presettlement fire regime, we collected fire scar samples from ponderosa pine trees in three study areas, McKenna Park, Langstroth Mesa, and Gilita Ridge. These areas were chosen on the basis of proximity to approved PNF areas and accessibility. (Figure 1 shows the relative location of the study areas within the Wilderness and National Forest.) All three study areas are within the Petran Montane Conifer Forest biotic community (Brown 1982). The overstory within the study areas is pure ponderosa pine, and the understory is composed of various grass species such as *Festuca arizonica* and *Muhlenbergia virescens*. Portions of the study areas also have dense stands of *Pteridium aquilinum* and scattered groups of *Quercus gambelii*.

METHODS

We obtained 44 cross sections from collection sites within the three larger study areas. (Table 1 identifies general characteristics of the collection sites within each of the study areas.) The collection sites included areas of less than 100 acres (40.5 ha) each. Fire-scarred trees were sampled in clusters or groups of at least two trees because it has been found that a composite of fire scar records from nearby trees generally provides more complete information for an individual site than records from single trees scattered over a larger area (Dieterich 1980).

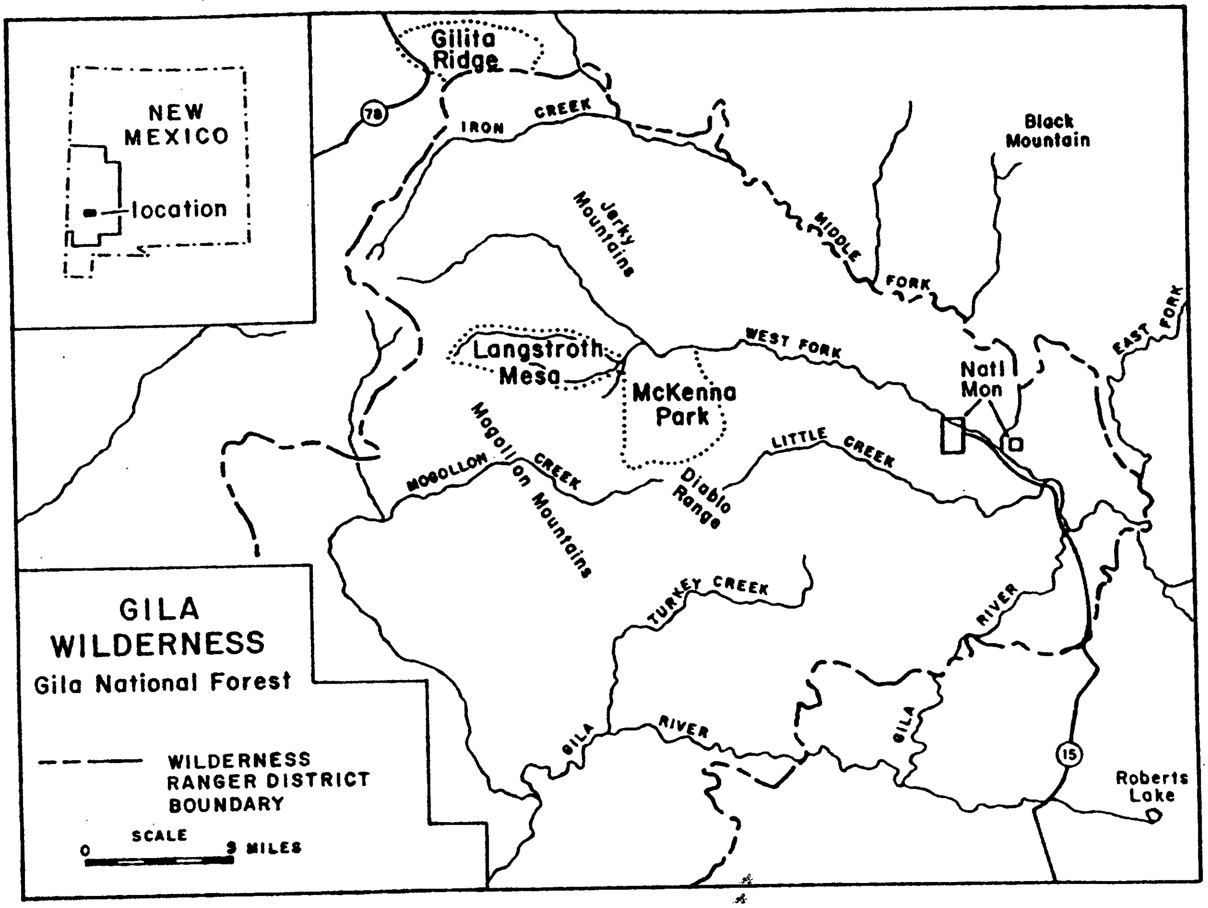

Figure 1.--Map of the Gila Wilderness.

All of the samples collected from the Wilderness were obtained by felling live and dead trees with a crosscut saw and then bucking off cross sections from the bole or stump. Samples were also obtained from downed logs. Fire-scarred material was packed out of the Wilderness by mule. Samples from Gilita Ridge, which is just outside the Wilderness boundary, were collected by using a chain saw to remove cross sections from stumps of trees recently felled during a timber harvest in the area.

Increment core collections were also obtained from each study area so that master tree-ring chronologies could be developed as dating controls. Two cores were taken from each of 15 to 20 trees in each of the study areas.

Increment cores were mounted in wooden holders, sanded, and crossdated as described by Stokes and Smiley (1968). The annual ring-widths of each core were then measured on a sliding stage micrometer interfaced with a microcomputer (Robinson and Evans 1980). The measured ring-width series was then standardized and averaged (Fritts 1976) using a series of computer programs (RWLIST, INDEX, SUMAC) (Graybill 1979).

The fire-scar samples were reduced in size with a bandsaw so that they could be conveniently observed under a microscope. Each cross section was carefully sanded with a power sander using belt grits from 40 to 400. The master tree-ring chronologies were then used as dating controls for dating annual rings of the fire-scarred specimens. They were considered controls because crossdating ensured that the master tree-ring chronologies, which were composed of measurements from many trees, included values for each year of the series, whereas ring series from individual trees may not be complete or accurate because rings may be false or absent in a particular area.

Crossdating is a preferred method of dating fire scars, especially in short fire interval types such as ponderosa pine (Madany and others 1982). The greater accuracy of crossdating is needed to distinguish between fire events that may occur as close together as 1 year. Precise fire dates are also necessary if analyses include comparisons between study areas or comparisons with climatic data because if fire dates are off by 1 or more years, possible correlations may not be observed. Crossdating also provides a means of determining fire dates from fire-scarred snags and downed logs.

Table 1.--Description of collection sites within study areas

Site	Number of specimens[1] L	D	T	Elevation feet	m	Topography Aspect	Slope Pct
				McKenna Park			
A	3	1	4	7,760	2 365	NE	0-5
B	5	1	6	7,800	2 377	SW	5-100
C	2	0	2	7,700	2 347	Flat	-
D	0	4	4	7,640	2 329	NW	5-20
	10	6	16				
				Langstroth Mesa			
A	5	0	5	8,000	2 438	N & S	5-10
B	1	3	4	7,800	2 377	Flat	-
C	2	2	4	8,400	2 560	E	0-5
D	3	2	5	7,800	2 377	Flat	-
	11	7	18				
				Gilita Ridge			
A	0	10	10	8,300	2 500	S	0-5

[1]L = live; D = dead (collected from snags, downed logs, and stumps); T = total.

After crossdating the ring series and fire scars of each sample, another dendrochronologist independently crossdated the samples as a check. All of the fire scar dates were then compiled for each specimen by collection site and study area, and the dates were included on a master fire chronology chart.

RESULTS

The master fire chronology charts for the McKenna Park, Langstroth Mesa, and Gilita Ridge study areas are shown in figure 2. The horizontal lines represent the life spans of individual fire-scarred trees and the arrowheads on either side of the lines indicate fire-scar dates from both sides of the cross section samples. Presentation of fire scar data in this form is useful because calculations of mean fire intervals (MFI's) alone do not indicate the inherent variability of a fire regime or the limitations of the MFI estimates. Mean fire intervals are the arithmetic average of fire intervals determined in a designated area during a designated time period (Romme 1980).

Several obvious features are apparent from inspection of the master fire chronologies. For example, the periodic recurrence of fires that scarred the sample trees ceased after about 1900. Another notable feature is the relatively consistent agreement of fire scar dates among the sample trees. It is also apparent that the most complete record of fire occurrence is for the period after 1800. Before 1800, fewer trees were alive or they had not yet been scarred by fire and were therefore less susceptible to scarring. Trees that have been scarred at least once have exposed cambium, and the pitch that exudes from the wound boundaries can be easily ignited. Such trees are termed fire-scar-susceptible trees (Romme 1980).

Tables 2 and 3 list the MFI computations for the three study areas by time period. The time periods were based on the characteristics of the records. For example, the 1801-1904 period in McKenna Park had the largest number of sample trees recording fires, whereas the 1633-1801 period had the fewest trees recording fires.

Because there was an obvious decline in the number of fires recorded after 1900, separate MFI's were computed for post-1900 periods.

The reason for computing MFI's for all fire years (table 2) and fire years recorded by more than one specimen (table 3) was to present the data in different perspectives. For periods after 1800, MFI's in table 2 are more representative of the time interval between any fire, while MFI's in table 3 are more representative of time intervals between larger fires. For periods before 1800 this distinction cannot be made because of the scarcity of fire scar evidence.

Mean fire intervals were computed for the 1837-1904 period in McKenna Park and Langstroth Mesa and for 1837-99 on Gilita Ridge because before 1837 there was a relatively long period in all three study areas when no fires were recorded by the sample trees. The length of this period was 12 years in McKenna Park (1825-37), 22 years on Langstroth Mesa (1815-37), and 18 years on Gilita Ridge (1819-37). Mean fire intervals are slightly shorter when this period is omitted from the computations.

DISCUSSION

Changes in the Fire Regime

Perhaps the most striking pattern observed in all three of the master fire chronologies was the sudden decrease in the number of fires recorded after 1900 by the sample trees (fig. 2). Only four fires were recorded in McKenna Park after 1904. Five fires were recorded by Langstroth Mesa specimens after 1904, and only one fire was recorded by Gilita Ridge specimens after 1899. Between the years 1640 and 1900, 58 fires were recorded in the three study areas (each fire recorded by at least two specimens).

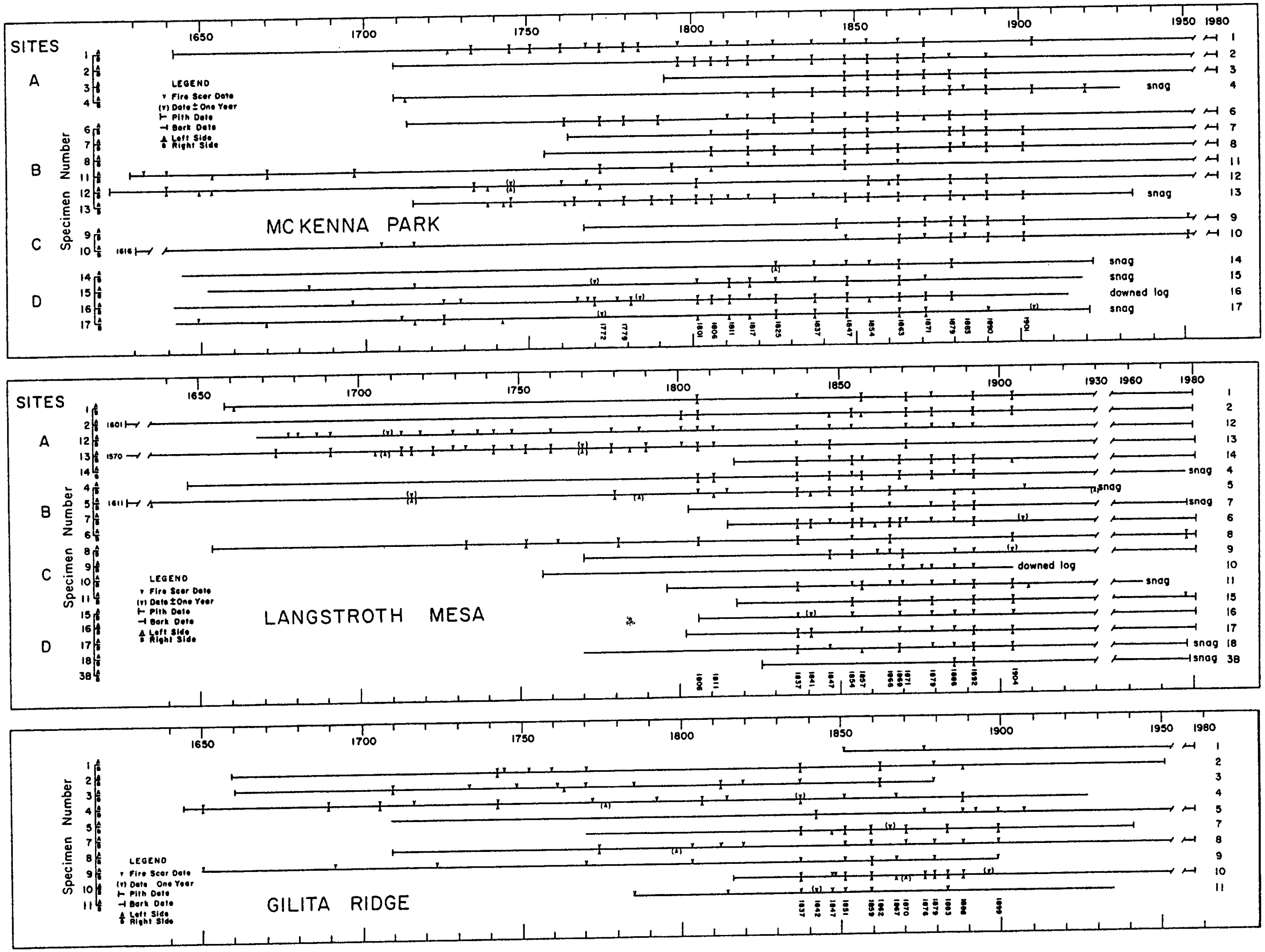

Figure 2. Master fire chronologies.

Table 2.--Mean fire intervals by study area and time period; all fire years included

Study areas and time periods	Fire interval Mean (years)	Fire interval Range (years)	Number of fire-scar-susceptible trees[1]	Number of trees collected
McKenna Park				16
1633-1801	4.3	1-16	0/11	
1801-1904	6.4	3-12	11/16	
1837-1904	6.1	3-11	14/16	
1904-1951	23.5	16-31	16/16	
Langstroth Mesa				18
1635-1801	5.7	1-26	0/5	
1801-1904	5.4	1-22	5/18	
1837-1904	4.5	1-12	7/18	
1904-1978	14.8	1-48	18/18	
Gilita Ridge				10
1650-1803	16.9	2-39	0/6	
1803-1907	4.7	1-18	6/10	
1837-1907	4.1	1-8	6/10	

[1]The numerator is the number of fire-scar-susceptible trees at the beginning of the period, and the denominator is the number susceptible at the end of the period.

Table 3.--Mean fire intervals by study area and time period; fire years recorded by more than one sample tree included

Study areas and time periods	Fire interval Mean (years)	Fire interval Range (years)	Number of fire-scar-susceptible trees[1]	Number of trees collected
McKenna Park				16
1640-1801	11.5	1-61	1/11	
1801-1904	7.4	3-12	11/16	
1837-1904	6.7	3-10	14/16	
1904-1951	47.0	-	16/16	
Langstroth Mesa				18
1691-1801	10.2	3-22	4/5	
1801-1904	6.9	1-26	5/18	
1837-1904	5.6	1-12	7/18	
1904-1978	74.0	-	18/18	
Gilita Ridge				10
1742-1803	20.3	15-28	3/6	
1803-1899	6.0	2-18	6/10	
1837-1899	5.2	3-11	6/10	

[1]The numerator is the number of fire-scar-susceptible trees at the beginning of the period, and the denominator is the number susceptible at the end of the period.

Several of the fires recorded after 1900 are documented by U.S. Department of Agriculture, Forest Service, records. For example, a 1951 fire that scarred specimens 9 and 10 in McKenna Park (fig. 2) was probably the 14,000-acre (5 670-ha) "Little Creek Fire." This fire was recorded only in collection site C. This assumption is reasonable because a map of this fire prepared by the fire boss after the fire was controlled shows that bulldozer firelines were constructed to the west of site C, which would have prevented the fire from spreading into any of the other collection sites.

The differences in fire regime before and after 1900 are also reflected in the MFI computations. For example, the MFI's for fires recorded by more than one sample for periods before 1900 are approximately 6 to 8 years in McKenna Park and 5 to 7 years on Langstroth Mesa and Gilita Ridge. For periods after 1900 the fire intervals are 47 years in McKenna Park, 74 years on Langstroth Mesa, and 82 years on Gilita Ridge. This evidence indicates that the fire regime that had persisted for centuries was essentially eliminated by the beginning of the 20th century. The decline of periodic fires was a direct result of a combination of human-induced changes. These changes included removing Apaches from the Gila area by the 1880's (since they probably started some fires), introducing thousands of sheep and cattle to the area beginning in the 1890's, and fire suppression efforts that began in the 1900's. The relationship of changes in land use to changes in fire regime has been recognized and discussed in many fire histories and other ecological studies (Leopold 1924; Weaver 1951; Cooper 1960; Arno 1980).

Areal Extent Of Pre-1900 Fires

Between the years 1801 and 1904, an average of 65 percent of the fire-scar-susceptible trees were scarred by each fire recorded in McKenna Park, and 62 percent were scarred by each fire recorded on Langstroth Mesa. Between 1803 and 1907, 42 percent of fire-scar-susceptible trees were scarred by each fire recorded on Gilita Ridge (computations include fire dates recorded by more than one tree). The agreement of fire dates among many of the sample trees and collection sites within the study areas (fig. 2) suggests that most fires burned throughout the study areas. These fires could have been caused by single or multiple ignitions.

It is also evident that some fires were more limited in area. For example, fires that burned in McKenna Park in 1844, 1860, 1920, and 1951 (the "Little Creek Fire") were recorded by only one or two specimens. The Langstroth Mesa master fire chronology demonstrates another example of the areal extent of past fires (fig. 2). Fires burned within the study area on three consecutive years--1869, 1870, and 1871; however, these fires did not burn over the same collection site in consecutive years. In 1869, sites A, B, and D burned. These sites are all on the eastern side of the study area. In 1870, site C, located on the western side of the study area, burned over. Then, during 1871, fire again burned through sites A and B, although in site A this fire was recorded only by trees that were not scarred 2 years earlier. This pattern of burning suggests that the presence of adequate ground fuels was especially important in the timing and spread of fires. When fuels in one portion of the study area were not consumed by fire they were still available for burning the next year. Areas that had burned the previous year had not built up enough fuels to carry fire. Thus consecutive-year fires on the same site were unlikely to have occurred within the study areas, although fires occurring every other year (a 2-year interval) were confirmed. This pattern of burning also shows that although large fires were common for the pre-1900 fire regime, patchy burns also occurred occasionally, causing different amounts of fuel to be available at different locations.

Ignition Sources

The relative importance of Indian ignitions is unknown; however, the incidence of lightning fires in the Gila Wilderness is perhaps higher than in any other wilderness area in the National Forest System. Approximately 252 fires occur per million protected acres per year (Barrows 1978). Therefore, an abundant ignition source has probably been present for a long time, and a fire regime characterized by short-interval periodic fires would likely have prevailed whether Indians were setting fires or not.

Regardless of the pattern of ignition and spread of the pre-1900 fires, the fire scar record indicates that large areas burned during certain years. A conservative estimate of the areal extent of these fires is approximately 3,000 acres (1 124 ha); however, it is likely that some fires were larger. This estimate is based on the approximate size of the study areas and location of natural fire barriers.

The 1820's-1830's Fire Interval

Although evidence of patchy burns indicates the importance of fuel accumulation in the ignition and spread of fires, other evidence suggests the importance of climatic trends. As previously pointed out, there was an unusually long interval during the 1820's and 1830's in all three study areas when no large fires occurred. For all of the study areas these fire intervals were the longest for all periods after 1700.

One possible explanation for the 1820's-1830's gap may be that this period was unusually wetter or cooler or both, resulting in fewer successful ignitions. It has been well established that annual tree-ring widths are highly correlated with precipitation and temperature and that tree-ring series can be used as proxy climatic data (Fritts 1976). An examination of the master tree-ring chronologies developed for this study revealed that tree growth was greater than average during the 1820's-1830's gap, suggesting that this was a wetter than usual period. Schulman (1956) also analyzed tree-ring series from the Gila headwaters area. He listed periods of departures from expected growth and suggested that maximum departures indicated wetter than usual periods and minimum departures indicated drier than usual periods. The period 1826-40 was one of four listed as maximum departure or wetter than usual periods for a 350-year tree-ring series. Conkey (1977) reconstructed winter precipitation (November through February) for the Gila area using tree-ring chronologies and modern climatic data from areas near the Wilderness. The precipitation reconstructions showed that the 1820's-1830's period was the wettest period since about 1800; however, there was a wetter period during the late 1700's and yet no gap in the fire scar record occurred during that period. Apparently, the evidence favors a climatic explanation for the 1820's-1830's gap, but the evidence is not conclusive. Future climate-fire scar studies should investigate various combinations of climatic records, tree-ring records, and fire events.

Whatever the reason for the absence of fire scars during the 1820's and 1830's, such a change in the pre-1900 fire scar record suggests that there may be long-term fluctuations in the fire regime. In other words, fires usually occurred at short intervals (4 to 8 years); however, longer periods without fire (as long as 22 years) may also have occurred.

Agreement of Fire Dates Between Study Areas

The end of the 1820's-1830's gap is marked in all three study areas by fires that occurred in 1837. Nearly all of the sample trees recorded a fire during this year (fig. 2). Agreement of fire dates between study areas was noted in a number of other instances. To determine the significance of the number of agreements, a chi-square test was applied to various combinations of fire chronologies. The null hypothesis was that the number of agreements of fire dates between the study areas was not more than the number that would be expected by chance alone. The test was run on fire years recorded by more than one specimen and all fire years.

The null hypothesis can be rejected in 7 of the 16 classifications tested at the 0.05 level of significance (tables 4 and 5). These results show that from 1801 to 1904, fire occurrence in any one study area was not independent of fire occurrence in any other study area. In other words, if a fire occurred in a study area during a given year, there was a greater than random chance that fires would have also occurred in one or both of the other study areas.

Table 4.--Number (N) and percentage of fire years in common between study areas by time period; fire years recorded by more than one tree are included

	Time periods					
	1640-1801			1801-1904		
Study areas[1]	Total[2]	N	Percent	Total[2]	N	Percent
MKP/LNG	24	3	12.5	22	9	[3]40.9
MKP/GLR	19	0	0	28	4	14.3
LNG/GLR	15	1	6.7	29	4	13.8
MKP/LNG/GLR	27	0	0	34	3	[3]8.8

[1]MKP = McKenna Park; LNG = Langstroth Mesa; GLR = Gilita Ridge.

[2]Total number of fire years recorded in study areas being compared.

[3]Significant at the 0.005 level of significance (see text).

Table 5.--Number (N) and percentage of fire years in common between study areas by time period; all fire years are included

	Time periods					
	1633-1801			1801-1904		
Study areas[1]	Total[2]	N	Percent	Total[2]	N	Percent
MKP/LNG	58	11	19.0	28	9	[3]32.1
MKP/GLR	53	8	15.1	34	5	14.7
LNG/GLR	43	9	[3]20.9	34	8	[4]23.5
MKP/LNG/GLR	67	4	[3]6.0	41	4	[3]9.8

[1]MKP = McKenna Park; LNG = Langstroth Mesa; GLR = Gilita Ridge.

[2]Total number of fire years recorded in study areas being compared.

[3]Significant at the 0.005 level of significance (see text).

[4]Significant at the 0.05 level of significance (see text).

Results of the chi-square tests indicate that some factor may have affected fire occurrence over a large area that included the three study areas. This factor was probably climate. Drier than usual years or drought years would probably occur simultaneously in all three study areas. Lightning storms also tend to be widespread in the Gila during certain years. Both of these climatic factors probably caused fires in more than one study area. It is unlikely that the agreement in fire dates between study areas was due to spread of fire from one study area to another because they are separated by large distances and natural fire barriers, such as river canyons and mountain ranges.

SUMMARY AND MANAGEMENT IMPLICATIONS

More than 800 individual fire scars on 44 ponderosa pine cross sections were dated for this study. The fire scar dates span a period of 345 years (1633-1978). The record from 1800 to 1900 reveals that fires occurred at mean fire intervals of 4 to 8 years and that the range of intervals was as short as 1 year and as long as 26 years.

The fire scar evidence also indicates that most pre-1900 fires were extensive and probably burned throughout the study areas. A fewer number of fires burned smaller portions of the study areas and were only recorded within one or two collection sites or only by one specimen. This information suggests that large fires (greater than 3,000 acres [≅1 200 ha]) should be tolerated within approved PNF areas, subject to the limitations of wilderness boundaries, visitor safety, and management and suppression capabilities. Smaller fires and patchy fires should also be a part of the PNF Program.

The unusually long period without fire scar evidence in the 1820's and 1830's and the significant agreement of fire scar dates between study areas seems to indicate that a quantifiable relationship exists between fire occurrence and climatic events. Future studies of long-term climatic records and long-term fire records may help define this relationship.

Most of the living trees within the Gila, particularly the old-growth ponderosa pine, germinated, established, and lived most of their lives under the effects of repeated fires. These fires shaped the growth, composition, and age structure of the forest in a profound manner. If fire does not regain its role as a dominant natural force in the forest ecosystem, the result will be a very different wilderness in the future. If fire is to be effectively restored to wilderness lands, there may be a minimum frequency of burning that should be achieved. If managers wish to restore or simulate the pre-1900 fire regime, and also effectively remove accumulated fuels, the approximate burning interval that should be achieved within the ponderosa pine type is 4 to 8 years, or once or twice per decade. To reduce heavy fuel loading in some areas, shorter intervals may be required to restore stand conditions to pre-1900 levels. The past 9 years of experience with the PNF Program has indicated that these fire frequencies may not be achieved with lightning ignitions only. To meet the wilderness objective of restoring natural fire processes, fire management officers of the Gila National Forest have proposed that the PNF Program include the careful use of planned (scheduled) ignitions (see Webb, elsewhere in this volume).

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