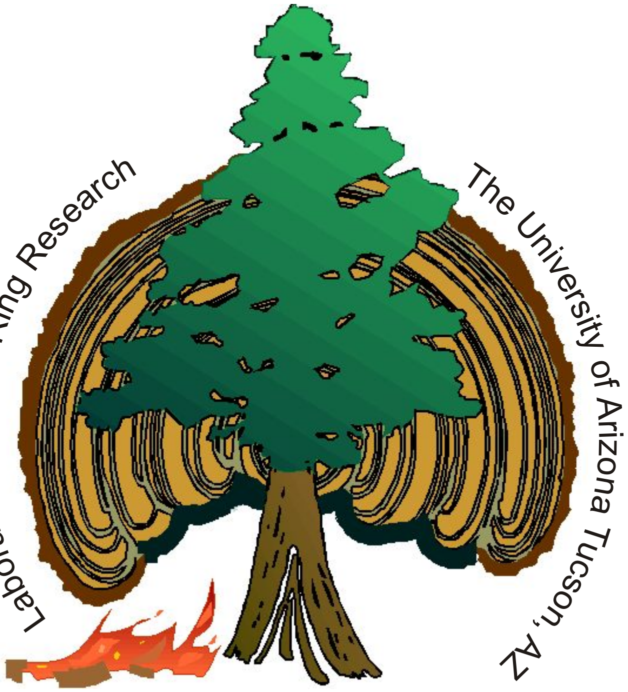
Historical Fire Regimes in the Chiricahua Mountains, Arizona:

An Examination of Fire Along an Elevation Gradient and in Mixed-Conifer Forest.



Fire History Workgroup

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INTRODUCTION

Fire is a fundamental ecological process operating across landscapes, influencing vegetation structure and dynamics. It comprises one component in a complex, hierarchical system that, in addition to vegetation, also includes topography and climate. Coarse patterns of vegetation, determined by the physical components of the system, are modified by fire. In turn, fire is modified by vegetation via fuel distribution, quantity and quality. The intensities and directions of interactions among these factors are dynamic over space and time and must be understood in order to manage the system in an ecologically-sound manner as mandated by current management policies (Grumbine 1994, Kauffman et al. 1994). The ecological approach to natural resource management is based on the premise that natural structures and processes are the best models for maintaining healthy, functioning ecosystems.

Models of natural ecosystem structure and function, however, are elusive. Contemporary landscapes have been significantly affected by a century's worth of commodity-based resource management. Land use practices and forest management policies based on short-term economic gain have greatly altered fire occurrence patterns within many Southwestern ecosystems. Vegetation structure and dynamics have consequently been altered due to ecological interactions between fire and vegetation. In this context, historical, or pre-settlement, data becomes an invaluable source of information regarding ecosystem structure and function with no, or minimal, impact from humans (Kauffman et al. 1994, Swetnam et al. 1999).

In this study, our goal is to facilitate the development of a fire management program for the Chiricahua Mountains by reconstructing the historical fire regime. Disturbance regimes are defined by multiple descriptors that may be organized along three semi-independent dimensions of space, time and magnitude (Glenn-Lewin and van der Maarel 1992). For example, the spatial component of fire may be described by size and location of burn; the temporal component of fire may include estimates of frequency and timing; and finally, the magnitude of the event may be measured either in terms of heat released or ecological impact.

Knowledge of the historical fire regime in the Chiricahua Mountains will provide managers with site-specific information regarding the controls and effects of fire over space and time. Our specific objectives are to characterize and elucidate 1) the relation between fire, in particular fire frequency, and elevation; and 2) fire occurrence and effects in the upper elevation mixed-conifer forests.

BACKGROUND

Fire and Elevation

The relation between fire frequency and elevation are based on systematic changes in vegetation (i.e. fuels) that occur as elevation increases or decreases. Martin (1982) proposed a bell-shaped curve to describe the range of variation that may occur across elevation gradients. Low fire frequencies may occur either at relatively low or high elevations. At lower elevations, the limiting factor is low fuel production while at higher elevations, it is high fuel-moisture levels. Low fire frequencies at higher elevations may also be related to lower rates of fine fuel production and fundamental differences in fuel type and arrangement (Swetnam and Baisan 1996). High fire frequencies occur where fuel production and fuel moisture levels are optimal for fire ignition and spread.

Modern lightning fire occurrence data from two of the larger mountain ranges in southeastern Arizona exemplify the bell-shaped curve. In the Rincon Mountains (Baisan and Swetnam 1990) and Chiricahua Mountains (Barton 1994), fire frequency is low up to approximately 2200m, then increases sharply, showing a spike roughly between ~2200 and ~2400m. It decreases moderately between ~2400 and 2700m, and decreases again but more drastically at elevations greater than ~2700m. In these two mountain ranges, low fire frequencies occur at low elevations where desert grasslands are typically found and at high elevations where mixed-conifer transition and spruce-fir forests typically occur. Peak fire frequencies correspond to elevation ranges where pine-oak forest tends to occur.

Fire history gradient studies in the Southwest indicate that more complex relations exist between fire frequency, topography and vegetation. Wilkinson (1997) found that the relation between fire frequency and vegetation was stronger than between fire frequency and elevation, highlighting the fact that the primary relation is between fuels and fire and that elevation alone can be a variable indicator of vegetation type. Topography and aspect tend to offset the location of vegetation along the elevation gradient (Shreve 1915, Whittaker and Niering 1965). For example, drainages tend to displace vegetation toward lower elevations and drier aspects tend to displace vegetation toward higher elevations. Landscape connectivity can also alter the relation between elevation and fire frequency. More isolated sites may receive less fire than expected based on relative elevation and/or vegetation type (Huckaby and Brown 1995). And finally, historical and modern fire frequency-elevation relations may differ because historically, fire frequency at any location was probably affected by both fire spread and ignition location while presently, fire frequency is mostly affected by ignition location due to fire suppression (Caprio and Swetnam 1995). Moreover, historical fire frequencies may have been altered in some areas and during some periods by Native Americans. Several studies conducted in the Chiricahuas have evaluated the possible use of fire by Apaches in the Chiricahuas and its effect on fire frequency (Swetnam et al. 1989, Seklecki et al. 1996, Kaib 1998).

The Role of Fire in Mixed-Conifer Forest

Fire is a pivotal force in vegetation structure and dynamics within southwestern mixed-conifer forest. Fire effects can be highly variable, in part because of differential species responses but also because fire intensity varies over time and space. Jones (1974) proposed a set of models for succession following high-intensity events that are driven primarily by differences in elevation and species shade tolerance. Elevation serves to organize the particular combinations of mixed-conifer species that co-occur. Within these assemblages, vegetation dynamics is determined by relative shade tolerances. Species that are relatively shade intolerant, for example, ponderosa pine (*Pinus ponderosa*) and aspen (*Populus tremuloides*), dominate the early stages of succession, while species that are relatively shade tolerant, such as spruce (*Picea spp*.), firs (*Abies spp*.), and Douglas-fir (*Pseudotsuga menziesii*) characterize endpoints of succession. Jones (1974) recognized the variability in successional pathways and attributed this to the combined effects of habitat; the nature, severity and size of the disturbance; and subsequent events such as the kind, amount and timing of seedfall.

Sawyer and Kinraid (1980) customized this model for species combinations in the Chiricahua Mountains using vegetation plot data from the upper elevation forests. In addition, they pointed out two important facets of succession in this forest type. First, endpoints of succession may be determined by aspect and slope as well as elevation. And second, ponderosa pine (mostly Arizona pine - *Pinus arizonica*) and southwestern white pine comprise a significant component of the mixed-conifer landscape, and in some situations may be endpoints of succession.

METHODS

Study Area

The Chiricahua Mountains are located in the Basin and Range geologic province of southeastern Arizona. They are a southeast/northwest trending mountain range extending approximately 80 km. This study was conducted in the Chiricahua Wilderness where elevations span 1876-2988m (McLaughlin 1995). Steep, dissected canyons rise up to the main crest, which resembles a long, narrow plateau interrupted by a series of rolling hills (Sawyer and Kinraide 1980). Although the high country is less abrupt compared to the drainages that extend outward from both sides of the crest, topographic diversity remains high within this undulating terrain.

Vegetation in the Chiricahua Wilderness changes along environmental gradients, a pattern typical of mountain ranges throughout the Basin and Range province. The physical variables that influence species distributions have been found to vary systematically with both elevation and topography (Whittaker and Niering 1965, Shreve 1915). From low to high elevations, the following general sequence of vegetation occurs: desert grassland, open oak woodland, pine-oak woodland, pine-oak forest, pine forest, mixed-conifer, and spruce-fir. Actual elevation ranges for each of these vegetation types is shifted upward on drier aspects and slope exposures, and downward in drainages. In the Chiricahua Mountains, open oak woodland occurs roughly between 1550-1750m and is dominated by Emory oak (*Quercus emoryi*), Arizona white oak (*Q. arizonica*), junipers (*Juniperus monosperma* or *J. deppeana*) and piñon (*Pinus discolor*); pine-oak woodland occurs roughly between 1750-1850m is characterized by a mixture of Chihuahua pine (*P. leiophylla*), piñon (*Pinus discolor*), Arizona white oak and silverleaf oak (*Q. hypoleucoides*); pine-oak forest occurs roughly between 1850-2200m and includes Chihuahua pine, Apache pine (*P. engelmannii*), and silverleaf oak; pine forest occurs roughly between 2200-2400m and is dominated by Apache pine and Arizona pine (*P. arizonica*); and, mixed-conifer forest occurs above ~2400m and includes silverleaf oak, Gambel oak (*Q. gambelii*), southwestern white pine (*P. strobiformis*), and Douglas-fir (*Pseudotsuga menziesii*) (Barton 1994). At higher elevations, vegetation is predominantly controlled by aspect. Engelmann Spruce (*Picea engelmannii*), aspen and mixed-conifer stands are primarily associated with wetter, north-facing slopes and in drainages, while pine-dominated stands occur on drier, south-facing slopes (Robinson 1968, Sawyer and Kinraid 1980).

The climate in southeastern Arizona is semi-arid with a bi-modal distribution of precipitation. The summer rainy season occurs between July and September and the winter rainy season is between December and March (Horn and Bryson 1960, Mitchell 1976). Generally, winter precipitation tends to be more spatially homogeneous, comprised of storms having longer durations relative to summer precipitation which occur in short bursts over parts of the region (Bahre 1991). In the Chiricahua Mountains, mean annual precipitation at 1600m is 442 mm (Sellers and Hill 1974). Temperatures at the same elevation are warmest in late June and early July with average minimums of 17.4°C and average maximums of 32.8°C, and coolest during January with average minimums of -0.2°C and average maximums of 14.7°C. Temperature and precipitation change with elevation at a rate of -2.2°C and +100-125mm for every 305m increase (Lowe 1985). Thus, in the high country, at 2900m, average annual precipitation is 872-980mm, average summer highs and lows are 23.3°C and 16.9°C, and average winter highs and lows are 5.2°C and -9.7°C.

The height of fire season in southeastern Arizona occurs in late spring and early summer. Throughout the spring, increasing temperatures and negligible precipitation create extremely dry conditions throughout the Southwest. Prior to the onset of the summer rainy season, around June, circulation patterns that draw moisture from the southeast are beginning to form (Schroeder and Buck 1970). Weak storm cells bring lightning but little rain. During this period, relatively few lightning ignitions occur but large areas may burn (Barrows 1978). As circulation patterns strengthen during July, more moisture is transported by storm cells, producing rain that reaches the ground, reducing fire danger. July fire statistics show a high frequency of lightning-ignited fires but less area burned compared to June (Barrows 1978).

Field

Fire History

Fire history sampling was conducted in two distinct areas to satisfy the primary objectives of this study: 1) evaluate the role of elevation on fire frequency patterns; and 2) evaluate the role of fire in mixed-conifer forest. Site selection will be described in the following sections. At each site in each of the study areas, an area of approximately one hectare was systematically searched for fire-scarred trees. Candidate trees were preferentially sampled to maximize the number of fires recorded. To this end, trees with relatively large numbers of well-preserved scars were sampled (Swetnam and Baisan 1996), using a chain saw (Arno and Sneck 1977). Each sample was labeled, sketched, and the location approximated on a topographic map.

Elevation Transect

An elevation transect was established in Mormon Canyon between ~ 2000 - 2700m. Vegetation ranged from oak woodlands at lower elevations to mixed-conifer transition forest at higher elevations (Table 1). Paired sites were located at 100-150m intervals, yielding a total of 5 pairs of sites. Paired sites were situated in a configuration that enabled us to evaluate both the influence of elevation and topographic position on fire frequency and spread patterns. In most cases, paired sites were comprised of one site situated on the upper slope, near the ridge separating Mormon and Ward Canyons, and the other site situated at the same approximate elevation on the lower slope near to the drainage of Mormon Canyon (Figure 1). One exception to this configuration was the highest elevation site pairing (UWC and WCP; see Figure 1). These two sites are separated by terrain with the highest degree of topographic complexity, as well as the largest distance, compared to other elevational pairings. The positioning of these two sites was exploratory in nature and was employed to examine the effect of more complex topography on fire spread patterns.

Mixed-Conifer Forest

Fire history sites in the mixed-conifer forest were distributed throughout the higher elevations of

Table 1. Fire history site information for elevation transect.

Site Code	Site Name	Elev. (m)	Aspect	Number of Samples	Species Composition of Samples[2]			DOMINANT overstory and Occasional tree species	Vegetation
					PIST	PIPO	PIEN		
WCP[1]	West of Cima Park	~2700	S	4	1	3	0	PSME, PIST, PIPO, pien	Mixed-conifer transition
UWC[1]	Upper Ward Canyon	~2680	N	4	2	2	0	PSME, PIST, acgl, abco, potr, rone	Mixed-conifer transition
UMC-1	Upper Mormon Canyon: Group 1	~2590	NW	6	0	6	0	PIPO, psme, pist	Pine forest
ORO	Opposite Rocky Outcrop	~2560	S	5	3	2	0	PIPO, PIST, psme, abco.	Pine forest
UMC-2	Upper Mormon Canyon: Group 2	~2440	NW	4	1	3	0	PIPO, psme. pist.	Pine forest
SDC	Sandy Corner	~2440	S	5	2	3	0	PIPO, pist, psme, arar, quhy, quru.	Pine forest
MMC	Middle Mormon Canyon	~2290	N	6	0	2	4	PIPO, QU spp., pien.	Open Pine/oak woodlands
SAB[1]	Steep and Burnt	~2260	N	3	0	3	0	PIPO, QU spp., psme	Open Pine/oak woodlands
MCS	Mormon Canyon Spring	~2070	S	7	0	1	4[3]	QU spp., JUDE, arar, pien	Oak woodland
LMC	Lower Mormon Canyon	~2040	N	5	0	0	4[4]	QU spp., JUDE, frve	Oak woodland

1. Sites located in Ward Canyon.
2. Species codes: PIST = *Pinus strobiformis*; PIPO = *P. ponderosa*; PIEN = *Picea engelmanii*; PSME = *Pseudotsuga Menzesii*; POTR = *Populus tremuloides*; ARAR = *Arbutus arizonica*; QUHY = *Quercus hypoleucoides*; QUAR = *Q. arizonica*; RONE = *Robina neomexicana*.
3. Two other samples were JUDE (= *Juniperus deppeana*), and QUAR.
4. Other sample was FRVE (=*Fraxinus velvutina*).

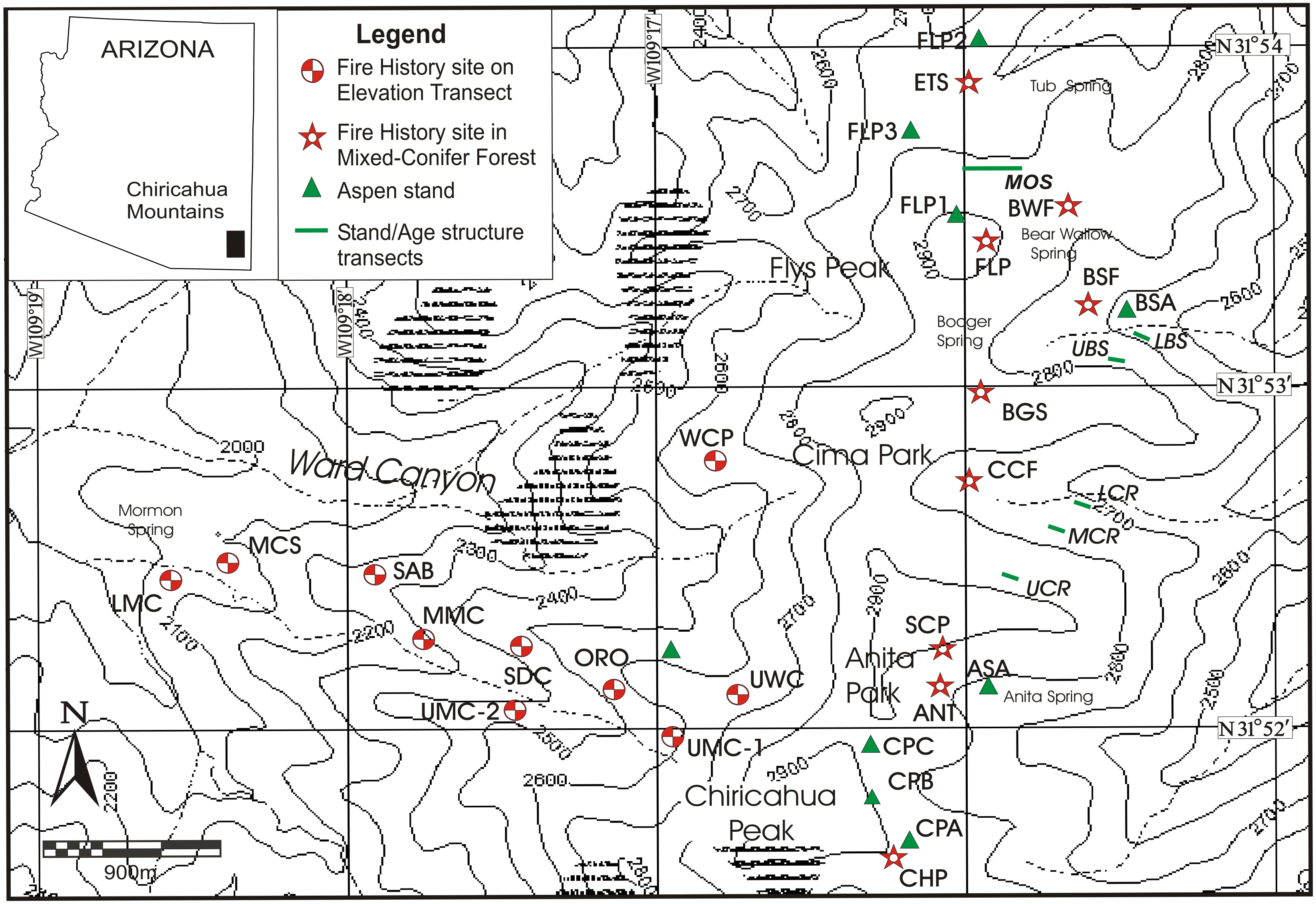

Figure 1. Map of study area. Fire frequency-elevation relations were evaluated primarily in Mormon Canyon. The role of fire in mixed-conifer forest were examined in the high country between Flys and Chiricahua Peaks. Hatched areas represent bare rock.

the Chiricahua Wilderness, between Flys and Chiricahua Peaks. Fire history sites were selected to yield an even spatial representation and to be situated near age structure plots. Sites were located at elevations greater than 2750m and predominantly on drier south and west aspects (Table 2).

Table 2. Fire history sample information for mixed-conifer sites.

Site Code	**Site**	**Elev. (m)**	**Aspect**	**Number of Samples**	**Species Composition of Samples**[1]				
					PIST	**PIAR**	**PSME**	**ABCO**	**PIEN**
ETS	East of Tub Spring	~2860	NE	2	0	1	0	1	0
BWF	Bear Wallow Flat	~2835	NE	3	1	1	0	0	1
FLP	Flys Peak	~2930	E	3	1	2	0	0	0
BGS	Booger Spring	~2880	W	10	3	7	0	0	0
BSF	Booger Spring Flat	~2780	S	5	3	0	0	0	0
CCF	Cima Cabin	~2755	S	2	0	2	0	0	0
SCP	South of Cima Park	~2926	S	8	4	4	0	0	0
ANT	Anita Park	~2895	W	2	1	1	0	0	0
CHP	Chiricahua Peak	~2895	S	3	1	1	1	0	0

1. Species codes: PIST = *Pinus strobiformis*; PIAR = *P. arizonica*; PIEN = *Picea engelmanii*; PSME = *Pseudotsuga Menziesii*; POTR = *Populus tremuloides*; ARAR = *Arbutus arizonica*; QUHY = *Quercus hypoleucoides*; QUAR = *Q. arizonica*; RONE = *Robina neomexicana*.

Stand and Age Structure

The role of fire in high-elevation forest dynamics was evaluated by collecting age and stand structure data in monospecific aspen and mixed-conifer stands. Aspen stands were sampled based on a field assessment of size. A subset of average-diameter trees were sampled throughout larger stands, using an increment borer.

Six transects were sampled to reconstruct and evaluate the role of fire in mixed-conifer stand initiation and development. Stands on north-facing slopes were targeted because of the distribution of this forest type. Two sets of transects in adjacent drainages were arranged to evaluate the effect of slope on vegetation response to fire (Figure 1). Transects were oriented parallel to the slope contours. The south set was comprised of three transects placed on the lower, middle and upper slope (LCR, MCR, and UCR). The north set was comprised of two transects placed on the lower and upper slope (LBS and UBS). An additional very long single transect was placed the north-facing slope of Flys Peak to evaluate spatial heterogeneity of fire effects at a constant slope position. All transects except one were fixed area (Table 3a). The MOS transect was a variable-width transect having a fixed length of 400m (Table 3b).

For all transects, all live trees greater than 2.5cm dbh were cored as close to the ground as possible. For each live and dead tree, we recorded the following information: linear position along the transect (x-coordinate only); species; diameter at breast height (dbh); coring height;

and crown class. Four categories of crown class were identified relative to average canopy height. *Dominant* trees had crowns of above average canopy height; *co-dominant* trees had crowns at average canopy height; *sub-dominant* trees had crowns below average canopy height. *Understory* trees had crowns that were below the canopy. In the MOS transect, additional data were recorded for seedlings and saplings within a band extending 1m from each side of the center line. We recorded the following information for each plant: linear position along the transect (x-coordinate only); species; and height.

Table 3a. Dimensions (in meters) and areas (in hectares) of mixed-conifer stand structure plots. **b**. Dimensions of variable-width sampling areas based on tree diameter for the Flys Peak (MOS) transect. Transect length was 400m. "Diameter" is reported in cm.

a)

Transect Name	Code	Length	Width	Area
Lower Booger Springs	LBS	100	20	0.20
Upper Booger Springs	UBS	100	20	0.20
Lower Cima Ridge	LCR	140	12	0.17
Middle Cima Ridge	MCR	110	12	0.13
Upper Cima Ridge	UCR	100	6	0.06

b)

Flys Peak (MOS)		
diameter	Width	Area
<2.5	1	0.08
>2.5-20.0	4	0.16
>20.0-40.0	6	0.24
>40.0	8	0.32

Laboratory

Fire History

Fire-scarred samples were trimmed and surfaced to optimize the visibility of ring structure. If necessary, samples were re-cut using a bandsaw. The reason for re-cutting was to prepare a flat, transverse surface that would facilitate sanding. The samples were sanded using successively finer grits, up to 320, and when necessary, up to 400. Cross-sections were examined under a variable power 10-30x microscope. Each cross-section was dated, using dendrochronological techniques (Fritts 1976). Then, each scar on each cross-section was assigned a calendrical date.

Stand and Age Structure

After drying, cores were glued onto wooden mounts to expose their transverse surface (wood cells oriented vertically). Cores were surfaced with a belt sander using sandpaper of progressively finer grits, starting with 280 and finishing with 320. In certain cases, a 400 grit sandpaper was employed by hand to yield a high-resolution surface. Cores were examined under a variable power 10-30x microscope and a year of the inner-most ring was determined by crossdating.

Piths were estimated by visually assessing the curvature of the inner-most 10-15 rings and extrapolating towards center (Applequist 1958). Sets of nested, regularly-spaced circles printed on transparencies were used as guides. Estimated pith dates were compiled and analyzed to assess establishment and stand development patterns.

Analysis

Fire History

Fire frequency and relative fire size were evaluated using fire scar data. Analyses of these data was conducted based on the following two premises. First, fire scar formation can be highly variable with adjacent, closely-spaced trees recording unique events relative to neighboring trees (Dieterich and Swetnam 1984). The composite record of fire events from multiple, closely-spaced trees will thus yield more accurate "point" estimations of fire frequency (Dieterich and Swetnam 1984, Baisan and Swetnam 1990). Second, once a tree has been scarred by fire, it becomes a more sensitive recorder of fire due to the absence of bark and the concentration of highly flammable resins in the affected region (Swetnam and Baisan 1996). FHX2 software (Grissino-Mayer 1995) was employed to analyze and generate graphics of fire history data.

Period of Analysis

Fire-interval analysis within sites, for both study areas, was conducted for a period beginning when at least two trees had recorded at least one fire. Fire frequencies were not computed for the mixed-conifer sites BWF and CCF, because each site consisted of only a single tree. Fire years recorded in these sites were, however, figured into the computation of fire frequencies for multi-site fires. Fire frequency for multi-site fires was characterized based on the number of sites recording an event during a period beginning when at least half of the sites had recorded fire. The period of analysis for spreading fires began in 1659 for the elevation transect sites, and in 1688 for the mixed-conifer sites. For both single and multiple site analysis of fire frequency, the period of analysis ended in 1908 when National Forest were established in the Chiricahua Mountains and a forest management policy of fire exclusion and suppression was enacted (Bahre 1991).

Fire and Climate

The relation between fire and climate was examined using superposed-epoch analysis (SEA) (Baisan and Swetnam 1990; Swetnam 1993). In this procedure, fire events were superposed onto a time series of reconstructed climate and statistically compared to randomly selected years, using Monte Carlo techniques (Mooney and Duval 1993). Events included all fires recorded in at least four sites for each data set. The time series used in this analysis was tree-ring reconstructed summer (June-July-August) Palmer Drought Severity Index (PDSI) (Grid Cell #43; Cook et al. 1999). Summer PDSI was deemed appropriate for this analysis because it accounts for water budget balances during the time of year when fire is most likely (Baisan and Swetnam 1990). Data were downloaded from "http://www.ngdcnoaa.gov/paleo/usclient2.html" and SEA was conducted using the computer program, EVENT (Holmes and Swetnam 1994).

Stand and Age Structure

Tree establishment dates estimated from increment cores are subject to three sources of inaccuracy. First, ring counts may underestimate or overestimate tree age due to missing or false rings (Fritts 1976, Fritts and Swetnam 1989). We addressed this problem by using crossdating techniques to determine the exact year of formation for the innermost ring on the increment core. Second, core samples do not always include the pith. We addressed this problem by using nested circles to estimate the number of rings to pith (see Lab Methods). We also lumped estimated pith dates into 10-year age classes. And third, cores are often sampled at some height above ground level, thus the time required for the seedling to reach coring height must be accounted for in estimating regeneration dates. No adjustments in the data were made to account for seedling growth to coring height and it is likely that seedling growth rates are variable depending on species and microsite differences (Villalba and Veblen 1997). This lag, however, was taken into account when interpreting establishment dates with respect to fire events.

To characterize forest structure, species composition was characterized by canopy class. Dominant and co-dominant trees were combined into one category, *Upper Overstory*; sub-dominant trees comprised the *Lower Canopy*; understory trees remained classified as *Understory*.

RESULTS

Fire History

Elevation Transect

Elevation-related patterns of fire occurrence were assessed based on fire scars from 46 trees distributed among 10 sites. A total of 363 scars were crossdated, yielding 84 fire years. The earliest replicated fire-scar date was 1626 and the latest was 1994 (Figure 2). Fire interval statistics were computed for all sites (Table 4). Slope position did not appear to consistently influence fire frequency. The sites MMC, UMC_2, and UMC_1 are all lower-slope sites in their respective pairings but the MFIs of these sites were both higher or lower than upper slope counterparts at the same approximate elevation (Figure 3).

The difference in MFIs within and between site pairings suggested that fire frequency within the four highest sites pairs are not distinct and should perhaps be grouped. Large differences in MFI were observed within site pairs, ORO/UMC_1 and WCP/UWC (Figure 3). In fact, the range of fire intervals for the highest elevation site pair (WCP and UWC) almost approximates the range of fire intervals across the gradient from ~2200 to ~2700m (Figure 3). Only MMC stands out as a site having a distinctly lower mean and range of fire intervals.

Table 4. Fire frequency analysis of elevation-related patterns: descriptive statistics and period of analysis (PA). Sites are ordered from high to low. All statistics are measured in "years."

Site	PA Begin	PA Length	Number of Intervals	MFI[1]	MedFI[2]	Std. Dev.[3]	Min. Int.[4]	Max. Int.[5]
WCP	1762	140	10	12.3	13.0	7.6	1	23
UWC	1826	76	10	9.1	7.5	6.5	1	23
UMC_1	1707	195	23	9.1	8.0	5.1	2	23
ORO	1785	117	11	12.2	12.0	6.0	2	23
UMC_2	1711	191	22	9.4	8.5	5.8	1	23
SDC	1768	134	18	7.8	8.0	4.7	1	16
MMC	1744	158	28	6.4	6.0	3.6	1	16
SAB	1817	85	11	9.1	8.0	6.7	1	23
MCS	1748	154	11	15.4	12.0	13.4	1	49
LMC	1817	85	7	14.7	10.0	11.8	3	31

1. Mean fire interval.
2. Median fire interval.
3. Standard deviation.
4. Minimum fire interval.
5. Maximum fire interval.

Analysis of fires recorded by multiple sites indicated that fire spread readily within the elevation transect. The MFI for single-site events is low, 3.4 years, but among fires recorded by 2 to 6 sites, MFI's are relatively stable, between 8 and 13 years. These data suggest a bimodal

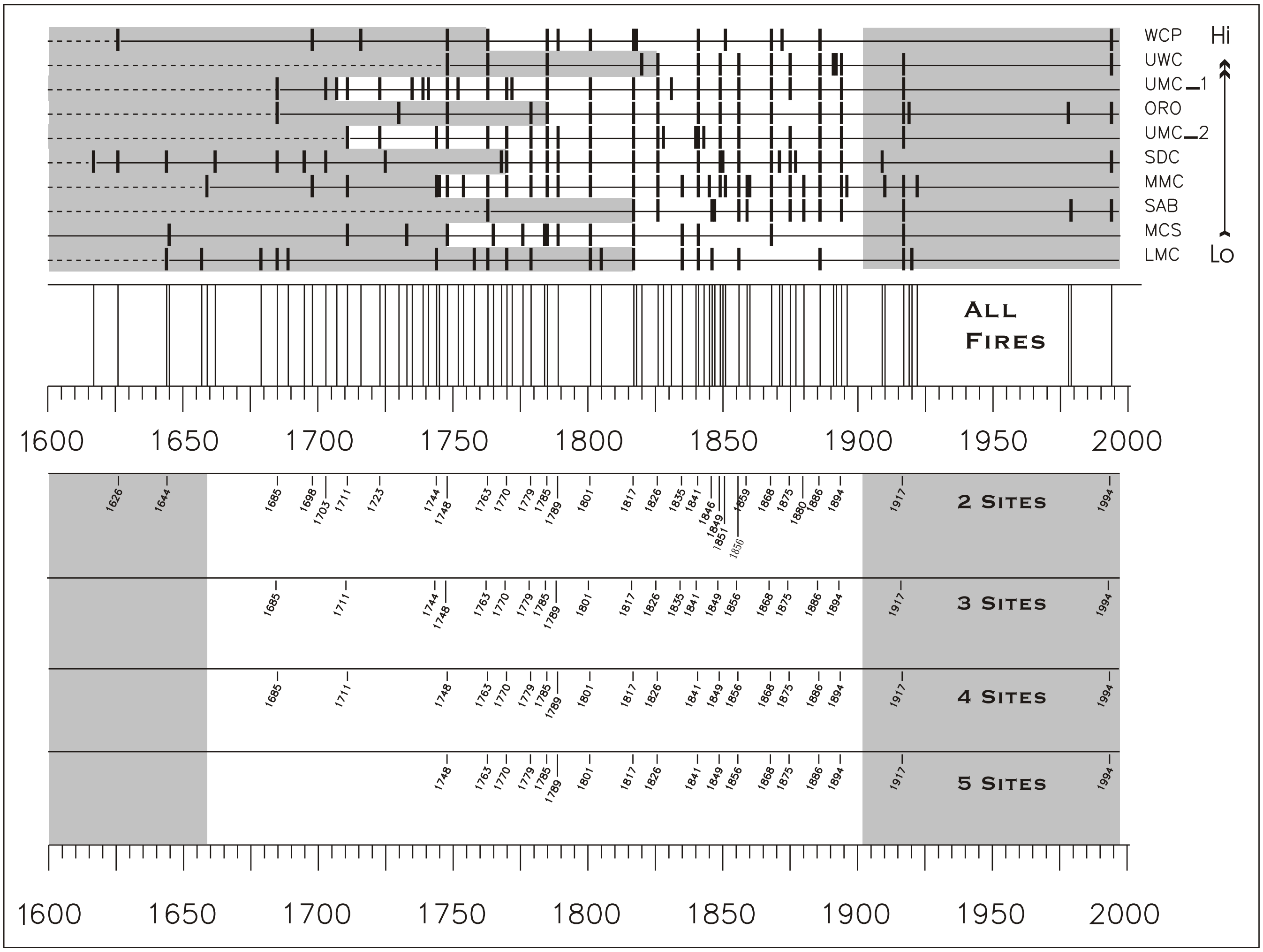

Figure 2. Elevation transect fire history chart. In the upper portion of the graph, horizontal lines represent individual sites and vertical bars represent fire years. The “bar code” feature illustrates the temporal pattern of all fires recorded in the elevation transect. Horizontal lines in the bottom portion of the graph are composite fire histories for fires recorded by successively larger numbers of sites. Unshaded portions highlight the Period of Analysis for single and multi-site fires (see Methods).

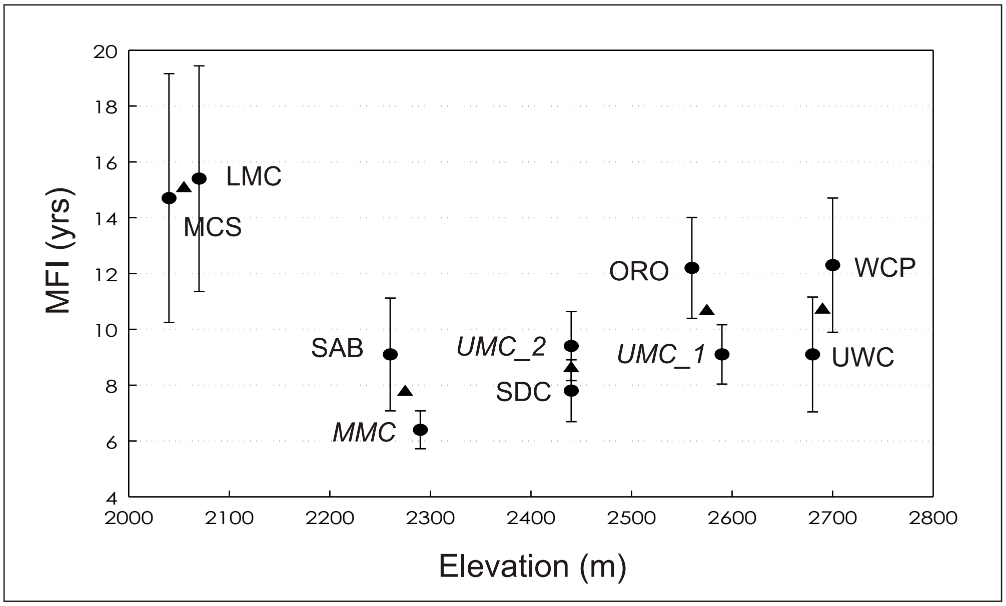

Figure 3. MFI plotted against elevation. Bars indicate one standard error. Triangles are positioned at mean elevation and MFI for each site pair. Italics denote lower-slope sites.

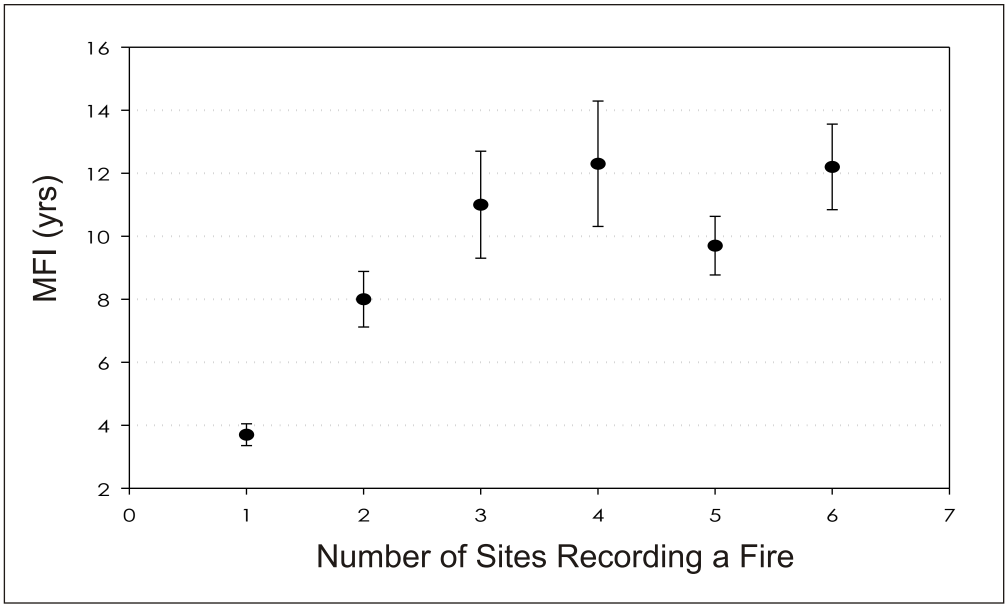

Figure 4. MFI stratified by number of sites recording a fire along the elevation transect. Bars indicate one standard error.

distribution of fire sizes, pivoting on the size approximated by two sites. That is, once fires exceed the two-site threshold, the probability of spread increases markedly (Table 5 & Figure 4). The minimum distance for fire to travel to exceed the "widespread-fire" threshold is approximately 500m, the average approximate distance between adjacent sites (Figure 1). Therefore, in a very simple scenario, the minimum size before exceeding the "widespread-fire" threshold is approximately 25 ha (Figure 5).

Landscape connectivity in the study area is further emphasized by the synchroneity of fire dates among sites located across potential fire barriers. For example, UMC_2 is located on the opposite side of the drainage of the other Mormon Canyon sites (Figure 1), yet the fire record shows good correspondence to fire on the opposite slopes (Figure 2). Similarly, the fire record in SAB and UWC, located over the ridge in the adjacent Ward Canyon, is essentially the same as Mormon Canyon. And finally, fire dates in WCP, the most spatially isolated fire history site, are essentially a subgroup of fires recorded in Mormon Canyon (Figure 2).

Table 5. Fire frequency analysis of fires recorded across elevations: descriptive statistics. Period of analysis is 1659 -1902.

Number of Sites	Number of Intervals	MFI	MedFI	Std. Dev.	Min. Int.	Max. Int.
1	65	3.7	3.0	2.8	1	17
2	26	8.0	7.0	4.5	2	21
3	19	11.0	9.0	7.4	4	33
4	17	12.3	9.0	8.2	4	37
5	15	9.7	9.0	3.6	4	16
6	12	12.2	11.5	4.7	7	22

Mixed-Conifer Forest

The mixed-conifer fire history was constructed using 30 fire-scarred trees from nine sites. Two hundred and forty-two scars were crossdated, yielding 64 fire years. The earliest replicated fire-scar date was 1685 and the latest was 1994 (Figure 6). Fire frequency was not analyzed in one case, ETS, due to no intervals and in two cases, BWF and CCF, due to inadequate sample size. For the rest of the sites, MFIs ranged from 8.2 to 16.1 years with minimum fire intervals ranging from 1 to 8 years and maximum fire intervals ranging from 18 to 32 years (Table 6 and Figure 7).

Fire frequencies of multi-site fires were analyzed between 1688 and 1902. During this period, a fire occurred at some point within the study area approximately every four years (Table 7). Fire size and frequency varied inversely with larger fires occurring at lower frequencies (Table 7). There was also a trend of increasing variability with increasing MFI (Figure 8).

Table 6. Fire frequency analysis of mixed-conifer fire history sites: descriptive statistics and period of analysis

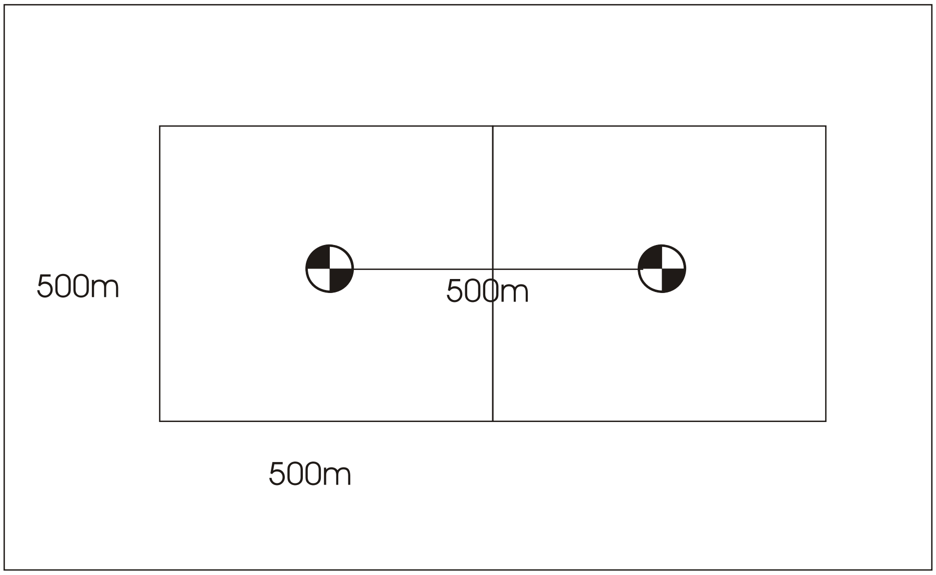

Figure 5. A simple model to illustrate the "widespread-fire" threshold size. Sites are assumed to be the center point of a square-shaped, homogeneous (same fire history throughout) area. The average approximate distance between adjacent sites in Mormon Canyon is 500m. Therefore, each site represents an area of 500x500m, or 25ha. Results suggest that when fire attains a size such that two sites record the event, there is a higher probability of the fire spreading throughout the canyon. A fire that ignites within one site area will, by definition, spread throughout it, growing to a size of 25ha. If the fire burns into the adjacent site area, it will again, by definition, spread throughout. Therefore, this fire, to be recorded in two sites, needs only to exceed a size of 25ha. This model is unrealistic on many counts, for example, fire history sites are not linearly arranged and topographic features that affect fire behavior are not incorporated; nevertheless, it provides a basis for conceptualizing fire size

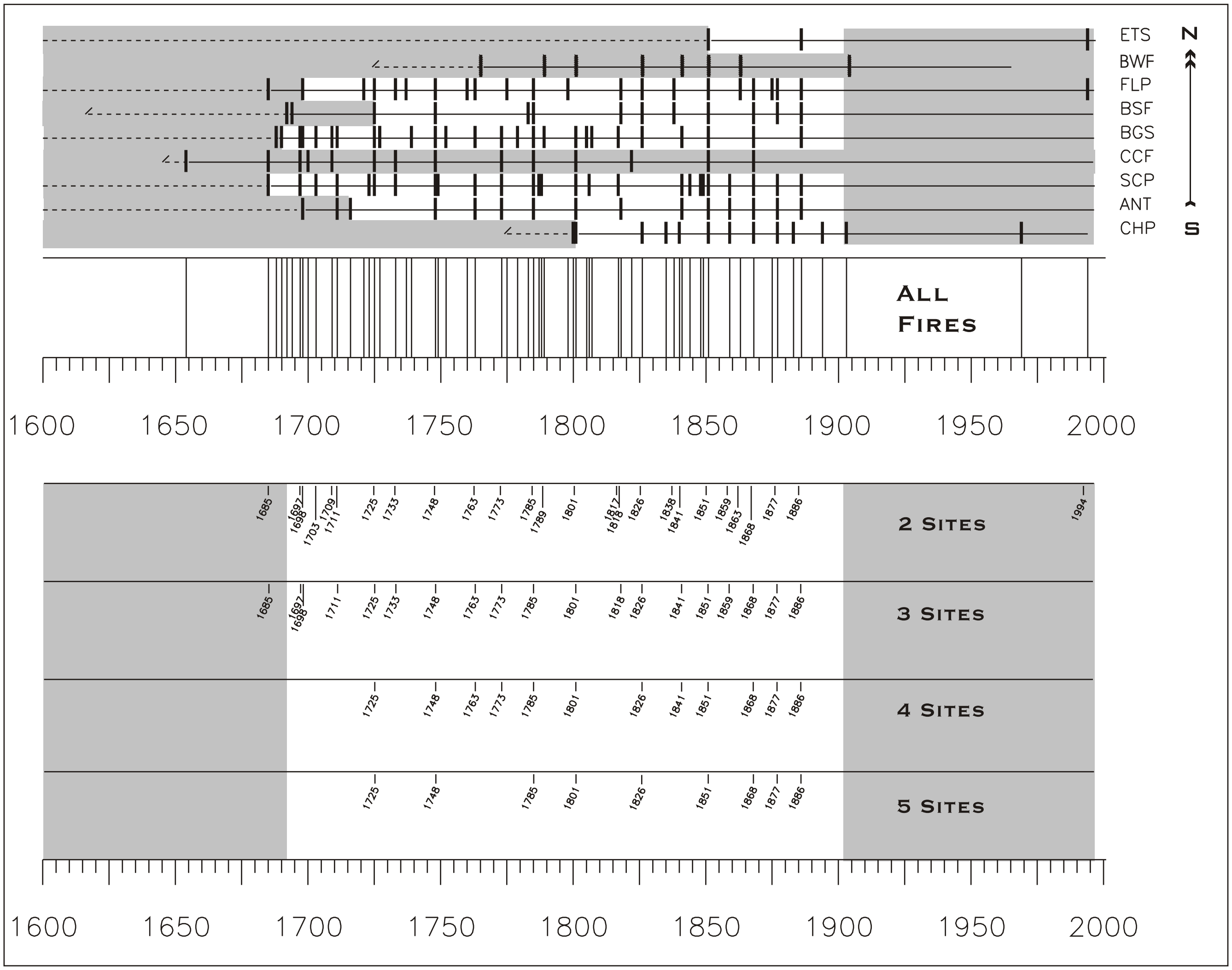

Figure 6. Fire history chart for mixed-conifer forest sites. In the upper portion of the graph, horizontal lines represent site composites and vertical bars represent fire years. The "bar code" feature in the center illustrates the temporal pattern of all fires recorded throughout the study area. The bottom portion of the graph are composite records of fires recorded by successively larger numbers of sites. Unshaded portions highlight the Period of Analysis for single and multi-site fires (see Methods).

(PA). Sites are ordered from north to south. All statistics are measured in "years."

Site	PA Begin	PA Length	Number of Intervals	MFI[1]	MedFI[2]	Std. Dev.[3]	Min. Int.[4]	Max. Int.[5]
ETS	1886	16	0	n/a	n/a	n/a	n/a	n/a
BWF	n/a[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FLP	1698	204	19	9.9	10.0	5.4	2	23
BSF	1725	177	10	16.1	12.5	11.0	2	35
BGS	1690	212	24	8.2	8.0	4.9	1	18
CCF	n/a[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SCP	1685	217	25	8.4	8.0	5.6	1	24
ANT	1716	186	12	14.2	11.0	7.2	8	32
CHP	1801	101	9	10.3	9.0	5.9	5	25

1. Fire frequency analysis was not computed because fire history was based on only one tree.

Table 7. Fire frequency and spread in the mixed-conifer forest for 1688 to 1902.

Number of Sites	Number of Intervals	MFI	MedFI	Std. Dev.	Min. Int.	Max. Int.
1	57	3.6	3.0	2.5	1	10
2	23	8.2	8.0	4.6	1	16
3	17	11.1	10.0	4.1	1	17
4	11	14.6	15.0	5.5	9	25
5	8	20.1	20.0	9.4	9	37
6	5	27.6	18.0	15.2	16	50

Fire Spread into High Elevations

Within the common Period of Analysis for multi-site fires, 1688 - 1908, sixty-three percent of fires in the mixed-conifer forest were also recorded on the elevation transect, suggesting that lower elevation fires were an important source of fire to the higher elevations (or vice versa). For larger fires in the higher elevations, the proportion of fire dates in common with the elevation transect increases. Notable exceptions include: 1725, 1773, and 1877 which were widespread fires in the mixed-conifer but not on the elevation transect. These events may have started locally or have spread from areas other than Mormon Canyon.

Fire and Climate

Fire-climate associations exhibited similar patterns for the elevation transect and mixed-conifer fire history data. In both cases, the year preceding the fire tended to be significantly wet (Figure 17). Although not statistically significant, widespread fires in the mixed-conifer forest tended to occur in drier years (Figure 9).

Stand and Age Structure

Aspen

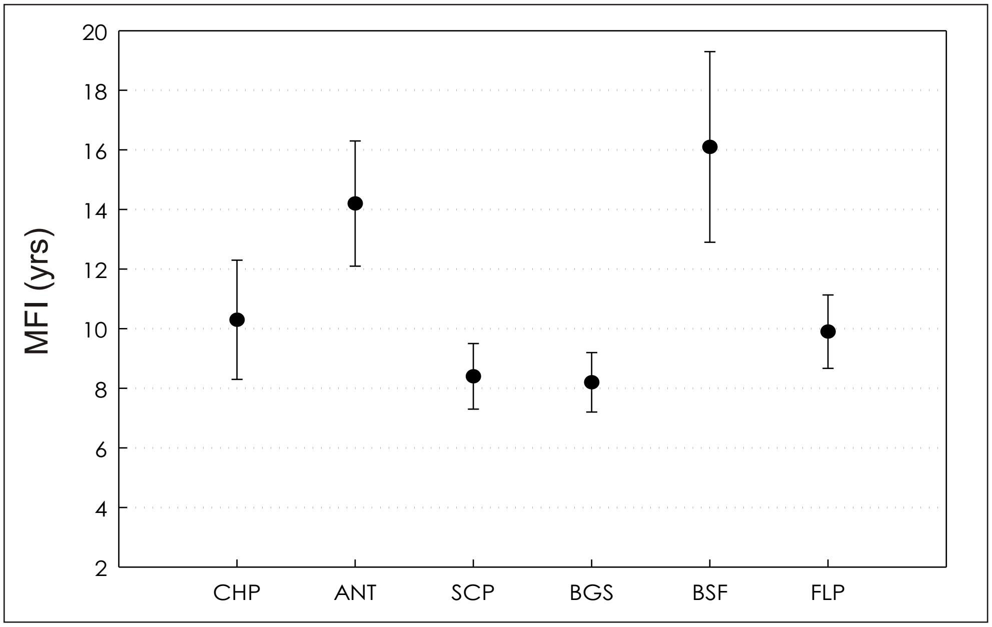

Figure 7. MFI for mixed-conifer fire history sites. Bars indicate one standard error.

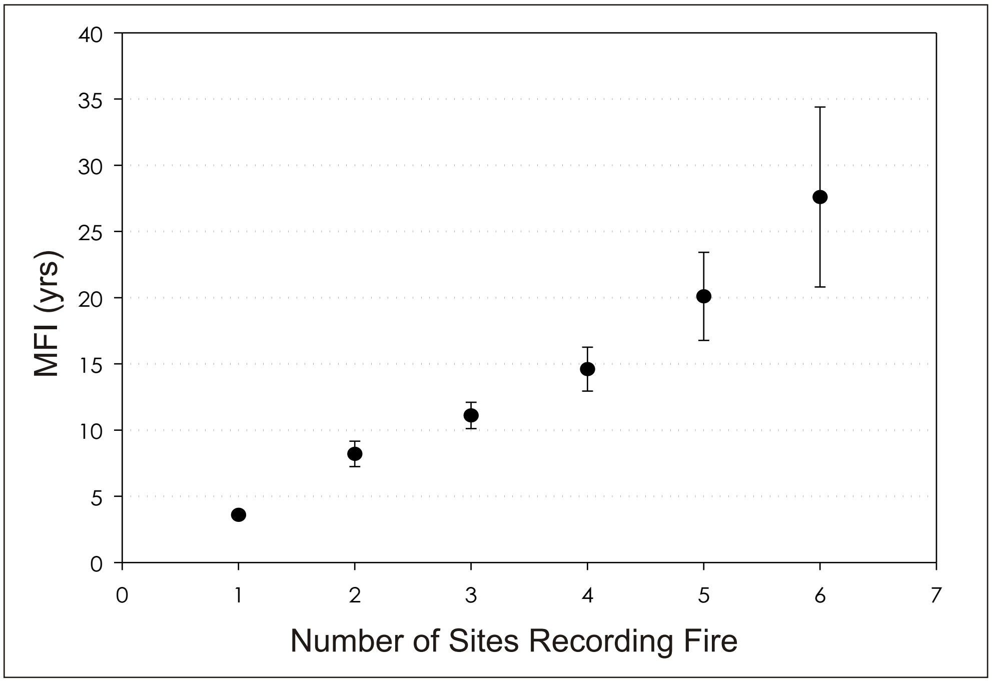

Figure 8. MFI stratified by number of sites recording a fire in mixed-conifer forest. Bars indicated one standard error.

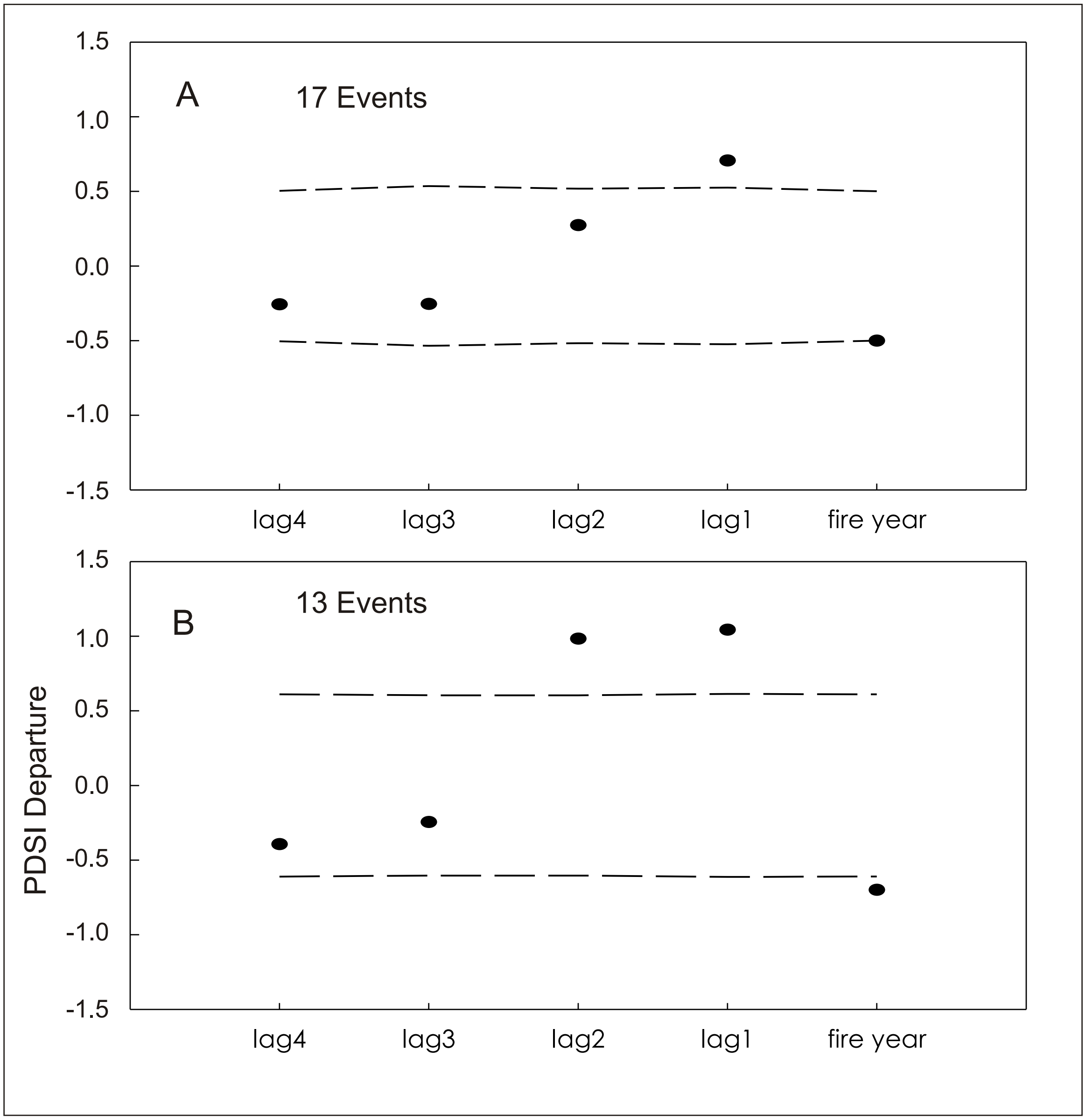

Figure 9. Associations between inter-annual PDSI values and widespread fires (occurring in at least four sites) for A. Elevation transect and B. Mixed-conifer forest. Positive departures are wetter-than-average conditions and negative departures are drier-than-averge conditions. Dashed lines represent 95% confidence intervals.

Nine aspen stands were sampled in the higher elevations of the Chiricahua Wilderness. A total of 136 aspen trees were sampled and dated. As expected, most pith dates were distributed in a pattern reflecting a strong pulse of establishment, with the highest number of trees generally concentrated within age classes coinciding with, or directly following, known fire years. Two fires emerged as probable events accounting for stand initiation: a fire in 1851 and a fire in 1886 (Figure 10). In some cases, however, estimated pith dates preceded the fire event. These may be attributed to the pith estimation procedure (for example, CPA, CPB, and FLP3) or perhaps the occurrence of two severe fires within the stand. FLP2 exemplifies the latter scenario. The majority of trees in this plot appeared to have established as a result of the 1886 fire; however, a small group of trees (5) were estimated to have established prior to this event, possibly as a result of the 1851 fire (Figure 10).

Mixed-conifer Forest

Stand Initiation

Six transects were sampled within the Chiricahua Wilderness, yielding data from 1118 trees. Age structure data suggest that the older transects (LBS, UBS, LCR, and MCR) originated in the early 1700s and the younger transects (UCR and most of MOS) originated in the late 1800s (Table 8). In some cases, a small number of trees pre-dated stand initiation dates (Figures 11&12). In other cases, complete mortality appears to have preceded stand initiation, suggesting the occurrence of a particularly high-intensity local fire (Figures 13,14&15).

While it is evident that these fires determined stand origin dates for these transects, caution must be exercised in inferring the intensity of these events. Occasionally, stand initiation may have been the result of the cumulative effect of sequential events. For example, in UBS, a high-intensity, stand-replacing fire may have occurred in 1685. A subsequent fire in 1725, while severe, need not have been as intense as the 1685 event because trees would have been highly susceptible to fire-induced mortality, having colonized the site within the last 40 years.

Table 8. Year of severe fire events for sampled stands.

Fire Years	Mixed-Conifer	Aspen
1685	MCR, (LBS)	---
1725	LCR, MOS, LBS	---
1851	---	BSA, FLP2, FLP3
1886	UCR, MOS	CPA, CPB, CPC, ASA, WCU, FLP1, FLP2

Although the number of sites recording fire probably reflects relative fire extent, it may not be a consistent estimator of fire intensity/severity in mixed-intensity fire regimes. For example, a fire in 1748 was recorded in six mixed-conifer fire history sites, which constituted 100% of the sites sampled for that point in time (Figure 6). Despite the widespread nature of this event, age structure data do not indicate any local areas of stand-initiating fire severity. In contrast, a fire in

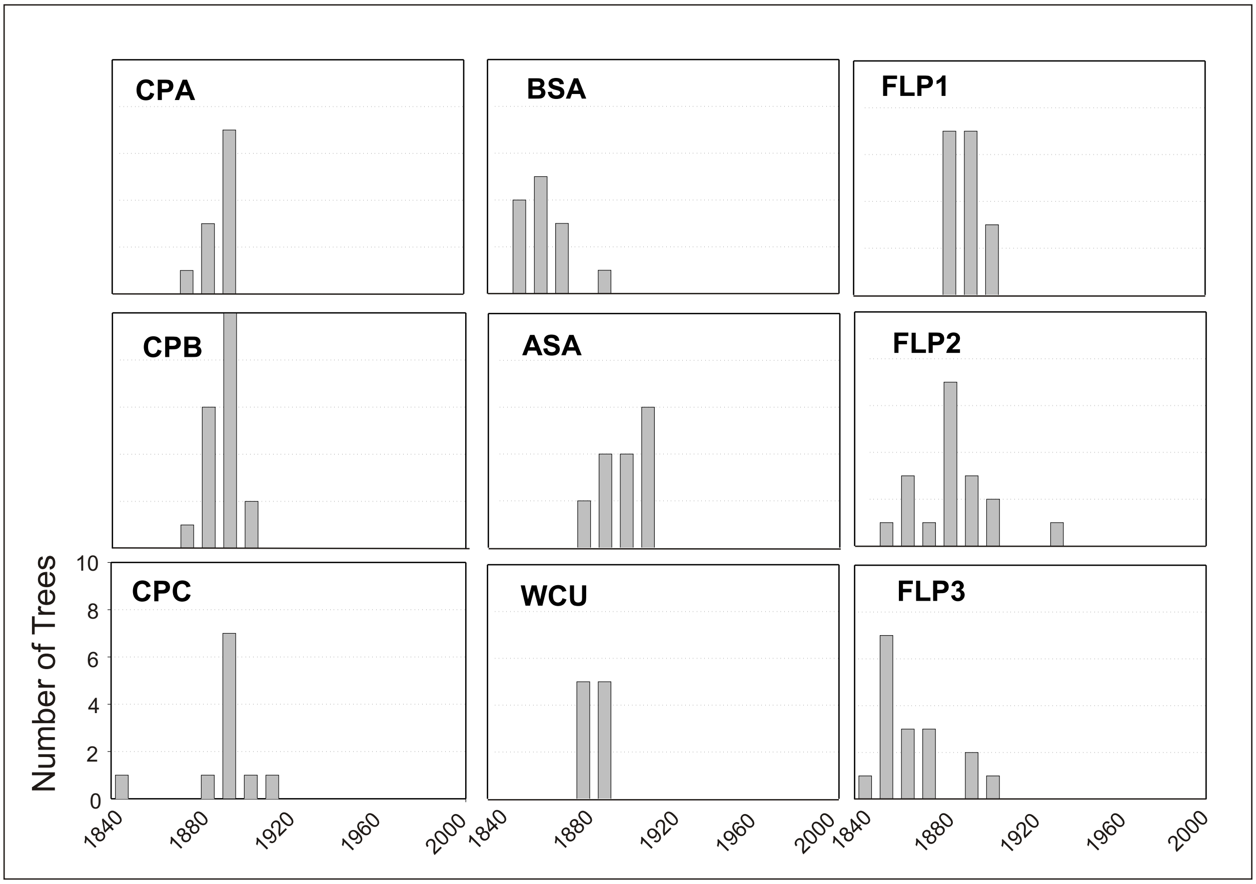

Figure 10. Estimated pith dates for monospecific aspen stands.

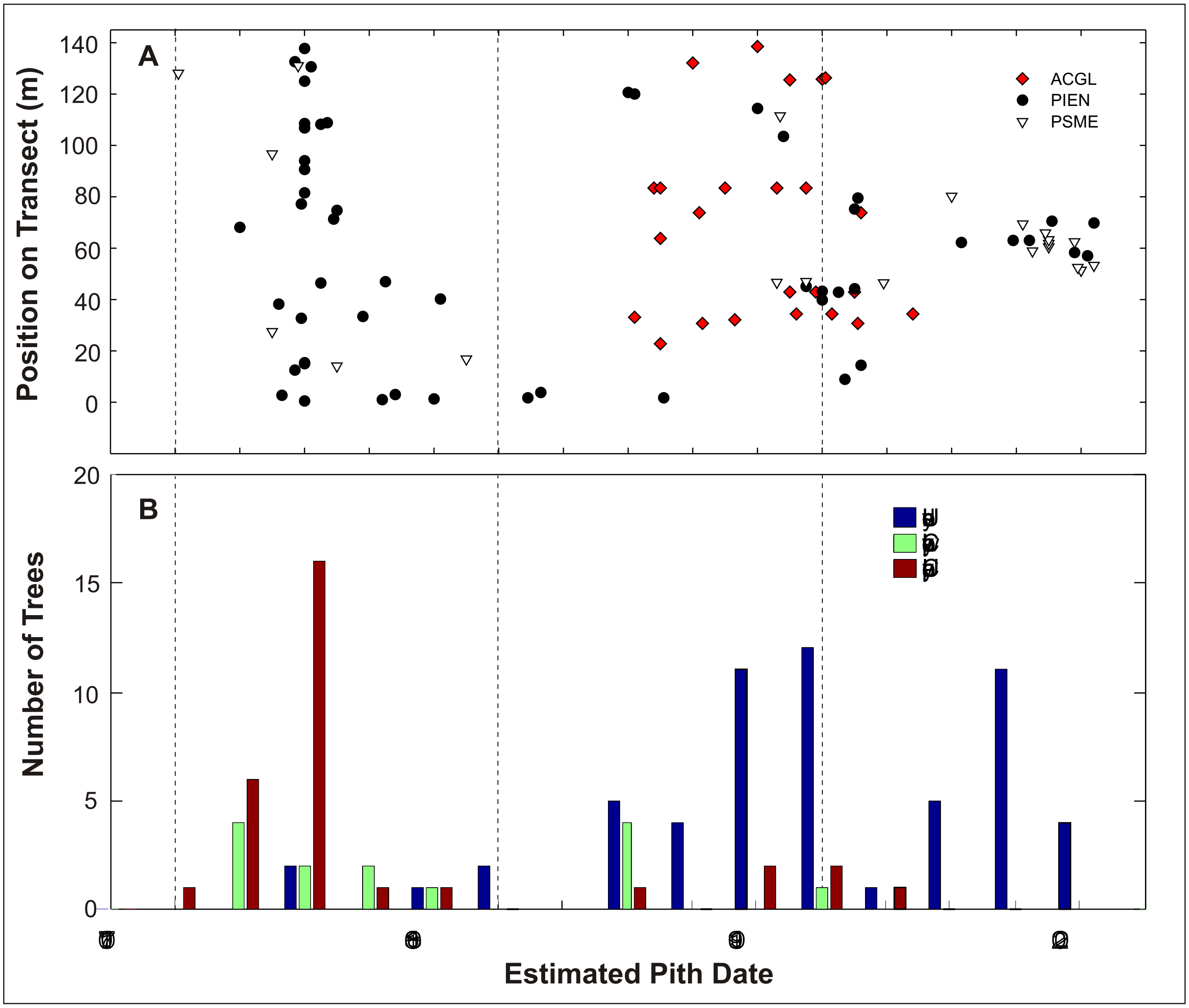

Figure 11. Lower Cima Ridge (LCR). A. Estimated pith dates and unidimensional location data of trees found on the transect. B. Estimated pith dates by 10-year classes for upper canopy (dominant and co-dominant), lower canopy (sub-dominant), and understory trees.

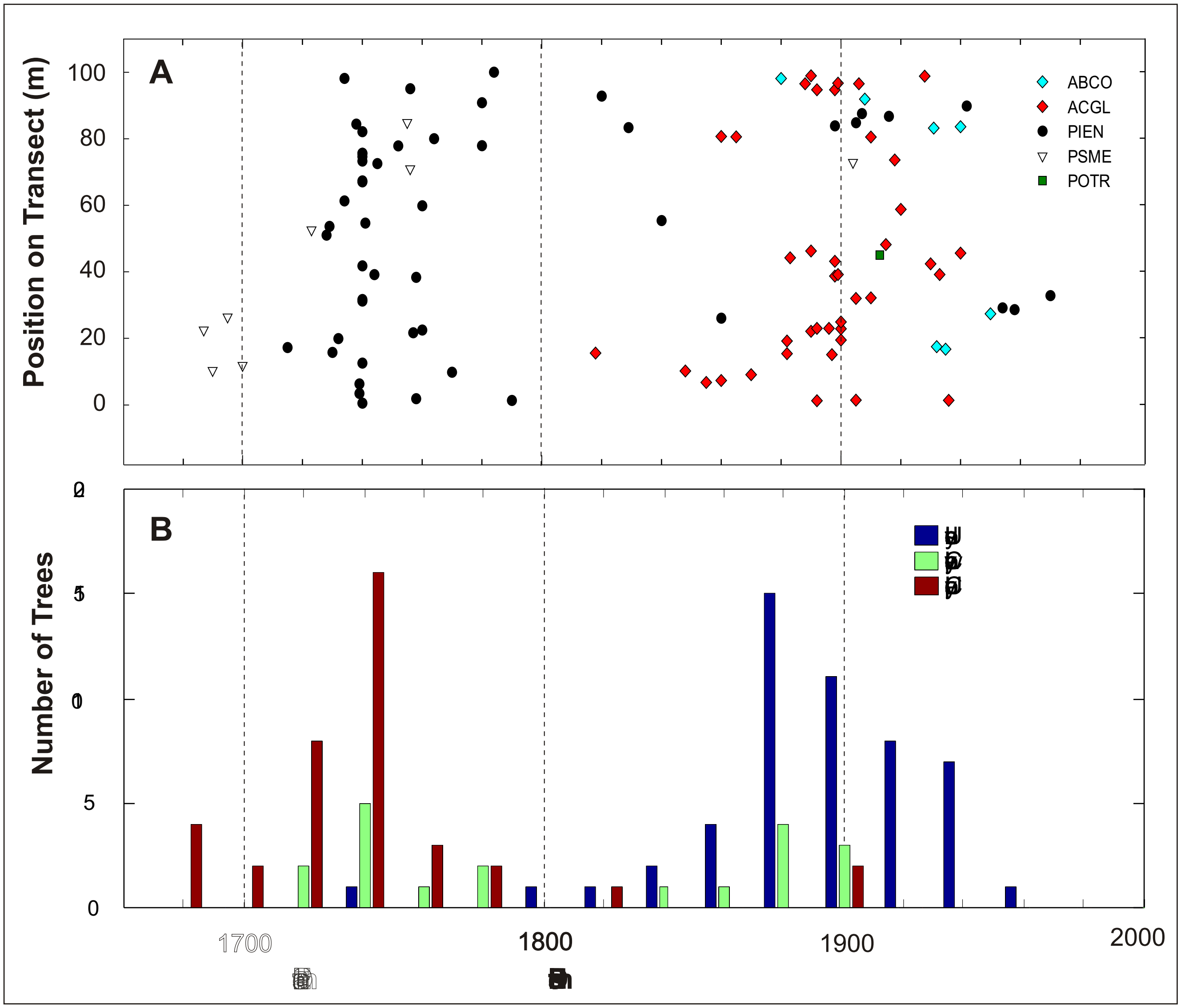

Figure 12. Lower Booger Springs (LBS). See Figure 10 for caption.

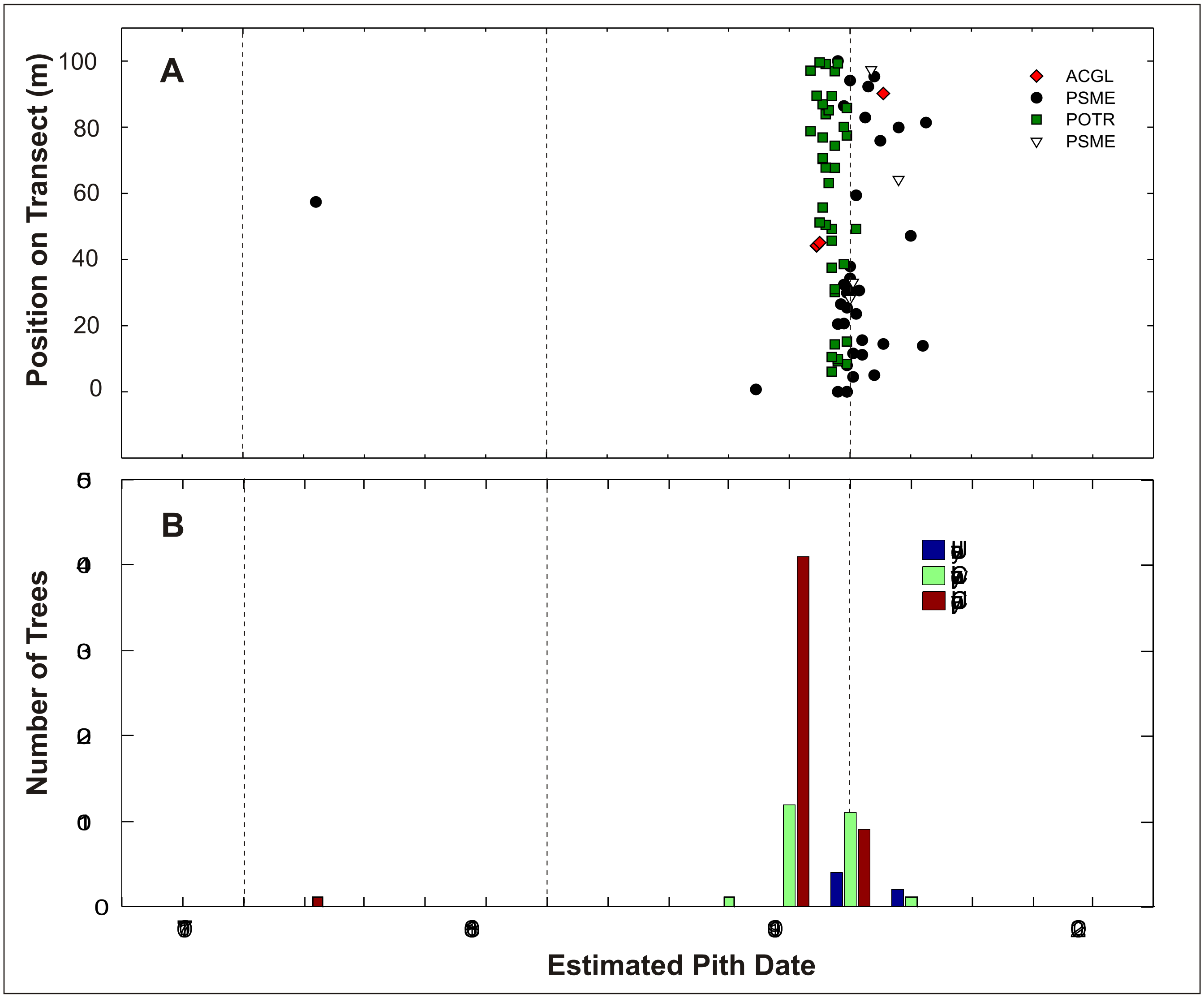

Figure 13. Upper Cima Ridge (UCR). See Figure 10 for caption.

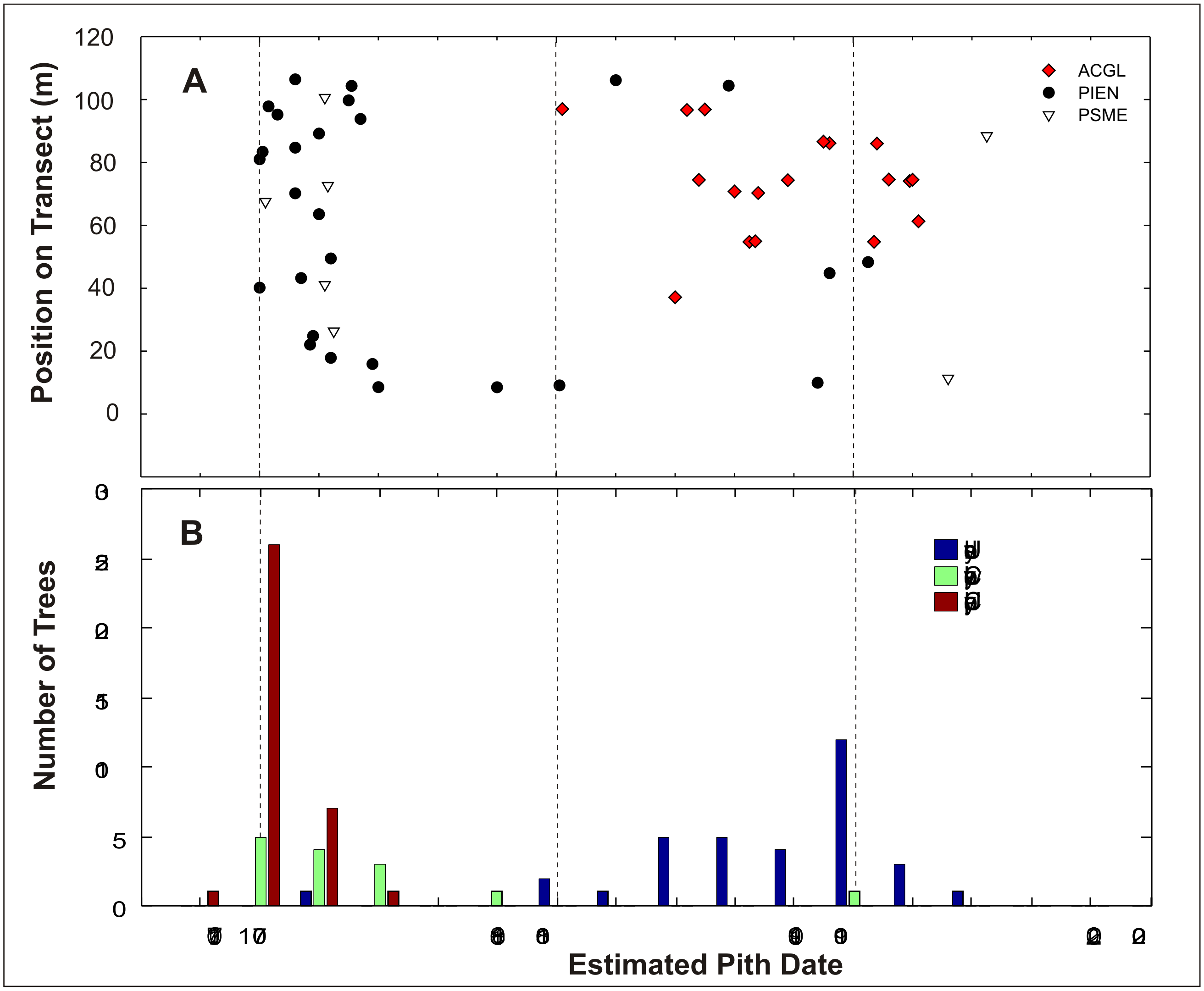

Figure 14. Middle Cima Ridge (MCR). See Figure 10 for caption.

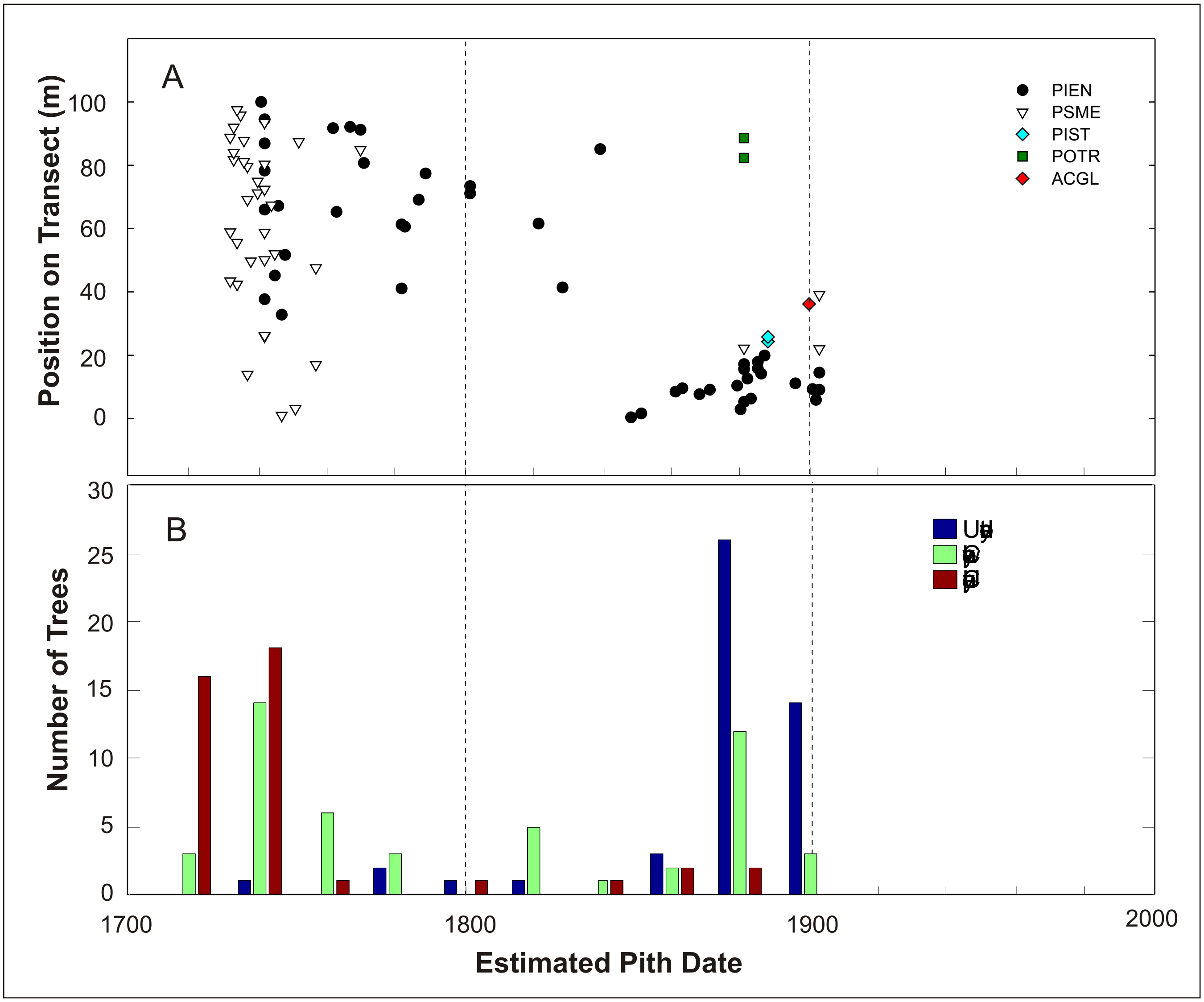

Figure 15. Upper Booger Spring (UBS). See Figure 10 for caption.

1886 was also recorded by six fire history sites but in this case, transect and aspen age structure data show several coinciding stand origin dates (Table 8). It is possible that the 1886 fire replaced some (or all) of the stands created by the 1748 fire.

Succession

Differences in overstory species composition reflect the variability of succession trajectories in these forests. Currently, overstory species composition of older stands are primarily composed of Engelmann spruce or Douglas-fir. Conversely, in both of the young transects, UCR and MOS, aspen codominates with Engelmann spruce (Figure 16a). Thus, it is possible that in transects that currently have an overstory dominated by Engelmann spruce, aspen was a prominent component of the initial colonizing cohort and has since died off and decayed.

The differences in overstory dominance by either Engelmann spruce (LBS, LCR, MCR) or Douglas-fir (UBS) may partly be influenced by the physical characteristics of the local environment. Sawyer and Kinraid (1980) found that the distribution of Douglas-fir and Engelmann spruce tended to segregate based on moisture availability. Using an index derived from aspect, elevation and slope, they found that Douglas-fir occupied drier sites compared to Engelmann Spruce. All of the older transects are located on slopes of similar aspects, N-NE, yet UBS has an overstory dominated by Douglas-fir, even though both UBS and MCR are also located at similar elevations and slopes. One difference between UBS and MCR, however, is that UBS is located closer to the ridge (Figure 1), perhaps making it more exposed and creating a comparatively more xeric environment. The influence of topographic position on species composition is also illustrated along the MOS transect. The majority of this transect originated following the 1886 fire. However, there is an older cohort that originated in the early 1700s which is located where the transect crosses a ridge (Figure 17).

If the physical environment was the primary factor controlling the distribution of Douglas-fir and Engelmann spruce, then, based on moisture requirements, locations having a predominantly Douglas-fir overstory should be relatively unsuitable for Engelmann spruce establishment. This is not the case, in UBS and MOS, Engelmann spruce as well as aspen, a species with even higher moisture requirements, have readily established in areas sympatric with Douglas-fir (Figures 15&17).

Our results indicate that in conjunction with topography, surface fire played an important role in stand development following severe fire within the mixed-conifer landscape. The interaction of fire and topography on stand development is perhaps best illustrated along the MOS transect. This extra-long transect begins in a small drainage and terminates on a ridge. There is an old cohort of Douglas-fir located on the ridge and several Douglas-fir logs and snags located on the transect near the drainage; the rest of the stand along the entire transect originated following an 1886 fire (Figure 17). Neither establishment nor death dates were estimated for the dead trees but coarse diameter groupings suggest that these trees may have belonged to the same cohort as the trees on the ridge (Figure 17). Thus, it appears that the Douglas-fir trees near the drainage

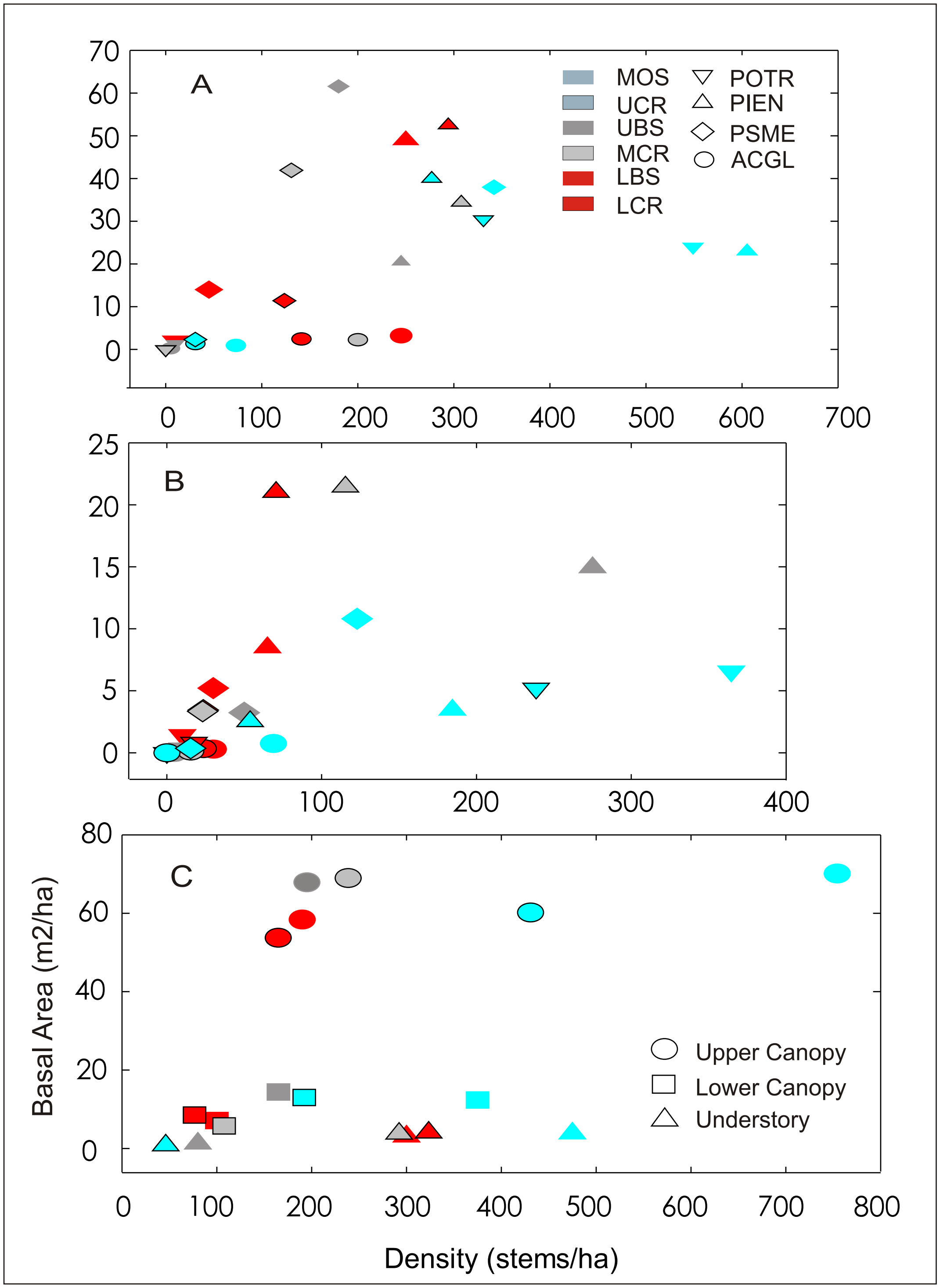

Figure 16. Density and basal area for all six transects. A. Live trees. B. Dead trees. C. Canopy position (live trees). Upper canopy corresponds to “dominant” and “codominant” trees (see Methods for details regarding classification scheme).

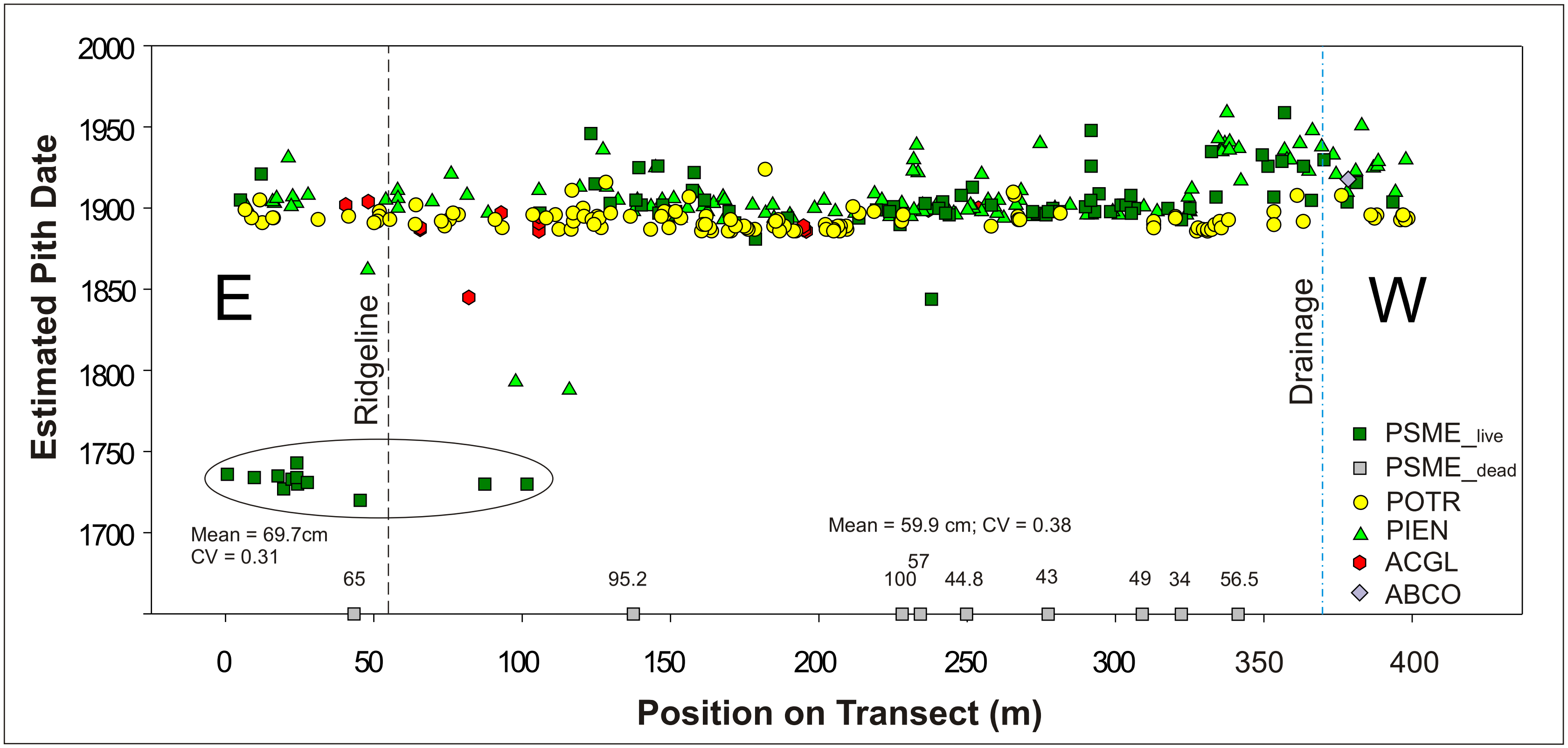

Figure 17. Flys Peak (MOS). On this extra-long transect, the estimated pith date of living trees are plotted against their location on the transect. The position of a set of larger-diameter, dead Douglas-fir are also represented. The dbh for each dead tree is shown. No pith estimates were made for these trees but they were assumed to be comparable in age to the group of Douglas-fir in the lower left corner of this graphic. The mean dbh and its coefficient of variation are presented for each group. Also indicated are topographical features that may explain particular age and stand structures.

were killed by the 1886 fire while those on the ridge survived, suggesting that fire away from the ridge potentially attains higher intensities.

Differences in fire intensity in the ridge versus slope portion of the MOS transect may have been driven by fire-mediated fuel accumulation rates whereby locally higher fire frequencies within the ridge microsite may have served to limit fuel accumulation. Species composition of the 1886 cohort illustrates that the physical characteristics along the ridge are not fundamentally limiting to the establishment of aspen and Engelmann spruce. While longevity may explain the absence of aspen, the dominance of Douglas-fir relative to Engelmann spruce in this microsite may reflect mortality of the fire-sensitive Engelmann spruce from recurrent fire. In fact, field observations corroborated the sensitivity of Engelmann spruce to fire. Among all transects, UBS had the largest number of dead Engelmann spruce (Figure 16b). Based on the state of decay and presence of char, it was evident that most of the mortality was the result of the 1994 Rattlesnake fire.

Age structure data from the older transects indicate a general temporal pattern of recruitment after fire in higher elevation forests of the Chiricahua Mountains: following an initial colonization period that lasts for approximately 40 years, recruitment subsides for about 80-100 years, then high rates of establishment resume beginning in the late 1800s. In light of the probable role of surface fires in stand development at these elevations, the timing of understory establishment may in some cases be related to concurrent decreases in fire frequency versus some endogenous stand factor. For example, UBS has a predominantly Douglas-fir overstory with an understory of fire-sensitive Engelmann spruce that established in the late 1800s. In transects where Engelmann spruce dominates the overstory, i.e., LBS, LCR and MCR, the role of surface fire in understory recruitment is less clear. Even though recruitment of fire-sensitive maples coincides with decreased fire frequency during the late 1800s, an historical regime of frequent fires would presumably have favored Douglas-fir relative to Engelmann spruce survival. Stem density of Engelmann spruce exceeds Douglas-fir in all three transects as does basal area in two of the three transects (Figure 16a). Moreover, Robinson (1968) characterized Engelmann spruce stands in the Chiricahua Mountains as having dense tree cover and subsequently a sparse herbaceous understory which may have limited surface fire occurrence in these stands. Robinson (1968), however, focused his study on Flys Peak (where MOS was located). Thus, the Engelmann spruce stands to which he refers may have been the 1886 cohort that retained their initial high densities because of fire suppression. In fact, among older stands, overstory stem densities of the Engelmann spruce-dominated transects (LBS, LCR, and MCR) are similar to the overstory stem density of UBS where Douglas-fir dominates (Figure 15c), suggesting that historically, there may have been more herbaceous growth in Engelmann spruce stands than Robinson (1968) suggests.

DISCUSSION

Fire and Elevation

In Mormon Canyon, historical data indicate increases in fire frequency with elevation in a pattern similar to that observed for modern lightning fire data from southeastern Arizona (Baisan and Swetnam 1990, Barton 1994). One difference, however, is that the prominent peak in fire frequency, occurring between ~2200 and ~2400m in the modern data, is not detected in the historical data. Instead, fire frequencies for sites between ~2300 and ~2700 were highly comparable. Moreover, several common fire dates among sites indicate that, historically, the landscape was relatively homogeneous; specifically, with respect to the fine fuels that drive low-intensity fire regimes. The difference between historical and modern patterns of fire frequency and elevation may be an artifact of fire suppression (Barton 1994, Caprio and Swetnam 1995). Historically (before livestock grazing and fire suppression), fires spread more readily across the landscape; therefore, fire frequency at any one location was a function of both ignition location and fire spread.

Fire history data at elevations greater than ~2700m, from the mixed-conifer sites, complete the elevation gradient. However, landscape heterogeneity complicates typical fire-elevation patterns. A “bell-shaped” curve relating fire frequency and elevation (*sensu* Martin 1982) emerges but only when larger fires (eg., recorded in >4 sites) are considered. This pattern may be explained by the ecologically-significant, aspect-driven differences in fuel moisture content that occur at the high elevations of the Chiricahua Mountains (Robinson 1968). In any given year, drier aspects may support fire while wetter aspects will have fuel moisture contents too high for fire spread. This results in high frequencies of smaller, patchy fires. Occasionally, however, conditions are uniformly dry enough across the higher elevation forests to increase landscape connectivity such that widespread fires may occur.

Fire and Climate

More extensive fires tended to occur following years having wet spring/summers and during years having slightly drier spring/summer both on the elevation transect and in the mixed-conifer forest. Similar patterns were found for ponderosa pine forests and mixed-conifer forests in the Santa Catalina Mountains (Baisan and Swetnam 1990). Based on these patterns, Baisan and Swetnam (1990) hypothesize that antecedent wet conditions serve the dual purpose of fine fuel production and suppressing fire ignitions, enabling fuels to homogenize over extensive areas.

Other studies have found that antecedent wet conditions are not associated with widespread fires in mixed-conifer forests (Wilkinson 1997, Grissino-Mayer et al. 1994, Touchan et al. 1996). There are two possible explanations for the different fire-climate associations reported for mixed-conifer forests. First, in the latter studies, a winter component was incorporated as a variable in fire-climate analyses. The two patterns are not mutually exclusive. It is plausible that widespread fires in mixed-conifer forest occur under the combined conditions of: 1-2 prior wet summers plus a dry period that begins during the winter and proceeds through to midsummer. Alternatively, differences in fire-climate patterns may be based on the nature of the mixed-conifer forest and landscapes that were studied. Mixed-conifer forest in the Southwest is highly diverse (Jones 1974) and may be organized along a continuum of dry to wet. Fire-climate patterns that indicate drier-than-average conditions during the fire year without prior wet conditions may be characteristic of mixed-conifer forests at the wetter end of the spectrum. In contrast, fire-climate patterns that point to the importance of a prior wet period may typify drier mixed-conifer forests where fuel buildup is necessary for landscape connectivity.

The Role of Fire in Mixed-Conifer Forest

By examining forest structure within a temporal framework and including fire history, we were able to build upon the models of mixed-conifer forest succession in the Southwest proposed by Jones (1974; Figure 18a) and Sawyer and Kinraid (1980; Figure 18b). In comparison to Sawyer and Kinraid (1980), our study had a more restricted topographic scope. We focused primarily on mesic aspects so that we could evaluate stand development following high-severity fire in mixed-conifer forests. We elaborate upon the Sawyer-Kinraid model in the following ways. Following severe fire, we envision species composition of the colonizing cohort as being organized along a continuum of differing proportions of aspen, Engelmann spruce and Douglas-fir (Figure 18c). The occurrence of aspen-conifer mixtures was observed by Jones (1974) but not incorporated into succession models. Factors controlling composition may include: pre-fire stand composition, proximity of seed sources, physical site conditions and fire intensity (Jones 1974, Moir and Ludwig 1979). Stands can develop either into Engelmann spruce-dominated stands or Douglas-fir-dominated stands with succession trajectories driven by the combined and interacting effects of moisture availability, as determined by the physical environment, and fire occurrence. Less mesic sites, as determined by slope position will tend to be more prone to fire occurrence. At these sites, fire functions as an environmental filter enabling Douglas-fir (the most fire resistant of the three species) to eventually dominate a stand even though it may comprise a relatively low proportion of the colonizing cohort.

The other modification we propose to the Chiricahua succession model is that in some cases, severe fire may recur at relatively short intervals in aspen stands (Figure 18c). We observed in one instance, indication of aspen establishment related to two events separated by ~40 years. Multi-cohort aspen stands have also been found in the Jemez Mountains of northern New Mexico (Touchan et al. 1996, Morino et al. 1998) and the Gila Wilderness in southwestern New Mexico (Abolt 1997). Pure aspen stands are generally considered highly fire resistant (Jones and Debyle 1995) but perhaps there is a window when the stand is relatively young that fire-induced resprouting can occur, yielding multi-aged aspen stands. Our model indicates that aspen stands eventually develop into spruce stands but this is highly speculative as we did not sample seedlings or saplings within aspen stands. It is also possible that high-severity fire may occur in aspen stands before there is a conversion of relative dominance in the overstory. Thus, maintaining aspen in some locations in perpetuity.

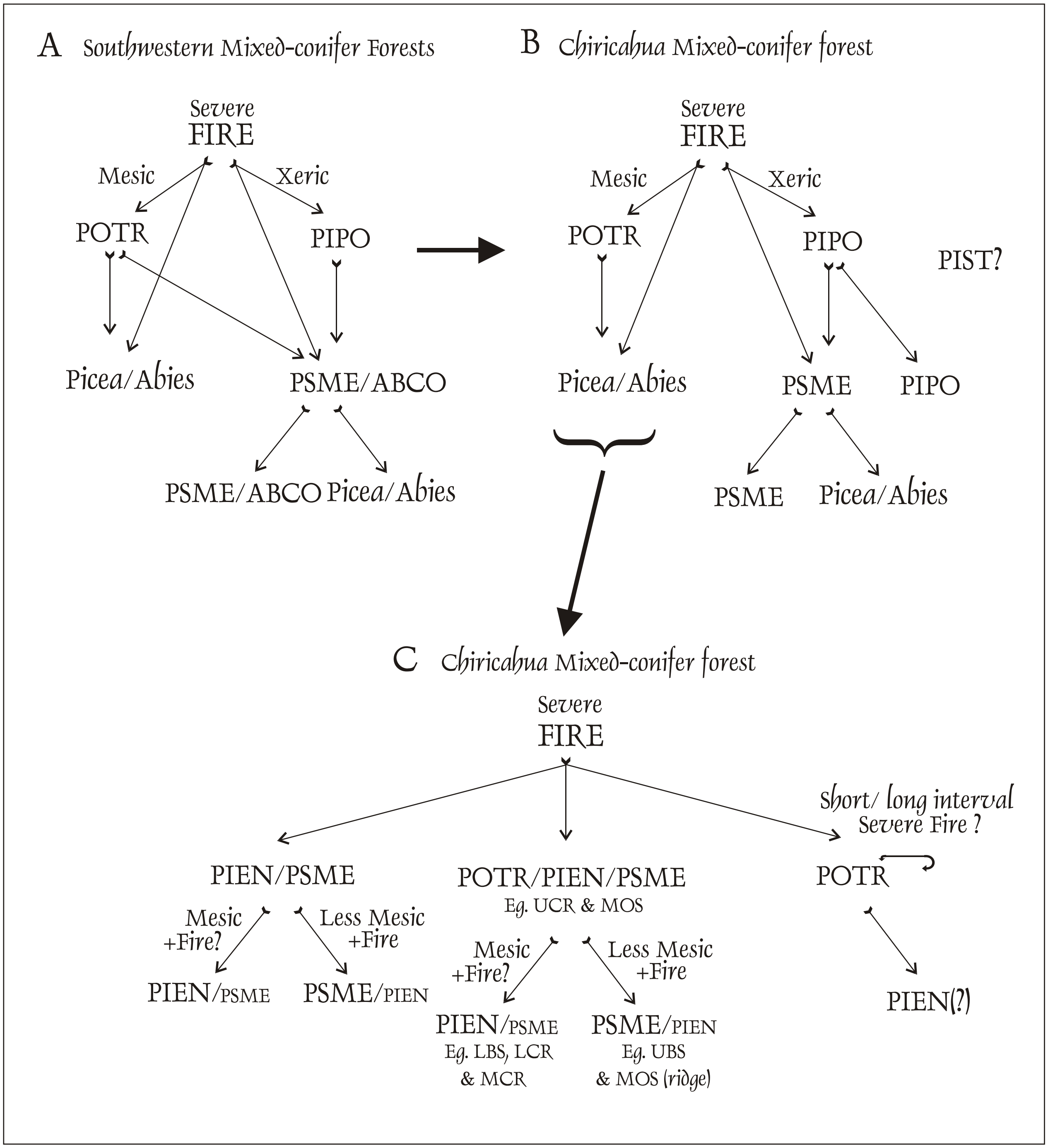

Figure 18. The development of succession models for the high elevation forests in the Chiricahua Mountains. A. Jones (1974). B. Sawyer and Kinraid (1980). C. This study.

MANAGEMENT IMPLICATIONS and RECOMMENDATIONS

The absence of fire during roughly the last century has altered forest and landscape structure in the Chiricahua Mountains. The Rattlesnake fire is an example of anomalies that may occur under current conditions. In total ,this fire burned approximately 11,100 ha (27,500 ac; Allen 1995). From a historical perspective, its size was probably comparable to other events. On the other hand, local fire severity in some areas far exceeded the range of historical natural variation. For example, we encountered an impressive display of erosion in upper Ward Canyon: a 10m deep cut that had exposed layers as old as 100,000 years, according to Dr. W. Bull, a geologist at The University of Arizona (unpublished report). The extremely high severities that characterized some parts of the Rattlesnake fire are undoubtedly related to unprecedented fuel accumulations. The process of fire restoration in the Chiricahuas will first require fuel reduction before fire can settle into its natural role.

In general, current fuel loads tend to be more anomalous within vegetation types where fire played a primary role in mediating fuel accumulation rates. As illustrated by the elevation transect data, low-intensity surface fires frequently occurred in pine-oak woodlands and pine forests of the Chiricahua Mountains, probably maintaining low tree densities and fuel loads. Contemporary vegetation structure of these forests could conceivably promote widespread crown fires in stands where, historically, there were none (Swetnam 1990, Covington and Moore 1994). The steep slopes where these stands occur favor destructive erosional processes, thus increasing the severity of an already extreme situation. Logically, these stands, and others of similar character, are prime candidates for fuel reduction efforts.

In addition, however, we recommend that higher elevation forests be targeted for fuel management. Our results indicate that, historically, surface fires occurred throughout the landscape at elevations greater than ~2700m. In fact, fire frequencies at some mixed-conifer sites were comparable to lower elevation sites. Fire spread, however, was more variable due to steep gradients in moisture levels across aspects. Nevertheless, it appears, based on stand development patterns and occasional widespread synchroneity of fire dates, that low to moderate-intensity surface fire also occurred in some topographic situations on more mesic aspects. The potential outcome of augmented fuel loads in the high country is that, relative to historical fires, higher mortality and intensities could occur within any given event. High-severity, stand-replacing fires were an integral component of the historical fire regime in the mixed-conifer forests of the Chiricahua Mountains and should be restored if fire is to fulfill its natural role; however, our data suggest that the location of these events was probably mediated by topography. Frequent, low-intensity fire tended to characterize drier aspects and less frequent higher intensity fire tended to characterize wetter aspects. In this respect, we observed further anecdotal evidence of the anomalous behavior of the Rattlesnake fire: high mortality and intensities on the south-facing slopes of Flys Peak.

Management-ignited burns may be the most efficient way to achieve fuel reduction objectives.

Steep terrain and Wilderness Area mandates preclude easy use of mechanical techniques for controlling fuel loads. More importantly, using fire to manage vegetation is ecologically consistent with the natural dynamics of the system. Initially, however, it may be necessary to conduct management-ignited burns outside of the natural fire season for greater control over fire intensities.

In conclusion, fire restoration to the Chiricahua Mountains is a process that will require a landscape approach and long-term planning. A historical perspective of fire has provided insights regarding the controls and effects of fire in a system minimally influenced by human activities. This study indicated that fire was a pervasive force across vegetation types but that interactions among vegetation, topography and climate mediated fire spread and therefore fire effects. Effective fire management will need to take into consideration the dynamic nature of landscape connectivity, realizing that conditions that promote or inhibit fire spread are time and space-specific. Moreover, in light of the duration of altered fire regimes in the Chiricahua Mountains, restoring fire to its natural role will require multiple treatments to be applied over a period of time. And while this study has improved our understanding of this system and has provided necessary baseline information upon which to build a fire management program, monitoring and careful planning of prescribed burns will be an invaluable source of information that should be incorporated into future management plans.

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Appendices

APPENDIX A

This appendix consists of fire scar data for fire history sites on the elevation transect. Both unspecified injuries and fire scars were noted and recorded. Uppercase letters following fire scar dates refer to intra-ring scar position. U = Unknown; D = Dormant, i.e., on the boundary between two rings; E = Early earlywood, i.e., in the first third of the earlywood; M = Middle earlywood, i.e., in the second third of the earlywood; L = Late earlywood, i.e., in the last third of the earlywood; and A = Latewood, i.e., in the latewood. “FI” refers to “fire interval,”i.e., the number of years between that and the preceding fire scar. No intervals were computed between injuries or between fire scars and injuries.

West of Cima Point (WCP)

Series 1 : WCP01
Pith Date : 1650
Outer Ring : 1837
Length of sample : 188
Number in final analysis : 93
Information on fire history :
1725 U injury
1736 U injury
1738 U injury
1748 M fire scar
1763 E fire scar FI = 15
1785 U injury
1789 U injury
1817 U fire scar FI = 54

Series 2 : WCP02
Inner Ring : N/A
Outer Ring : N/A

Series 3 : WCP03
Inner Ring : 1576
Outer Ring :1716
Length of sample : 141
Number in final analysis : 91
Information on fire history :
1626 M fire scar
1698 U fire scar FI = 72
1716 U fire scar FI = 18

Series 4 : WCP04
Pith Date : 1760
Bark Date : 1996
Length of sample : 237
Number in final analysis : 208
Information on fire history :
1789 L fire scar
1801 E fire scar FI = 12
1818 D fire scar FI = 17
1851 L fire scar FI = 33
1868 M fire scar FI = 17
1886 M fire scar FI = 18
1994 U fire scar FI = 108

Series 5 : WCP05
Inner Ring : 1744
Outer Ring : 1994
Length of sample : 251
Number in final analysis : 232
Information on fire history :
1763 E fire scar
1785 E fire scar FI = 22
1818 M fire scar FI = 33
1841 E fire scar FI = 23
1851 L fire scar FI = 10
1872 E fire scar FI = 21
1886 M fire scar FI = 14

Upper Ward Canyon (UWC)

Series 1 : UWC01
Inner Ring : 1813
Outer Ring : 1976
Length of sample : 164
Number in final analysis : 137
Information on fire history :
1818 E injury
1841 M fire scar
1849 L fire scar FI = 8
1856 M fire scar FI = 7
1868 L fire scar FI = 12
1886 L fire scar FI = 18
1917 M fire scar FI = 31

Series 2 : UWC02
Inner Ring : 1813
Bark Date : 1996
Length of sample : 184
Number in final analysis : 111
Information on fire history :
1886 M fire scar
1917 M fire scar FI = 31
1994 L fire scar FI = 77

Series 3 : UWC04
Inner Ring : 1714
Bark Date : 1996
Length of sample : 283
Number in final analysis : 249
Information on fire history :
1748 E fire scar
1763 E fire scar FI = 15
1785 M fire scar FI = 22
1820 U fire scar FI = 35
1841 E fire scar FI = 21
1868 M fire scar FI = 27
1891 E fire scar FI = 23
1892 E fire scar FI = 1
1906 U injury
1929 U injury

Series 4 : UWC03
Pith Date : 1796
Outer Ring :1917
Length of sample : 122
Number in final analysis : 92
Information on fire history :
1826 M fire scar
1841 L fire scar FI = 15
1856 E fire scar FI = 15
1868 L fire scar FI = 12
1875 E fire scar FI = 7
1886 L fire scar FI = 11
1894 M fire scar FI = 8
1917 U fire scar FI = 23

Upper Mormon Canyon, Group 1 (UMC_1)

Series 1 : UMC01
Pith Date : 1654
Outer Ring : 1865
Length of sample : 212
Number in final analysis : 163
Information on fire history :
1703 U fire scar
1752 U fire scar FI = 49
1763 E fire scar FI = 11
1770 E fire scar FI = 7
1785 E fire scar FI = 15
1801 D fire scar FI = 16
1817 M fire scar FI = 16
1841 M fire scar FI = 24
1856 E fire scar FI = 15

Series 2 : UMC02
Pith Date : 1660
Outer Ring : 1770
Length of sample : 111
Number in final analysis : 86
Information on fire history :
1685 E fire scar
1707 M fire scar FI = 22
1711 M fire scar FI = 4
1723 E fire scar FI = 12
1735 L fire scar FI = 12
1739 E fire scar FI = 4
1741 U fire scar FI = 2
1748 E fire scar FI = 7
1763 U fire scar FI = 15

Series 3 : UMC03
Pith Date : 1804
Outer Ring : 1978
Length of sample : 175
Number in final analysis : 153
Information on fire history :
1826 M fire scar
1831 L fire scar FI = 5
1841 L fire scar FI = 10
1856 E fire scar FI = 15
1868 L fire scar FI = 12
1886 M fire scar FI = 18
1894 M fire scar FI = 8

Series 4 : UMC04
Inner Ring : 1686
Bark Date : 1994
Length of sample : 309
Number in final analysis : 210
Information on fire history :
1785 M fire scar
1801 U fire scar FI = 16
1817 U fire scar FI = 16
1841 M fire scar FI = 24
1849 L fire scar FI = 8
1856 E fire scar FI = 7
1868 M fire scar FI = 12
1886 M fire scar FI = 18
1894 U fire scar FI = 8
1917 E fire scar FI = 23

Series 5 : UMC05
Inner Ring : 1791
Bark Date : 1996
Length of sample : 206
Number in final analysis : 196
Information on fire history :
1801 M fire scar
1817 L fire scar FI = 16
1841 M fire scar FI = 24
1856 M fire scar FI = 15
1875 U fire scar FI = 19
1894 D fire scar FI = 19
1917 E fire scar FI = 23

Series 6 : UMC06
Inner Ring : 1739
Outer Ring : 1854
Length of sample : 116
Number in final analysis : 92
Information on fire history :
1763 E fire scar
1770 E fire scar FI = 7
1772 L fire scar FI = 2
1773 L injury
1785 M fire scar FI = 13
1801 L fire scar FI = 16
1805 U injury
1817 M fire scar FI = 16
1841 E fire scar FI = 24
1849 M fire scar FI = 8

Opposite Rocky Outcrop (ORO)

Series 1 : ORO01
Inner Ring : 1662
Bark Date : 1996
Length of sample : 335
Number in final analysis : 312
Information on fire history :
1685 E fire scar
1730 E fire scar FI = 45
1748 E fire scar FI = 18
1779 E fire scar FI = 31
1801 E fire scar FI = 22
1817 M fire scar FI = 16
1826 E fire scar FI = 9
1841 E fire scar FI = 15
1849 E fire scar FI = 8
1894 D fire scar FI = 45
1917 E fire scar FI = 23
1957 U injury

Series 2 : ORO02
Inner Ring : 1778
Bark Date : 1996
Length of sample : 219
Number in final analysis : 212
Information on fire history :
1785 M fire scar
1819 U injury
1841 E fire scar FI = 56
1919 E fire scar FI = 78

Series 3 : ORO03
Pith Date : 1779
Bark Date : 1996
Length of sample : 218
Number in final analysis : 171
Information on fire history :
1826 L fire scar
1841 M fire scar FI = 15
1849 M fire scar FI = 8
1856 E fire scar FI = 7
1868 L fire scar FI = 12
1894 M fire scar FI = 26
1917 L fire scar FI = 23
1925 U injury
1978 D fire scar FI = 61
1994 E fire scar FI = 16

Series 4 : ORO05
Inner Ring : 1835
Bark Date : 1996
Length of sample : 162
Number in final analysis : 156
Information on fire history :
1841 L fire scar
1856 D fire scar FI = 15
1868 L fire scar FI = 12
1886 M fire scar FI = 18
1894 M fire scar FI = 8
1917 M fire scar FI = 23
1978 E fire scar FI = 61
1994 M fire scar FI = 16

Upper Mormon Canyon, Group 2 (UMC_2)

Series 1 : UMC07
Pith Date : 1665
Outer Ring : 1894
Length of sample : 230
Number in final analysis : 132
Information on fire history :
1763 M fire scar
1770 E fire scar FI = 7
1779 L fire scar FI = 9
1789 M fire scar FI = 10
1801 E fire scar FI = 12
1817 D fire scar FI = 16
1826 E fire scar FI = 9
1840 E fire scar FI = 14
1843 E fire scar FI = 3

Series 2 : UMC08
Inner Ring : 1671
Bark Date : 1996
Length of sample : 326
Number in final analysis : 249
Information on fire history :
1748 E fire scar
1785 M fire scar FI = 37
1801 E fire scar FI = 16
1817 M fire scar FI = 16
1826 M fire scar FI = 9
1841 M fire scar FI = 15
1849 L fire scar FI = 8
1856 E fire scar FI = 7
1868 M fire scar FI = 12
1875 D fire scar FI = 7
1886 M fire scar FI = 11
1894 E fire scar FI = 8
1917 D fire scar FI = 23

Series 3 : UMC09
Pith Date : 1659
Outer Ring : 1916
Length of sample : 258
Number in final analysis : 206
Information on fire history :
1711 L fire scar
1723 L fire scar FI = 12
1744 L fire scar FI = 21
1763 E fire scar FI = 19
1770 E fire scar FI = 7
1779 M fire scar FI = 9
1789 M fire scar FI = 10
1801 E fire scar FI = 12
1826 E fire scar FI = 25
1828 U fire scar FI = 2
1841 M fire scar FI = 13
1856 D fire scar FI = 15
1875 D fire scar FI = 19
1886 M fire scar FI = 11

Series 4 : UMC10
Pith Date : 1650
Outer Ring : 1851
Length of sample : 202
Number in final analysis : 141
Information on fire history :
1711 E fire scar
1744 L fire scar FI = 33
1748 L fire scar FI = 4
1763 E fire scar FI = 15
1770 M fire scar FI = 7
1779 E fire scar FI = 9
1785 M fire scar FI = 6
1801 D fire scar FI = 16
1817 D fire scar FI = 16
1826 M fire scar FI = 9
1841 E fire scar FI = 15

Sandy Corner (SDC)

Series 1 : SDC03
Pith Date : 1741
Bark Date : 1979
Length of sample : 239
Number in final analysis : 195
Information on fire history :
1785 E fire scar
1801 E fire scar FI = 16
1817 M fire scar FI = 16
1826 M fire scar FI = 9
1841 M fire scar FI = 15
1868 E fire scar FI = 27

Series 2 : SDC04
Pith Date : 1541
Outer Ring : 1925
Length of sample : 385
Number in final analysis : 309
Information on fire history :
1617 M fire scar
1626 D fire scar FI = 9
1644 M fire scar FI = 18
1662 E fire scar FI = 18
1685 D fire scar FI = 23
1695 E fire scar FI = 10
1703 E fire scar FI = 8
1725 E fire scar FI = 22
1748 U injury
1770 E fire scar FI = 45
1785 E fire scar FI = 15
1850 E fire scar FI = 65
1871 E fire scar FI = 21
1877 E fire scar FI = 6

Series 3 : SDC01
Inner Ring : 1755
Bark Date : 1996
Length of sample : 242
Number in final analysis : 229
Information on fire history :
1768 M fire scar
1779 M fire scar FI = 11
1789 L fire scar FI = 10
1801 U fire scar FI = 12
1826 U fire scar FI = 25
1841 E fire scar FI = 15
1849 E fire scar FI = 8
1856 E fire scar FI = 7
1875 U fire scar FI = 19
1886 U fire scar FI = 11
1894 U fire scar FI = 8
1909 L fire scar FI = 15
1994 U fire scar FI = 85

Series 4 : SDC02
Pith Date : 1742
Bark Date : 1919
Length of sample : 178
Number in final analysis : 141
Information on fire history :
1779 U fire scar
1789 U fire scar FI = 10
1801 U fire scar FI = 12
1826 U fire scar FI = 25
1841 U fire scar FI = 15
1868 U fire scar FI = 27
1894 M fire scar FI = 26

Middle Mormon Canyon (MMC)

Series 1 : MMC01
Inner Ring : 1556
Outer Ring : 1927
Length of sample : 372
Number in final analysis : 185
Information on fire history :
1626 U injury
1744 L fire scar
1763 M fire scar FI = 19
1779 L fire scar FI = 16
1789 L fire scar FI = 10
1791 E injury
1795 E injury
1801 M fire scar FI = 12
1826 L fire scar FI = 25
1849 M fire scar FI = 23
1868 L fire scar FI = 19
1886 M fire scar FI = 18
1894 M fire scar FI = 8
1917 M fire scar FI = 23

Series 2 : MMC03
Inner Ring : 1721
Bark Date : 1996
Length of sample : 276
Number in final analysis : 243
Information on fire history :
1754 L fire scar
1763 E fire scar FI = 9
1770 E fire scar FI = 7
1779 E fire scar FI = 9
1785 E fire scar FI = 6
1789 E fire scar FI = 4
1801 E fire scar FI = 12
1809 E injury
1817 M fire scar FI = 16
1826 E fire scar FI = 9
1835 E fire scar FI = 9
1841 E fire scar FI = 6
1856 E fire scar FI = 15
1868 L fire scar FI = 12
1875 E fire scar FI = 7
1886 M fire scar FI = 11
1894 L fire scar FI = 8
1917 M fire scar FI = 23
1922 E fire scar FI = 5
1941 U injury
1947 U injury
1949 U injury
1958 U injury
1967 U injury

Series 3 : MMC04
Inner Ring : 1628
Outer Ring : 1918
Length of sample : 291
Number in final analysis : 260
Information on fire history :
1659 M fire scar
1698 A fire scar FI = 39
1711 M fire scar FI = 13
1723 M injury
1745 M fire scar FI = 34
1748 E fire scar FI = 3
1750 U injury
1763 M fire scar FI = 15
1773 M injury
1785 M fire scar FI = 22
1789 L fire scar FI = 4
1801 M fire scar FI = 12
1804 L injury
1817 M fire scar FI = 16
1826 L fire scar FI = 9
1835 D fire scar FI = 9
1841 M fire scar FI = 6
1849 L fire scar FI = 8
1856 E fire scar FI = 7
1868 L fire scar FI = 12
1875 E fire scar FI = 7
1880 M fire scar FI = 5
1886 M fire scar FI = 6
1894 M fire scar FI = 8
1910 M fire scar FI = 16
1917 M fire scar FI = 7

Series 4 : MMC02
Inner Ring : 1792
Outer Ring : 1887
Length of sample : 96
Number in final analysis : 39
Information on fire history :
1849 M fire scar
1856 E fire scar FI = 7
1868 L fire scar FI = 12
1881 U injury
1886 M fire scar FI = 18

Series 5 : MMC05
Inner Ring : 1762
Outer Ring :1894
Length of sample : 133
Number in final analysis : 94
Information on fire history :
1801 E fire scar
1817 D fire scar FI = 16
1826 M fire scar FI = 9
1835 E fire scar FI = 9
1841 M fire scar FI = 6
1849 E fire scar FI = 8
1856 E fire scar FI = 7
1860 M fire scar FI = 4
1868 M fire scar FI = 8
1875 E fire scar FI = 7
1886 M fire scar FI = 11
1894 M fire scar FI = 8

Series 6 : MMC06
Pith Date : 1636
Outer Ring : 1905
Length of sample : 270
Number in final analysis : 127
Information on fire history :
1779 U fire scar
1785 U fire scar FI = 6
1801 E fire scar FI = 16
1826 U fire scar FI = 25
1841 U fire scar FI = 15
1845 U fire scar FI = 4
1851 U fire scar FI = 6
1859 U fire scar FI = 8
1886 M fire scar FI = 27
1894 U fire scar FI = 8
1896 U fire scar FI = 2

Steep and Burnt (SAB)

Series 1 : SAB01
Inner Ring : 1729
Outer Ring : 1994
Length of sample : 266
Number in final analysis : 232
Information on fire history :
1763 E fire scar
1817 L fire scar FI = 54
1826 M fire scar FI = 9
1847 M fire scar FI = 21
1875 E fire scar FI = 28
1880 M fire scar FI = 5
1886 M fire scar FI = 6
1894 M fire scar FI = 8
1917 M fire scar FI = 23
1979 E fire scar FI = 62

Series 2 : SAB02
Inner Ring : 1818
Bark Date : 1993
Length of sample : 176
Number in final analysis : 148
Information on fire history :
1846 L fire scar
1856 U fire scar FI = 10
1859 U fire scar FI = 3
1868 L fire scar FI = 9
1880 L fire scar FI = 12
1886 L fire scar FI = 6
1894 L fire scar FI = 8
1917 M fire scar FI = 23
1968 U injury

Series 3 : SAB03
Inner Ring : 1756
Bark Date : 1996
Length of sample : 241
Number in final analysis : 180
Information on fire history :
1817 M fire scar
1846 L fire scar FI = 29
1868 U fire scar FI = 22
1880 E fire scar FI = 12
1886 M fire scar FI = 6
1894 L fire scar FI = 8
1917 M fire scar FI = 23
1969 D injury
1973 D injury
1994 E fire scar FI = 77

Mormon Canyon Spring (MCS)

Series 1 : MCS02
Inner Ring : 1713
Outer Ring : 1883
Length of sample : 171
Number in final analysis : 136
Information on fire history :
1748 E fire scar
1785 E fire scar FI = 37
1789 E fire scar FI = 4
1801 E fire scar FI = 12
1817 M fire scar FI = 16
1835 E fire scar FI = 18
1841 M fire scar FI = 6

Series 2 : MCS03
Inner Ring : 1642
Outer Ring : 1867
Length of sample : 226
Number in final analysis : 157
Information on fire history :
1711 U fire scar
1733 U fire scar FI = 22
1748 U fire scar FI = 15
1765 U fire scar FI = 17
1784 U fire scar FI = 19

Series 3 : MCS04
Inner Ring : 1583
Outer Ring :1868
Length of sample : 286
Number in final analysis : 95
Information on fire history :
1745 U injury
1760 U injury
1776 U fire scar
1785 M fire scar FI = 9
1801 U fire scar FI = 16
1820 U injury
1835 U injury
1841 U fire scar FI = 40
1845 U injury
1868 M fire scar FI = 27

Series 4 : MCS06
Inner Ring : 1434
Outer Ring : 1726
Length of sample : 293
Number in final analysis : 256
Information on fire history :
1471 U fire scar
1487 U fire scar FI = 16
1577 U fire scar FI = 90
1590 U fire scar FI = 13
1645 U fire scar FI = 55

Series 5 : MCS07
Inner Ring : 1859
Bark Date : 1996
Length of sample : 138
Number in final analysis : 129
Information on fire history :
1868 U fire scar
1886 U injury
1917 U fire scar FI = 49

Lower Mormon Canyon (LMC)

Series 1 : LMC01
Inner Ring : 1571
Outer Ring : 1764
Length of sample : 194
Number in final analysis : 123
Information on fire history :
  1617 M injury
  1631 E injury
  1644 L fire scar
  1657 E fire scar FI = 13
  1679 M fire scar FI = 22
  1685 E fire scar FI = 6
  1689 E fire scar FI = 4

Series 2 : LMC02
Inner Ring : 1717
Outer Ring : 1868
Length of sample : 152
Number in final analysis : 125
Information on fire history :
  1744 M fire scar
  1758 M fire scar FI = 14
  1763 M fire scar FI = 5
  1770 M fire scar FI = 7
  1779 M fire scar FI = 9
  1789 U injury
  1801 E fire scar FI = 22
  1805 A fire scar FI = 4
  1817 M fire scar FI = 12

Series 3 : LMC03
Inner Ring : 1765
Bark Date : 1996
Length of sample : 232
Number in final analysis : 112
Information on fire history :
  1842 U injury
  1886 M fire scar
  1920 L fire scar FI = 34

Series 4 : LMC05
Pith Date : 1800
Bark Date : 1996
Length of sample : 197
Number in final analysis : 180
Information on fire history :
  1817 L fire scar
  1835 E fire scar FI = 18
  1841 L fire scar FI = 6
  1846 L fire scar FI = 5
  1856 E fire scar FI = 10
  1886 E fire scar FI = 30
  1917 M fire scar FI = 31

Series 5 : LMC04
Pith Date : 1816
Bark Date : 1996
Length of sample : 181
Number in final analysis : 111
Information on fire history :
  1886 U fire scar

APPENDIX B

This appendix consists of fire scar data for fire history sites in mixed-conifer forest. Both unspecified injuries and fire scars were noted and recorded. Uppercase letters following fire scar dates refer to intra-ring scar position. U = Unknown; D = Dormant, i.e., on the boundary between two rings; E = Early earlywood, i.e., in the first third of the earlywood; M = Middle earlywood, i.e., in the second third of the earlywood; L = Late earlywood, i.e., in the last third of the earlywood; and A = Latewood, i.e., in the latewood. “FI” refers to “fire interval,”i.e., the number of years between that and the preceding fire scar. No intervals were computed between injuries or between fire scars and injuries.

EAST of TUB SPRING

Series 1 : ETS30
Inner Ring : 1772
Bark Date : 1996
Length of sample : 225
Number in final analysis : 146
Information on fire history :
1851 E fire scar
1886 M fire scar FI = 35
1994 U fire scar FI = 108

Series 2 : ETS31
Pith Date : 1769
Bark Date : 1967
Length of sample : 199
Number in final analysis : 82
Information on fire history :
1886 D fire scar
1917 U injury

BEAR WALLOW FLAT (BWF)

Series 1 : BWF01
Pith Date : 1724
Outer Ring : 1965
Length of sample : 242
Number in final analysis : 201
Information on fire history :
1765 M fire scar
1789 M fire scar FI = 24
1801 M fire scar FI = 12
1826 E fire scar FI = 25
1841 E fire scar FI = 15
1851 E fire scar FI = 10
1863 M fire scar FI = 12
1904 U fire scar FI = 41

FLYS PEAK (FLP)

Series 1 : FLP51
Inner Ring : 1793
Bark Date : 1996
Length of sample : 204
Number in final analysis : 171
Information on fire history :
1826 L fire scar
1838 L fire scar FI = 12
1851 M fire scar FI = 13
1868 M fire scar FI = 17
1877 M fire scar FI = 9
1886 M fire scar FI = 9
1994 L fire scar FI = 108

Series 2 : FLP52
Inner Ring : 1647
Outer Ring :1875
Length of sample : 229
Number in final analysis : 191
Information on fire history :
1685 E fire scar
1725 E fire scar FI = 40
1733 M fire scar FI = 8
1748 E fire scar FI = 15
1763 D fire scar FI = 15
1785 E fire scar FI = 22
1790 U injury
1818 D fire scar FI = 33
1838 U fire scar FI = 20
1849 U injury
1875 U fire scar FI = 37

Series 3 : FLP50
Inner Ring : 1682
Bark Date : 1996
Length of sample : 315
Number in final analysis : 299
Information on fire history :
1698 E fire scar
1721 E fire scar FI = 23
1737 E fire scar FI = 16
1760 E fire scar FI = 23
1775 E fire scar FI = 15
1798 E fire scar FI = 23
1838 E fire scar FI = 40
1851 E fire scar FI = 13
1863 E fire scar FI = 12
1886 E fire scar FI = 23
1994 E fire scar FI = 108

BOOGER SPRING (BGS)

Series 1 : BGS02
Pith Date : 1688
Bark Date : 1996
Length of sample : 309
Number in final analysis : 299
Information on fire history :
1698 E fire scar
1703 E fire scar FI = 5
1711 M fire scar FI = 8
1725 E fire scar FI = 14
1748 E fire scar FI = 23
1763 D fire scar FI = 15
1773 U fire scar FI = 10
1801 E fire scar FI = 28
1817 A fire scar FI = 16
1851 M fire scar FI = 34
1868 M fire scar FI = 17

Series 2 : BGS03
Inner Ring : 1733
Bark Date : 1996
Length of sample : 264
Number in final analysis : 249
Information on fire history :
1748 E fire scar
1763 E fire scar FI = 15
1773 E fire scar FI = 10
1789 E fire scar FI = 16
1801 E fire scar FI = 12
1817 A fire scar FI = 16
1826 U fire scar FI = 9
1851 E fire scar FI = 25
1886 E fire scar FI = 35
1994 U injury

Series 3 : BGS04
Pith Date : 1681
Outer Ring : 1868
Length of sample : 188
Number in final analysis : 144
Information on fire history :
1725 D fire scar
1748 E fire scar FI = 23
1752 U fire scar FI = 4
1763 E fire scar FI = 11
1773 U fire scar FI = 10
1779 E fire scar FI = 6
1785 U injury
1789 U fire scar FI = 10
1801 E fire scar FI = 12
1805 U fire scar FI = 4
1817 A fire scar FI = 12
1841 L fire scar FI = 24
1851 M fire scar FI = 10

Series 4 : BGS05
Pith Date : 1719
Outer Ring : 1887
Length of sample : 169
Number in final analysis : 149
Information on fire history :
1739 U fire scar
1748 D fire scar FI = 9
1763 D fire scar FI = 15
1773 D fire scar FI = 10
1785 M fire scar FI = 12
1801 E fire scar FI = 16
1817 A fire scar FI = 16
1826 L fire scar FI = 9
1841 M fire scar FI = 15
1851 M fire scar FI = 10
1868 E fire scar FI = 17
1886 M fire scar FI = 18

Series 5 : BGS06
Pith Date : 1678
Outer Ring : 1786
Length of sample : 109
Number in final analysis : 99
Information on fire history :
1688 E fire scar
1725 E fire scar FI = 37
1748 D fire scar FI = 23
1763 E fire scar FI = 15
1773 E fire scar FI = 10
1785 U fire scar FI = 12

Series 6 : BGS07
Pith Date : 1626
Outer Ring : 1815
Length of sample : 190
Number in final analysis : 94
Information on fire history :
1632 E injury
1661 U injury
1685 E injury
1725 E fire scar
1748 D fire scar FI = 23
1763 E fire scar FI = 15
1785 M fire scar FI = 22
1807 M fire scar FI = 22

Series 7 : BGS08
Inner Ring : 1785
Outer Ring : 1869
Length of sample : 85
Number in final analysis : 85
Information on fire history :
1785 M fire scar
1801 E fire scar FI = 16
1817 A fire scar FI = 16
1851 E fire scar FI = 34
1868 U fire scar FI = 17

Series 8 : BGS09
Pith Date : 1694
Bark Date : 1978
Length of sample : 285
Number in final analysis : 270
Information on fire history :
1709 M fire scar
1711 U fire scar FI = 2
1725 D fire scar FI = 14
1727 D fire scar FI = 2
1748 D fire scar FI = 21
1763 D fire scar FI = 15
1801 L fire scar FI = 38
1817 A fire scar FI = 16
1868 U fire scar FI = 51
1886 M fire scar FI = 18

Series 9 : BGS10
Pith Date : 1681
Outer Ring : 1855
Length of sample : 175
Number in final analysis : 166
Information on fire history :
1690 M fire scar
1697 E fire scar FI = 7
1711 E fire scar FI = 14
1725 E fire scar FI = 14
1748 U fire scar FI = 23
1763 U fire scar FI = 15
1773 D fire scar FI = 10
1785 M fire scar FI = 12
1801 D fire scar FI = 16
1817 A fire scar FI = 16
1826 D fire scar FI = 9
1851 M fire scar FI = 25

CIMA CABIN (CCF)

Series 1 : CCF01
Pith Date : 1645
Outer Ring : 1877
Length of sample : 233
Number in final analysis : 224
Information on fire history :
1654 U fire scar
1685 E fire scar FI = 31
1697 D fire scar FI = 12
1700 D fire scar FI = 3
1709 M fire scar FI = 9
1725 D fire scar FI = 16
1733 U fire scar FI = 8
1748 D fire scar FI = 15
1757 E injury
1773 U fire scar FI = 25
1785 E fire scar FI = 12
1794 M injury
1801 U fire scar FI = 16
1822 U fire scar FI = 21
1851 M fire scar FI = 29
1868 U fire scar FI = 17

SOUTH of CIMA PARK (SCP)

Series 1 : SCP01
Inner Ring : 1826
Bark Date : 1993
Length of sample : 168
Number in final analysis : 153
Information on fire history :
1841 A fire scar
1851 A fire scar FI = 10
1886 L fire scar FI = 35

Series 2 : SCP02
Inner Ring : 1692
Bark Date : 1994
Length of sample : 303
Number in final analysis : 270
Information on fire history :
1725 M fire scar
1776 U injury
1844 E fire scar FI = 119
1851 E fire scar FI = 7
1868 E fire scar FI = 17
1886 M fire scar FI = 18

Series 3 : SCP03
Inner Ring : 1836
Bark Date : 1994
Length of sample : 159
Number in final analysis : 154
Information on fire history :
1841 L fire scar
1848 D fire scar FI = 7
1849 D fire scar FI = 1
1851 L fire scar FI = 2
1868 M fire scar FI = 17
1886 L fire scar FI = 18

Series 4 : SCP04
Inner Ring : 1662
Bark Date : 1996
Length of sample : 335
Number in final analysis : 312
Information on fire history :
1685 E fire scar
1697 E fire scar FI = 12
1701 U injury
1709 U injury
1711 D fire scar FI = 14
1725 E fire scar FI = 14
1748 E fire scar FI = 23
1773 U fire scar FI = 25
1779 U injury
1801 U fire scar FI = 28
1806 E fire scar FI = 5
1817 U fire scar FI = 11
1841 U fire scar FI = 24
1868 U fire scar FI = 27

Series 5 : SCP06
Pith Date : 1648
Bark Date : 1990
Length of sample : 343
Number in final analysis : 306
Information on fire history :
1685 E fire scar
1697 U fire scar FI = 12
1711 U fire scar FI = 14
1723 U fire scar FI = 12
1733 D fire scar FI = 10
1744 U injury
1749 E fire scar FI = 16
1763 E fire scar FI = 14
1785 M fire scar FI = 22
1787 L fire scar FI = 2
1788 A fire scar FI = 1
1801 E fire scar FI = 13
1817 A fire scar FI = 16
1859 E fire scar FI = 42
1868 E fire scar FI = 9
1877 E fire scar FI = 9
1886 E fire scar FI = 9

Series 6 : SCP08
Pith Date : 1649
Bark Date : 1996
Length of sample : 348
Number in final analysis : 294
Information on fire history :
1703 E fire scar
1725 D fire scar FI = 22
1748 D fire scar FI = 23
1763 E fire scar FI = 15
1785 M fire scar FI = 22
1801 E fire scar FI = 16
1817 L fire scar FI = 16
1841 M fire scar FI = 24
1859 E fire scar FI = 18
1877 M fire scar FI = 18
1886 M fire scar FI = 9

ANITA PARK (ANT)

Series 1 : ANT01
Inner Ring : 1660
Bark Date : 1987
Length of sample : 328
Number in final analysis : 293
Information on fire history :
1664 U injury
1667 U injury
1685 U injury
1698 U fire scar
1711 M fire scar FI = 13
1748 U fire scar FI = 37
1763 E fire scar FI = 15
1773 E fire scar FI = 10
1801 E fire scar FI = 28
1818 D fire scar FI = 17
1841 M fire scar FI = 23
1851 L fire scar FI = 10
1868 M fire scar FI = 17
1877 M fire scar FI = 9

Series 2 : ANT02
Pith Date : 1670
Bark Date : 1974
Length of sample : 305
Number in final analysis : 261
Information on fire history :
1702 U injury
1711 M injury
1716 E fire scar
1748 E fire scar FI = 32
1763 E fire scar FI = 15
1773 E fire scar FI = 10
1785 L fire scar FI = 12
1801 E fire scar FI = 16
1818 E fire scar FI = 17
1841 E fire scar FI = 23
1851 L fire scar FI = 10
1859 E fire scar FI = 8
1868 M fire scar FI = 9
1877 M fire scar FI = 9
1886 M fire scar FI = 9

CHIRICAHUA PEAK (CHP)

Series 1 : CHP01
Pith Date : 1774
Bark Date : 1986
Length of sample : 213
Number in final analysis : 187
Information on fire history :
1800 D fire scar
1826 D fire scar FI = 26
1835 U fire scar FI = 9
1861 D injury
1865 D injury
1868 L fire scar FI = 33
1894 M fire scar FI = 26
1903 M fire scar FI = 9

Series 2 : CHP02
Pith Date : 1790
Bark Date : 1994
Length of sample : 205
Number in final analysis : 194
Information on fire history :
1801 E fire scar
1835 L fire scar FI = 34
1840 E fire scar FI = 5
1851 M fire scar FI = 11
1859 M fire scar FI = 8
1868 M fire scar FI = 9
1877 D fire scar FI = 9
1883 D fire scar FI = 6
1894 M fire scar FI = 11
1969 M fire scar FI = 75

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