Fire History of a Mixed Oak-Pine Forest in the Foothills of the Sierra Nevada, El Dorado County, California[1]

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Abstract: *Fire history and stand composition (species, density, basal area) of a mixed oak-pine forest was investigated in three plots with varied aspects (south, east) and slopes (5 , 30, and 50 percent) in Diamond Springs, El Dorado County, California. Elevation varied from 530 to 600 m in the fire history plots. Oaks dominate the area, contributing 75 percent of the basal area. Fire history information from 1850 to 1952 was obtained from 31 ponderosa pine stumps that were logged in 1952. Mean fire intervals in the three plots were 7.8, 7.8, and 7.7 years and the period between fires varied from 2 to 18 years. The last fire in this area occurred in 1947. Although the sources of these fires are uncertain, the use of fire by early range managers is a plausible explanation given the past land uses of this area.*

Vegetation types common in the Sierra Nevada foothills include foothill woodlands, chaparral, mixed evergreen woodlands, and California black oak (*Quercus kelloggii*) forests (Baker and others 1981). Very little fire history information exists for these vegetation types (Parsons 1981). The lack of fire history information is in part due to a lack of trees that are appropriate (old, fire-scarred trees resistant to decay) for fire-scar sampling because of early logging, range improvement, and firewood cutting operations.

One fire history study has been carried out in foothills of the Sierra Nevada at the University of California Sierra Foothill Range Field Station, 30 km east of Marysville, California (McClaran and Bartolome 1989). In this study, fire-scarred trees were sampled in a blue oak (*Quercus douglasii*) woodland. Mean fire intervals (MFI) (Stokes 1980) at two sites within the field station were 7.4 years. Fire intervals varied from 2 to 17 years and there was no significant difference ($p > 0.2$) in MFI between the sites from 1890 to 1948. MFI was significantly reduced between Anglo-American settlement in 1848 and fire suppression in the 1940's because of historic range management practices (McClaran and Bartolome 1989).

Fire scars can be assigned a calendar year when cross-dating techniques are used (Swetnam and others 1985). With this technique, a composite fire history can be produced, and differences in MFI over the sampling period can be examined. When cross dating techniques are not possible because of false and missing rings, intervals between fires have been reported (Finney and Martin 1992).

Significant Anglo-American settlement in foothill woodlands started shortly after the discovery of gold in 1848, and large numbers of livestock and alien annual plants became landscape dominants by 1900 (Burcham 1957). Early investigators reported that burning was a common practice in the foothills of the Sierra Nevada from 1900 to 1940 (Leiberg 1902; Sampson 1944). Ranchers commonly burned oak forests/woodlands to maintain forage production, and the intervals between fires were commonly between 8 and 15 years (Sampson 1944).

Native Americans also influenced the fire regime in the foothills of the Sierra Nevada. Native Americans possibly shortened the intervals between fires for specific land management objectives (Anderson 1993). More than 75 percent of the plant material used by most tribes of the Sierra Nevada came from epicormic branches or adventitious shoots from a diverse group of native plants (Anderson 1993). New shoots were long, flexible and straight, had few bark blemishes, and were not forked,

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making them excellent material for basket making. Shoots with these characteristics are produced only after fire or pruning. Native Americans also specifically burned areas with California black oak to reduce the loss of acorns to insects such as filbert worms (*Melissopus latiferreanus*) and filbert weevils (*Curculio* spp.) (Anderson 1993). Many of the Native American-ignited fires probably spread extensively through the mixed oak-pine forests in the foothills of the Sierra Nevada.

Fires that occurred prehistorically in the Sierra Nevada burned in a variety of sizes, severities, intervals, and, to a lesser extent, seasons (Swetnam and others 1992). Fire suppression has changed the prehistoric fire regimes of the Sierra Nevada by suppressing most low- and moderate-intensity events. This fundamental change has reduced pyrodiversity (the variety in intervals between fires, seasonality, and fire characteristics, producing biological diversity at the micro, stand and landscape scales [Martin and Sapsis 1991]) in mixed oak-pine forests of the Sierra Nevada. The resulting diverse ecosystem structures, in turn, produced the conditions necessary for future diverse fires. Today, most low- and medium-intensity fires are suppressed by wildfire agencies. The most extreme fires burn, because suppressing these fires is almost impossible given high fuel loads coupled with extreme fire weather (Stephens 1995).

The objective of this paper is to develop a fire history for a mixed oak-pine forest in the foothills of the Sierra Nevada. Information from this study can be used to determine the historic fire regime that occurred in this ecosystem in the late 19th and mid-20th centuries.

Methods

Study Area

Fire history was investigated in a mixed oak-pine forest in the foothills of the Sierra Nevada approximately 8 km southwest of the town of Diamond Springs, California (*fig. 1*). The plots are located in T9N R11E NE 1/4 of section 17, latitude 38° 38′, longitude 120° 46′ 45″, between 530 and 600 m above sea level, approximately 1.5 km northwest of the North Fork of the Cosumnes River.

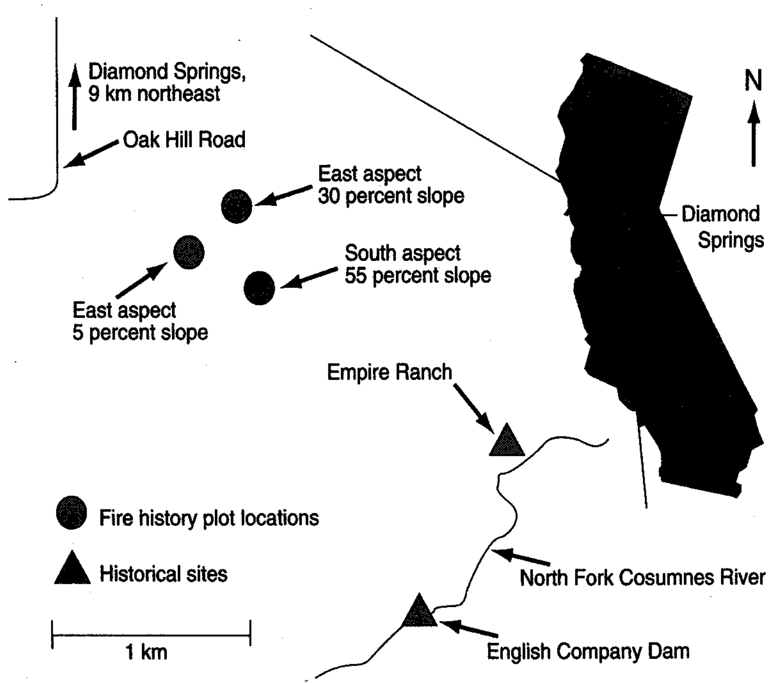

Figure 1—Location of fire history plots in a mixed oak-pine forest in the foothills of the Sierra Nevada, El Dorado County, California.

Forest Composition

Twelve 0.04-ha circular plots were randomly placed within the 10-ha study area to determine forest composition. All trees greater than 1.37 m in height were measured at diameter at breast height (DBH). The following stand parameters were calculated for each species: basal area (m^2/ha), tree density (trees/ha), average quadratic mean diameter (DBH), percent basal area by species, and percent tree density by species. The diameter of all ponderosa pine (*Pinus ponderosa*) stumps within the 12 plots were also measured, and stump density and basal area were calculated. Stump diameter was measured at approximately 40 cm above the soil surface.

Fire History

Thirty-one fire-scarred ponderosa pine stumps were sampled in three fire history plots. Combinations of aspect and slope (east aspect, 5 percent slope; east aspect, 30 percent slope; south aspect, 55 percent slope) were used to determine whether these factors affected MFI. The Smirnov test (Lehmann 1975) was performed to evaluate whether significant differences ($P < 0.05$) in MFI existed between sample locations (McClaran and Bartolome 1989). The sampled area was logged in 1952, and all ponderosa pines larger than 30 cm DBH were harvested. An extensive survey of the area produced only two live ponderosa pines with fire scars, and they were sampled to determine the last year that a fire had occurred in the study area. Fire-scarred interior live oak (*Quercus wislizenii*) trees were found in the study area, but determination of MFI was impossible because of extensive rot in the scarred area.

Ponderosa pine stumps were sectioned with a chainsaw in order to locate the best series of fire scars (Finney and Martin 1992); up to four wedges or full cross sections for each stump were removed and taken to the laboratory for analysis. All fire scar samples were sanded to a smoothness of 400 grit. Fire scars were identified by the characteristic disruption and healing patterns of radial tree-ring growth (McBride 1983, Finney and Martin 1992).

Intervals between fire scars were obtained by counting annual rings. Annual rings were counted along radii with the widest increment; often this involved tracing individual rings from zones of narrow growth to those of wider increment (Finney and Martin 1992). Scar intervals were assembled for each stump, and plot MFI was calculated by averaging all fire intervals within each of the fire history plots.

Results

This mixed oak-pine forest is composed of interior live oak, canyon live oak (*Quercus chrysolepis*), foothill pine (*Pinus sabiniana*), black oak, gray leaf manzanita (*Arctostaphylos viscida*), ponderosa pine, toyon (*Heteromeles arbutifolia*), valley oak (*Quercus lobata*), California buckeye (*Aesculus californica*), and blue oak in order of decreasing basal area (*table* 1). Average tree density was 1,635 trees/ha, and average basal area was 30.27 m^2/ha. Oaks dominate the area, comprising 75 percent of the average basal area, whereas ponderosa and foothill pines contributed 16 percent of the basal area. Ponderosa pine stump density was 16.67 stumps/ha (standard error = 4.7), and average stump basal area was 7.95 m^2/ha (standard error = 2.38). Stump diameter varied from 56 to 110 cm in all plots.

Average MFI for the east aspect 5 percent slope, east aspect 30 percent slope, and south aspect 55 percent slope were 7.8, 7.8, and 7.7 years, respectively (*table* 2). No significant differences ($P > 0.05$) in MFI were detected between the three fire history plots. Fire intervals varied from 2 to 18 years within the three plots (*figs*. 2–4).

Table 1—Summary of average mixed oak-pine forest inventory calculations in the foothills of the Sierra Nevada, El Dorado County, California[1]

Species	Basal area	Density	DBH	Pct basal area	Pct density
	m²/ha	*trees/ha*	*cm*	*pct*	*pct*
Interior live oak	14.50 (1.57)	692.53 (80.5)	16.54 (0.93)	47.91	42.35
Canyon live oak	5.62 (2.55)	200.09 (83.99)	17.73 (2.56)	18.57	12.24
California black oak	2.19 (0.66)	25.25 (8.70)	31.56 (3.03)	7.23	1.53
Gray leaf manzanita	2.17 (0.67)	260.74 (63.10)	10.45 (1.63)	7.18	15.94
Toyon	0.40 (0.13)	348.12 (84.19)	3.64 (0.20)	1.31	21.30
Foothill pine	3.54 (1.24)	33.42 (10.36)	38.24 (5.62)	11.69	2.04
Ponderosa pine	1.42 (1.14)	69.20 (24.45)	10.45 (2.43)	4.68	4.21
Valley oak	0.21 (0.02)	2.08 (0.03)	36.00 (3.01)	0.70	0.13
Blue oak	0.10 (0.01)	2.08 (0.03)	25.00 (2.08)	0.34	0.13
California buckeye	0.12 (0.01)	2.08 (0.03)	27.00 (2.25)	0.39	0.13

[1] Numbers in parentheses are standard errors.

Discussion

The length of the fire history record of the east aspect, 30 percent slope plot was 102 years (*table* 2), corresponding to 1850-1952 AD. This is the period when significant Anglo-American settlement occurred in the foothill woodlands, and during this period surface fires were common. The three plots had approximately equal MFI of 7.8 years which is similar to the MFI of 7.4 years found by McClaran and Bartolome (1989) in blue oak woodlands approximately 80 km northwest of this location.

The three fire history plots were approximately 1.5 km northwest (uphill) of the Empire ranch that began operations in 1868 (possibly earlier) adjacent to the North Fork of the Cosumnes River, T9N, R11E, S16 (Peabody 1988). This area was used as winter range for cattle (Peabody 1988). Mining was also common in this area, and the English Company Dam was constructed on the North Fork of the Cosumnes River (Peabody 1988) approximately 1.75 km southeast (downhill) of the fire history plots. The dam may have been a hydraulic mining debris basin and was the origin of a ditch weir diverting water for sluicing at Dead Man Hollow and Martinez Creek (Peabody 1988). The Alta California Telegraph line was located 2 km east of the fire history plots, and it was installed in 1856 (Peabody 1988). Mining, cattle grazing, and early development were therefore extensive in this area, beginning shortly after the discovery of gold in 1848.

A Miwok Native American community was located 4 km north of the study site in Squaw Hollow (Peabody 1988). This was an extensively used area and a ceremonial roundhouse was built at this site. Several bedrock mortars and

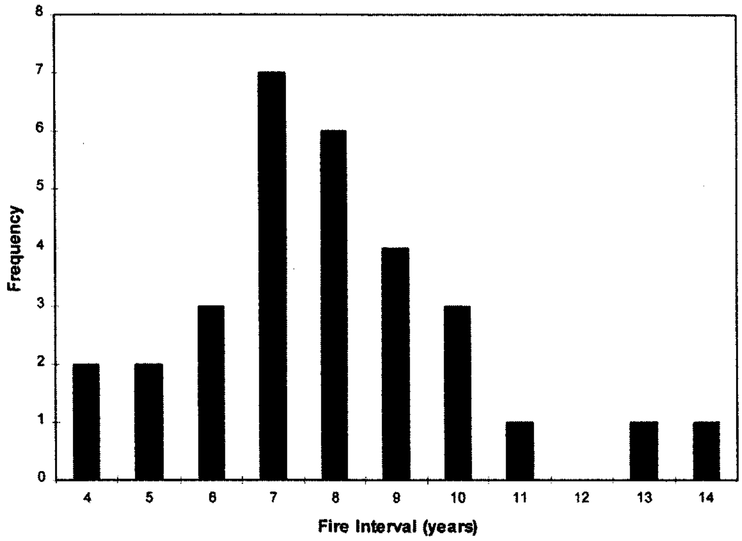

Figure 2—Distribution of fire intervals from the east aspect, 5 percent slope, fire history plot.

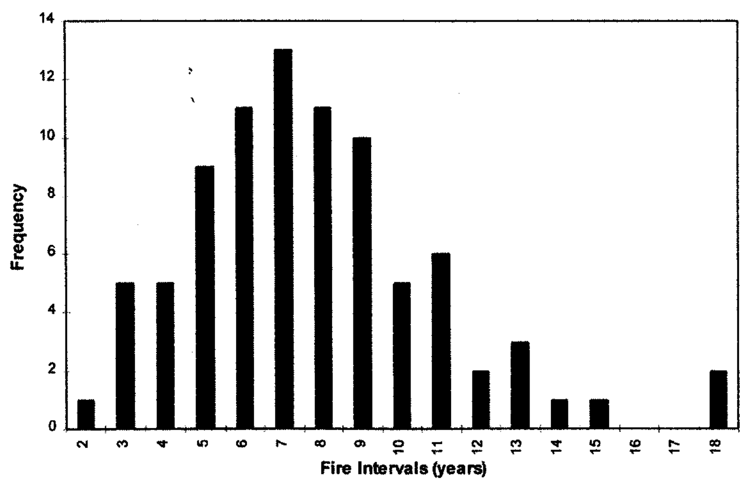

Figure 3—Distribution of fire intervals from the east aspect, 30 percent slope, fire history plot.

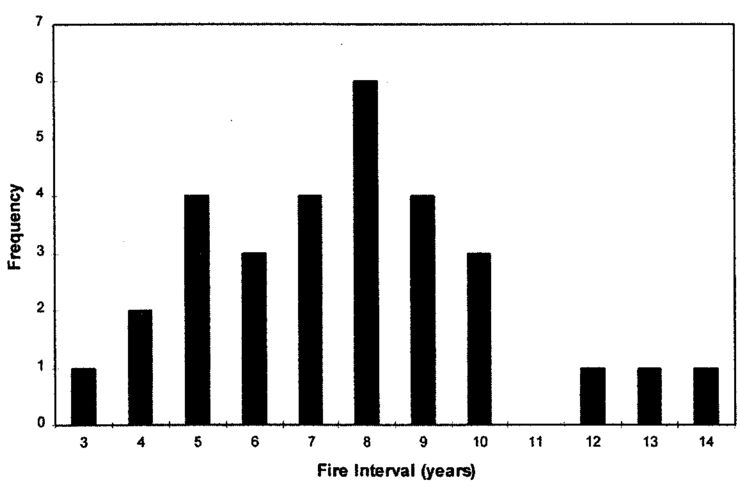

Figure 4—Distribution of fire intervals from the south aspect, 55 percent slope, fire history plot.

Table 2—Summary of fire history information in the foothills of the Sierra Nevada, El Dorado County, California

Plot location	East aspect 5 pct slope	East aspect 30 pct slope	South aspect 55 pct slope
Number of stumps sampled	7	17	7
Number of fire scars	30	85	30
Mean fire interval (yr)	7.8	7.8	7.7
Fire interval range (yr)	4 to 14	2 to 18	3 to 14
Median fire interval (yr)	7	7	8
Fire record length (yr)	87	102	82
Plot elevation (m)	600	560	530
Plot area (ha)	1.0	1.5	0.75
Last fire	1947	1947	1945

cremation grounds are located within 1.5 km of the fire history plots, indicating there was once a significant Native American presence in the region.

The fire history information analyzed in this study cannot be attributed to Native American burning because the record begins in the Anglo-American settlement period of 1850. The MFI found in this study agrees with the recorded burning practices of early ranchers (Sampson 1944).

Lightning fires are relatively rare in oak woodlands throughout California (Griffen 1988). During the 1970's, an average of 23 lightning ignitions were recorded annually for each 1,000,000 ha protected by the California Department of Forestry in the Amador-El Dorado ranger units (Keeley 1981). This study area is within the boundaries of the Amador-El Dorado ranger unit. In contrast, the number of lightning ignitions over the same period in the Eldorado National Forest was 148 for each 1,000,000 ha protected (Keeley 1981). Lightning ignitions are more common at higher elevations.

The exact origin of the fires recorded in this study cannot be determined. No comprehensive historical information exists on the number of lightning fires in this area from 1850 to 1952. Although the sources of these fires are uncertain, the use of fire by early range managers is a plausible explanation given the past land uses of this area. Other areas in the Sierra Nevada such as the mixed conifer forest had fire suppression programs beginning in the 1900's, but fires ignited for range management purposes continued at this location until the late 1940's.

Fire history studies can give accurate and precise information about the temporal distribution of the past fire regime, but MFI determined from all techniques will be conservative. This occurs because all fires may not scar a tree and scars may be destroyed by later fires, rot, and insects (Finney and Martin 1992).

Use of fire history information to reconstruct past forest structure is difficult. Evaluation of the effects and behavior of past fires is limited when the fuel complexes they operated within were fundamentally different than the present. Surface fuel complexes present during the Anglo-American settlement period in the foothills of the Sierra Nevada were dominated by annual grasses (Burcham 1957) because of the frequent burning and livestock grazing. These fires were probably of relatively low intensity (Byram 1959), but they spread extensively through the foothill communities because of high horizontal fuel continuity from the grasses.

No significant differences in MFI were detected between the three fire history plots in this study. High surface fuel continuity allowed most fires to spread throughout the study area and, therefore, similar MFI were recorded in each fire history plot. Fires that were ignited near the North Fork of the Cosumnes River could have easily spread uphill and were recorded in the fire history plots.

The study site had some relatively large ponderosa pines before being logged in 1952. The largest stump measured had a diameter of 110 cm that is much larger than the current maximum of 47 cm DBH. This forest was likely relatively open before fire suppression began in the late 1940's. Fire scars recorded in this study could have been produced from the consumption of leaf litter, dead and down fuel, and annual grasses. Current tree density of 1,635 trees/ha has produced a forest structure that is more susceptible to large, high-intensity wildfires. Frequent burning in this ecosystem reduced fire hazard because of the reduction in fuel load and fuel continuity.

A large prescribed burning program could be implemented again in this area, but restrictions from home building and development would complicate the process. Many homes have been built on 2- to 8-ha parcels in this region of El Dorado County since 1970. This development has produced a fragmented urban-wildland intermix area, and prescribed burning programs would be difficult to implement.

Conclusion

Average MFI in this mixed oak-pine forest were approximately 7.8 years from 1850 to 1952. Fire intervals varied from 2 to 18 years in this ecosystem during the early settlement period. Although the sources of these fires are uncertain, the use of fire by early range managers is a plausible explanation given the past land uses of this area.

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