NATIVE AMERICAN FIRE PATTERNS IN YOSEMITE VALLEY: A CROSS-DISCIPLINARY STUDY

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ABSTRACT

The inability to distinguish between human-caused and lightning ignitions in fire-history studies has led to three major problems: 1) a basic assumption that all pre–Euro-American settlement fire regimes are ''natural'' unless findings are aberrant, i.e., outside the range of ''natural'' lightning fire regimes; 2) a lack of studies that explicitly or quantitatively determine ignition sources; and 3) use of regional anthropological overviews rather than site-specific ethnographic and archaeological data.

A cross-disciplinary dendrochronological fire history and archaeological study conducted in Yosemite Valley, Yosemite National Park, California, shows that fire return intervals in areas with no historical lightning ignitions and a large Native American population were similar to those in locations with a high number of lightning ignitions. Native American fire regimes in Yosemite Valley consisted of spatially small, low-intensity surface fires in all areas regardless of differences in distance from a village site, identified land uses, or village size. Fire patterns appear to be independent of climatic fluctuations and dependent on human disturbance patterns. Archaeological and ethnographic data show no major difference between the population size, land-use patterns, or material culture of the Ahwah'-nee, the prehistoric occupants of Yosemite Valley, and other native groups in the Sierra Nevada or Great Basin. The cultural data and initial findings from this study suggest that lightning and Native American influences on fire regimes cannot be differentiated based only on fire return intervals and fire regimes; additional cross-disciplinary studies are needed to gain better understanding of human–fire interactions.

keywords: anthropogenic fire regimes, archaeology, California, fire history, mixed conifer, Sierra Nevada, Yosemite Valley.

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INTRODUCTION

Within California and the Sierra Nevada, anthropological studies have shown that Native Californians used fire to manipulate vegetation for various reasons (Reynolds 1959, Lewis 1973, Pyne 1983, Gruell 1985, Roper Wickstrom 1987, Anderson 1988, Anderson and Moratto 1996, Williams 2003). Ethnographic data from throughout North America illustrate 11 broad cross-cultural categories or motives for fire use: hunting, crop management to increase growth and yields, fire proofing areas, insect collection, pest management, warfare or economic extortion, clearing areas for travel, felling trees, clearing riparian areas, ''careless campfires,'' and ritual use (Stewart 1956, Lewis 1973, Barrett 1981, Anderson 1988, Bonnicksen et al. 1999, Williams 2003).

The debate over Native American use of fire and its effects is not new, but over recent years has re-emerged as a research topic. It is often a polarizing debate, and as an attempt to bring greater understanding to this topic, this study used both a dendrochronological fire history and anthropological studies to test common assumptions from both sides of the debate. The first step is to test the basic assumption of whether we can distinguish between a ''natural'' lightning fire regime and an anthropogenic fire regime through fire history alone.

From the viewpoint of an anthropologist, fire histories assume all pre–Euro-American settlement fire regimes are ''natural'' unless findings are aberrant, i.e., outside the range of lightning fire regimes. It is often assumed that anthropogenic fire signatures are outside of the natural fire regime. For the purposes of this paper, *natural fire regime* is that obtained through lightning ignitions only. Often it is implied that anthropogenic fire regimes will be different due to either shorter or longer fire return intervals than produced by lightning alone, fires occurring during seasons when lightning does not generally occur, and fires that are asynchronous with climate trends (i.e., fire in wet years and no fire in dry years).

These ideas have not been strenuously tested because the majority of published dendrochronological fire history studies have not explicitly or quantitatively determined ignition sources; and such studies use broad regional anthropological overviews rather than site-specific ethnographic and archaeological data. In this study, I test those assumptions using fire-scar data and archaeological data.

STUDY AREA

As a first step to understanding how one Native American tribal group may have burned the landscape, I sought a location where fire scars could be attributed

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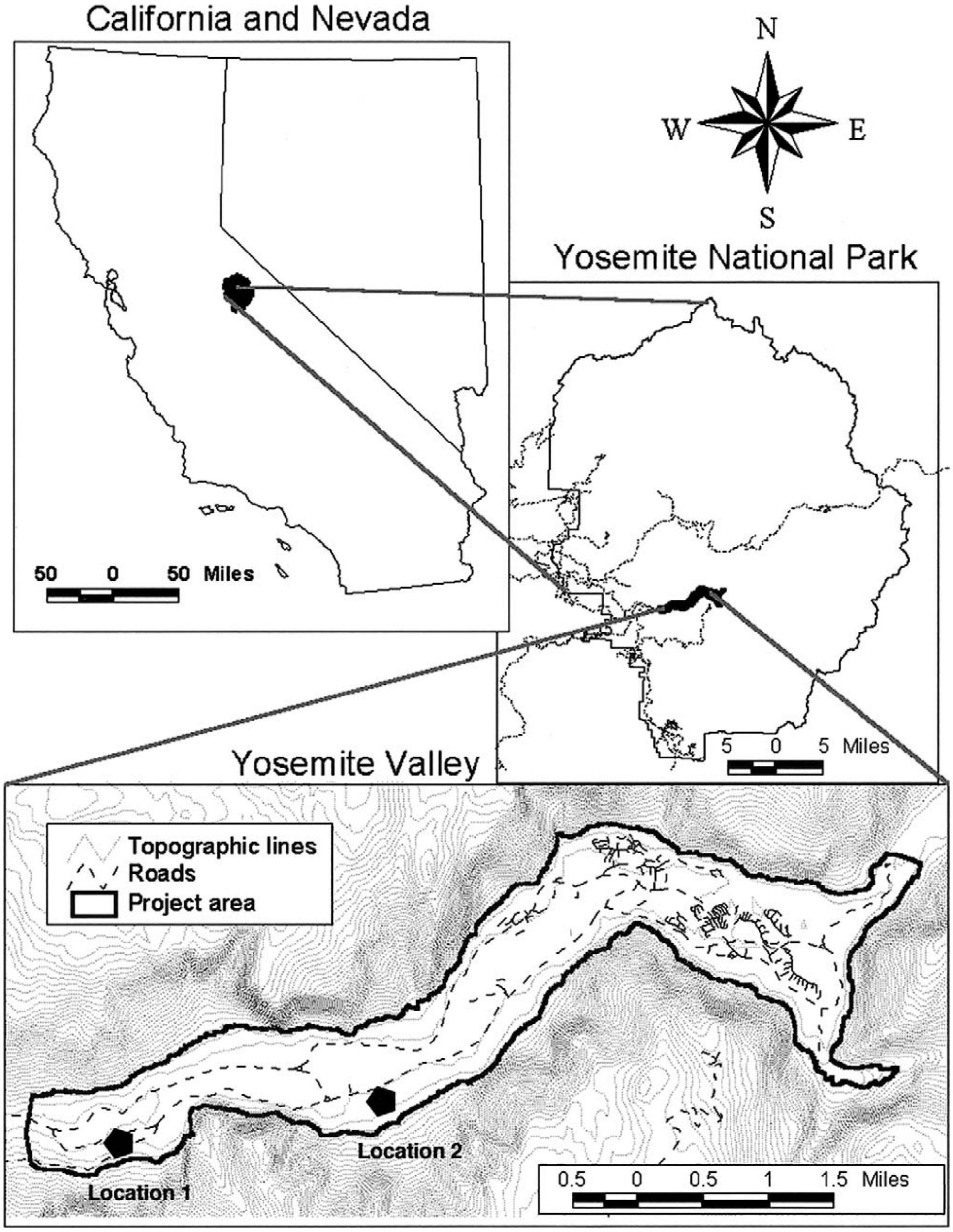

Fig. 1. Location of study sites in Yosemite Valley, Yosemite National Park, California.

largely to ignitions by humans, due to a lack of lightning ignitions in the area, and where ethnographic and archaeological data were available to determine the spatial relationship of fire to known periods of occupation. Such a location would have a unique geography that lacked lightning-ignited fires, ethnographic data with known village sites and gathering areas, and archeological data that supported the ethnographic data.

Yosemite Valley (37.7438°N, 119.5900°W [NAD83/WGS84]), in Yosemite National Park, on the western slope of the central Sierra Nevada of California, fit these criteria. Located approximately 250 km east of San Francisco, Yosemite Valley was a glacially carved valley approximately 1.6 km wide by 11.4 km long (Figure 1). The valley was a U-shaped cross section, with broad expanses of glacially scoured granite cliffs topped by exposed bedrock domes. The valley floor was at approximately 1,200 m in elevation.

The climate of the western slope of the Sierra Nevada was montane, with cool, moist winters and warm, dry summers. The high elevation of the Sierra Nevada presented a barrier to the pattern of prevailing storms moving east from the Pacific Ocean. Winter snows occurred in areas above approximately 1,065 m; Yosemite Valley was often snow-free, allowing year-round occupation (Hull and Kelly 1995). Yosemite Valley was located within the Sierran Montane Forest Mixed-Conifer vegetation type.

Ethnographic studies have shown that the Southern Sierra Miwok, who inhabited Yosemite Valley, used fire for crop management for at least 250 different plants (Barrett and Gifford 1933; Anderson 1988, 1993; Bibby 1994). Ethnographic work conducted within Yosemite Valley identified 23 plants obtained from 35 traditional gathering locations (Bibby 1994).

While the Southern Sierra Miwok probably used fire for all 11 of the cross-cultural motives previously listed, the topographic limitations of Yosemite Valley and cultural needs of the Ahwah'-nee probably made crop management the most common reason for using fire in this area. Fire was one tool used as part of intensive individual plant- or patch-level management practices that were required to produce the highest quantity of materials required for subsistence, basketry, cordage, and building (Anderson 1988).

Lightning Ignitions in Yosemite Valley

Since records have been kept, beginning in 1930 through 2002, no lightning-ignited fires were recorded on the floor of Yosemite Valley (National Park Service 2002). Modern fire-history data indicate that fewer lightning-caused fires occurred in the valley floor than in other areas of similar elevation within the park. Yosemite National Park contained approximately 256,975 vegetated burnable ha (635,000 acres) and averaged 41.5 lightning fires per year from an average of approximately 1,200 lightning strikes (van Wagtendonk 1993). Between 1930 and 2002, 2,877 lightning fires burned 69,759 ha (172,379 acres) within Yosemite National Park (National Park Service 2002). Yosemite Valley was located within the elevational range of 910–1,830 m, which had a high density of lightning-strike fires (van Wagtendonk 1993). A geographic information system (GIS) overlay of modern fire-history data (National Park Service 2002) and the study area showed that no lightning-ignited fires started or spread into the study area between 1930 and 2002.

While no published studies have reported the lack of lightning-ignited fires within Yosemite Valley, absence of such fires, in part, was likely due to the topography of the valley and its surrounding cliffs. Lightning strikes are a function of topography and gravitate toward high points, with ridge tops and mid-slope prominences being the most likely struck, features that are decidedly lacking on a valley floor (Komarek 1967). In a study from the Yosemite region, Reynolds (1959) found that of 319 lightning fires, 83% occurred in either the top or middle portion of a slope. The high granite walls that surrounded Yosemite Valley probably received the vast majority of lightning strikes in the valley area, resulting in more fires on the valley rim, above the valley floor, and outside the study area. Why the relatively few lightning strikes that occurred on the floor of Yosemite Valley did not cause fires at the same rate as in other areas is beyond the scope of this study.

Ethnographic and Archaeological Overview

Ethnographic studies show that Yosemite Valley was within the traditional territory of the Southern Sierra Miwok, although several other groups traveled to the valley for purposes of trade and possibly for limited periods of residence (Bennyhoff 1956, Hull and Kelly 1995). The Sierra Miwok were divided into tribelets. A tribelet consisted of approximately 100–300 people. Each tribelet controlled the natural resources within a defined territory and inhabited several permanent settlements and a larger number of seasonal campsites (Gifford 1916, Broadbent 1960). Merriam identified the inhabitants of Yosemite Valley as "the Ahwaneech or Ahwah'-nee Mew'-wah" (Merriam 1917). According to Merriam (1917), occupation in Yosemite Valley consisted of both permanent villages occupied throughout the year and summer camps used from May through October, and the valley was "somewhat depleted in the winter" when the residents moved down to the Merced River Canyon.

Numerous archaeological investigations have identified 130 sites of which >100 contain evidence of Native American use (Bennyhoff 1953, 1956; Grosscup 1954; Napton et al. 1974; Napton 1978; Hull and Kelly 1995). The archaeological evidence suggests that areas within Yosemite National Park have been inhabited since 7500–6000 BC. Currently, the first occupation observed within Yosemite Valley was radiocarbon-dated to 5200 BP (Moratto 1999). Archaeological data show that Yosemite Valley has been occupied continuously since this period. Changes in material culture suggest that the Miwok arrived in Yosemite Valley at approximately 700–450 BP (Moratto 1999). The material culture from the Yosemite region has suggested nine major periods or phases of occupation (Table 1).

Table 1. Proposed cultural chronology for Yosemite Valley, California (after Moratto 1999).

Date	Period	Phase
Post AD 1945	Historic 4	
AD 1891–1944	Historic 3	
AD 1864–1890	Historic 2	Rancheria
AD 1848–1863	Historic 1	Tenaya
AD 1800–1847	Protohistoric	Yosemite
AD 1350–1800	Late Prehistoric 3	Mariposa
AD 650–1350	Late Prehistoric 2	Tamarack
1200 BC–AD 650	Late Prehistoric 1	Crane Flat
3500–1200 BC	Intermediate Prehistoric 2	Merced Wawona
6000–3500 BC	Intermediate Prehistoric 1	Unnamed
7500–6000 BC	Early Prehistoric 4	El Portal

METHODS

Study Site Selection

Study sites consisted of a village paired with a gathering area and a fire-history "control" area in close proximity to each other. Within each study site, village, gathering, and control areas had no major topographic or geological barriers to ground fire spread (e.g., the gathering area could not be on a forested island within a landslide or river, separated from its paired village and control). These pairings capture the gradient of human land use from human occupation to resource extraction to nonuse.

Villages had to correspond with a village site identified in historic or ethnographic literature or field notes, archaeological data had to place occupation of the site partially or entirely within the latter portion of the Late Prehistoric 3, Protohistoric, or Historic 1–3 periods. Traditional gathering areas must have been identified in Bibby (1994) and controls must have lacked evidence of archaeological occupation and lacked evidence of use as a traditional gathering area. All areas were required to have 10–30 fire-scarred trees in or immediately surrounding the sampling area.

Historic and ethnographic records, including the work of Stephen Powers (1871–1876), S.A. Barrett and E.W. Gifford (1906–1920s), C. Hart Merriam (1900–1920s), Brian Bibby (1994), and M. Kat Anderson (1980s–1990s), were reviewed for information on village locations and land-use patterns (Gassaway 2004). All location-specific information was transferred into GIS. Historic and ethnographic maps were scanned and georeferenced using ArcView 3.2a and Arc/Info 8.02 (ESRI, Redlands, CA).

Archaeological surveys and excavation data were overlaid with the historic and ethnographic data layers to determine the known physical manifestation of Native American occupation and land use.

Based on the spatial analysis of human occupation, I conducted fire-history surveys focused on areas in and around each village to locate well-preserved, fire-scarred trees. Fire-scarred trees were mapped using a Global Positioning System (GPS) unit (Garmin, Olathe, KS; Trimble, Sunnyvale, CA; Magellan, Santa Clara, CA). GPS point locations were converted into a density grid of fire-scarred trees per hectare. The density grid was overlaid with ethnographic village sites, gathering areas, and prescribed fire locations (1970–2002).

Based on potential for numerous fire scars and spatial correspondence with ethnographic, archaeological, and gathering areas, three study sites were chosen for fire-history sampling and further archaeological investigations.

Archaeological Investigations

Surface archaeological constituents at the three study sites were reevaluated to determine if archaeological excavations were needed to refine period of occupation and extent of use. At one location, the extensive surface artifacts confirmed that occupation occurred throughout the Late Prehistoric, Protohistoric, and Historic periods. Two locations had minimal surface artifacts that were unreliable for dating, and limited archaeological testing took place to better define periods of occupation. Archaeological testing consisted of surface scrapes and shovel tests placed on a north–south and east–west grid that bisected at 5- or 10-m intervals. Surface scrapes consisted of 1 × 1-m units where all duff was removed to expose mineral soil. Shovel tests were 50 × 50 cm and limited to maximum depth of 50 cm. All soils were screened using 1.6-mm (1/16-inch) screen. I fully analyzed and categorized all artifacts collected based on Wilson et al. (2002), except lithic materials, which were analyzed and categorized based on Byram (1996).

Fire History Methods

At each study site, 30–90 ‘‘cookies’’ and wedges from live and dead incense cedar (*Calocedrus decurrens*) and ponderosa pine (*Pinus ponderosa*) were collected. This consisted of 10–30 samples from each village, gathering area, and control. The Vegetation Dynamics Lab at Pennsylvania State University and I conducted analysis of the fire-scar samples. All samples were air-dried and sanded until ring structure detail was visible. Specimens were cross-dated by matching common patterns of wide and narrow rings in comparison to local master chronologies (King 1991, Stephens and Collins 2004). For cross-dating specimens, I used methods based on Stokes and Smiley (1996) and Pennsylvania State University used methods based on Yamaguchi (1991). Fire scars were identified using 1) the presence of a gap or break within a ring or along a ring boundary, 2) charred wood within the gap or break, and 3) subsequent overlapping curvilinear growth over the gap (Stokes 1980, Dieterich and Swetnam 1984, Savage and Swetnam 1990). Each fire scar was assigned a calendar year. Scar positions were assigned to one of six categories: 1) early earlywood (first one-third of earlywood), 2) middle earlywood (second one-third of earlywood), 3) late earlywood (last one-third of earlywood), 4) latewood (in latewood), 5) dormant (at ring boundary), or 6) undetermined (Baisan 1990, Kaye and Swetnam 1999).

Statistical differences in fire-history data between the sampling areas, villages, and time periods were determined with Student's *t*-test, *F*-test, and two-sample Kolmogorov–Smirnov test produced using FHX2 software (Grissino-Mayer 2001). In order to determine when culture change or Euro-American influence may have affected Native American burning patterns, time periods developed by Moratto (1999) (Table 1) were used to compare changes of composite mean fire interval (MFI) over time. Statistical comparisons of each time period to subsequent periods were conducted using FHX2 software. To determine if patterns of anthropogenic fire use differed based on land-use patterns, fire-scar data were analyzed based on anthropological land-use types. At both study sites, fire-scar data were subdivided based their proximity to the village, gathering area, and control (Figures 2, 3).

RESULTS

Archaeological Excavations

Archaeological excavations were unable to locate any physical manifestations of Native American occupation at one study area. Surface manifestations and excavations found that two sites in the southwest portion of Yosemite Valley had Native American occupation during the Late Prehistoric 3, Protohistoric, and/or Historic 1–3 periods (Figure 1).

Location 1, the village of Sap-pah'sam-mah, was identified in the 1890s as ‘‘the lowermost (most westerly) village or camp on south side of the valley, about half a mile east of Pohono Meadows’’ (Merriam 1917: 205) (Figure 2). Archaeological evidence for Sap-

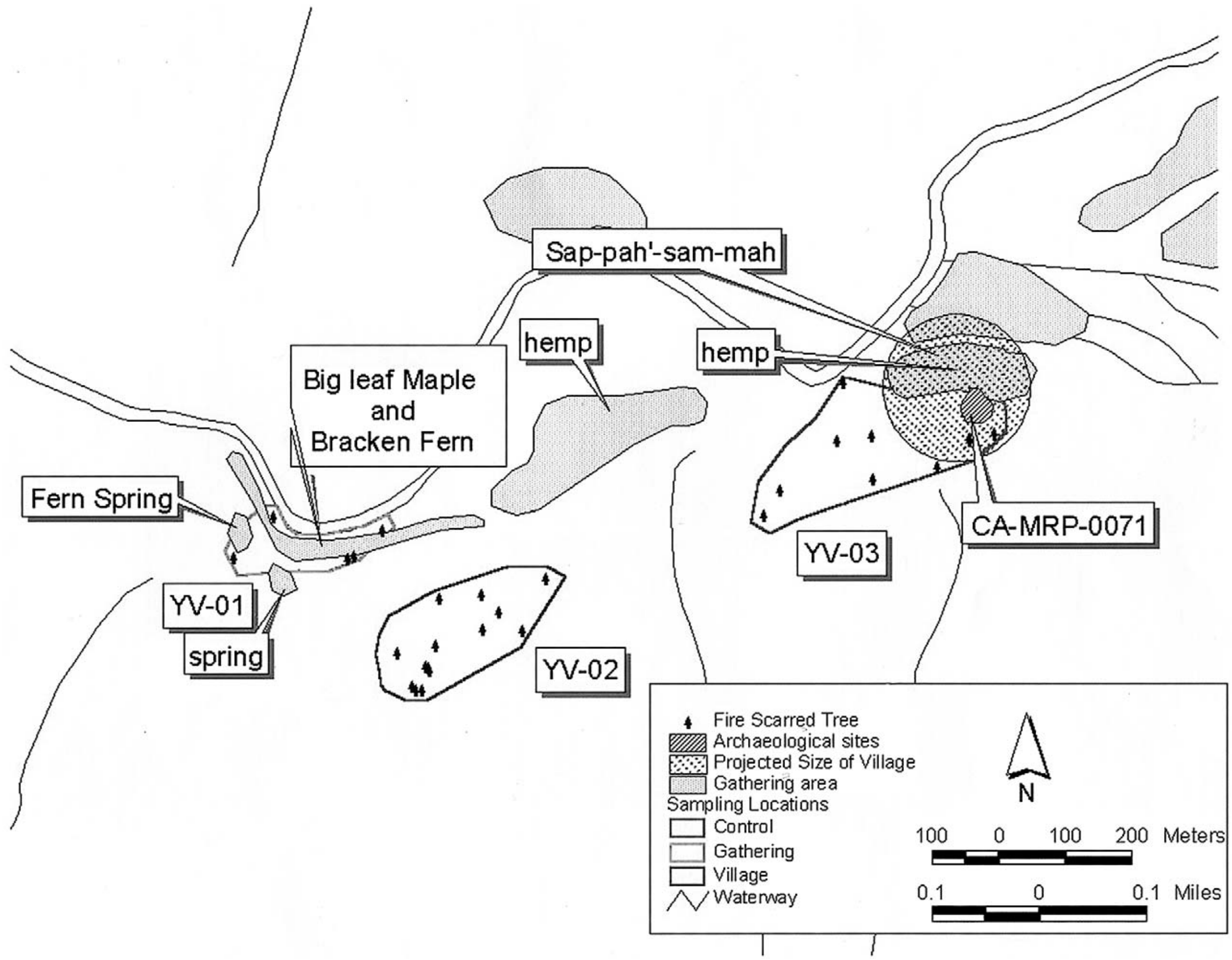

Fig. 2. Fire-scar samples from areas associated with the village of Sap-pah'sam-mah (location 1), Yosemite Valley, Yosemite National Park, California.

pah'sam-mah consists of one archaeological site, CA-MRP-71. Artifacts from the site were consistent with two periods of occupation. A late prehistoric period consisting of small obsidian retouch flakes and debitage, one transverse side scraper, and one blue glass trade bead, were all consistent with Merriam's description of a seasonal camp with possibly seasonally low-intensity use and with a low diversity of use. A second period of use consisted of artifacts dating from ca. 1870 to 1960s, which is consistent with Euro-American occupation and tourism associated with the Wawona Road, which opened in 1875.

Location 2, the village of Kis'-se, is located mid-valley, south of the Merced River (Figure 3). The first documented use of this area by Native Americans occurred in 1879 on the Wheeler Survey map (Wheeler 1883, Hutchings 1886). The map indicates that the area northwest of Kis'-se and its adjacent gathering area was ''Indian Pasture.'' The first written description of Kis'-se was by C. Hart Merriam (1917:207), who described Kis'-se or Kis's-se-uh it as a ''large village near the river . . . Kis'-se was the westernmost of the large villages on the south side.''

The village of Kis'-se consists of the archaeological site CA-MRP-76, which consists of midden soils, two stationary milling outcrops with 50 mortar cups, and an obsidian debitage scatter (Hull and Kelly 1995). C. Hart Merriam's identification of Kis'-se, and surface constituents, are consistent with Protohistoric and Historic 1 occupation.

Fire History

The fire return intervals observed in the dendrochronological fire history, AD 1552–2004, revealed a composite MFI of 1.92 and a point MFI of 17.83 y with a range of 1–56 y (Figure 4; Tables 2, 3).

Significant differences in burning patterns occurred between the Late Prehistoric 3 (AD 1350–1800) and Protohistoric (AD 1800–1847) periods and the Historic 2 (AD 1864–1890) and Historic 3 periods (AD 1891–1944) (Table 4). The majority of land-use types showed no statistical difference between any of the other land-use areas by time period. The only statistical difference was between the bigleaf maple (*Acer macrophyllum*) and bracken fern (*Pteridium aquilinum*) gathering area, YV-01 (Table 3). When data from land-use types at both village sites were merged, no differences were detected. Each land-use type showed

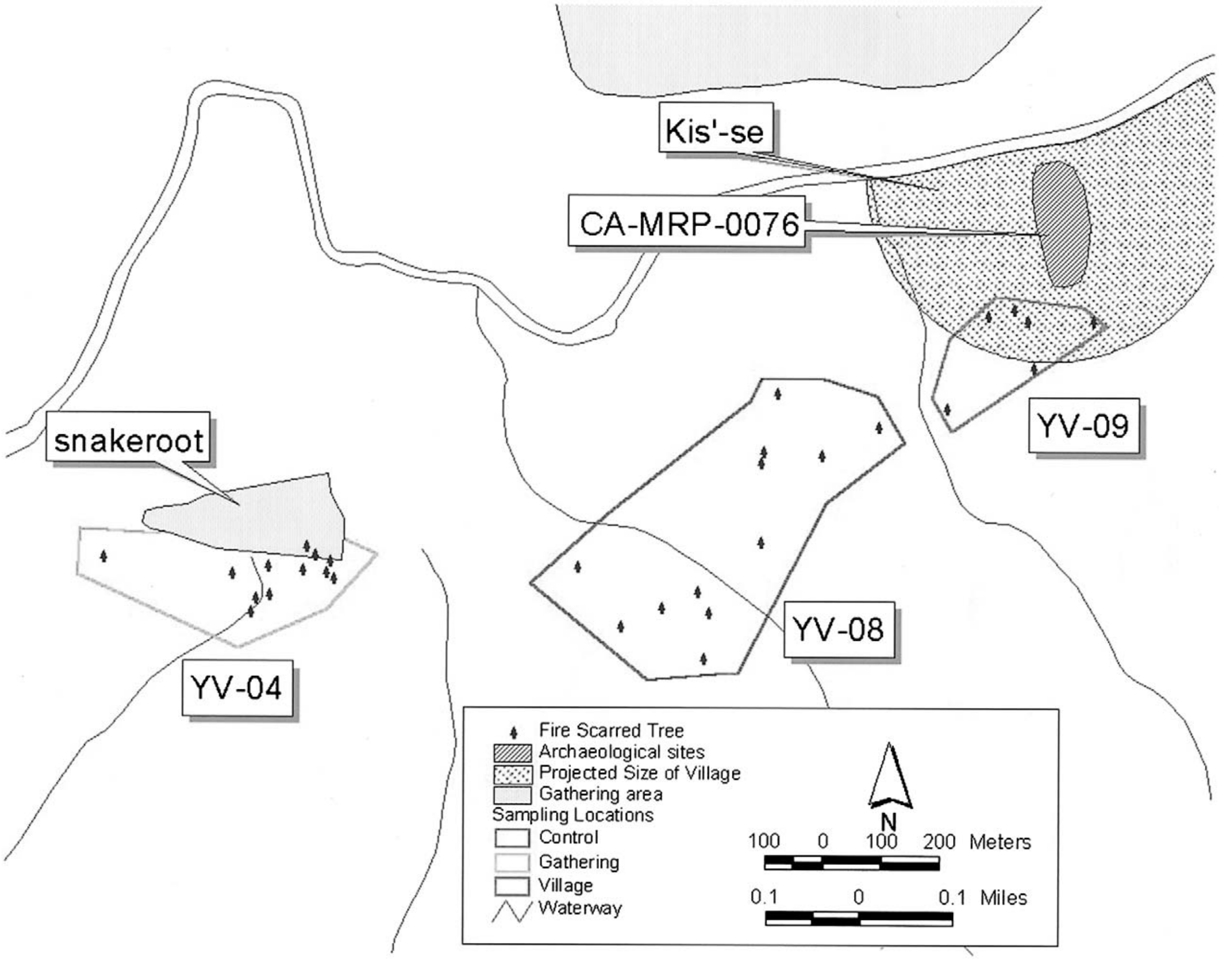

Fig. 3. Fire-scar samples from areas associated with the village of Kis'-se (location 2), Yosemite Valley, Yosemite National Park, California.

similar change in fire history over time, as did both study sites (Figure 5).

C. Hart Merriam (1917) suggested differences existed in the amount and extent of Native American use between the two study sites. Merriam identified occupation at location 1, Sap-pah'sam-mah, as a village or camp and location 2, Kis'-se, as a large village. The archaeological remains confirm a difference in the geographic extent of the two villages. Kis'-se (CA-MRP-76) encompassed 1.6 ha while Sap-pah'sam-mah (CA-MRP-71) extended only 0.2 ha. To determine if the village size had an effect on fire return intervals, all samples associated with Sap-pah'sam-mah (YV-01, -02, and -03) and Kis'-se (YV-04, -08 and -09) were combined and compared with a two-tailed *t*-test and a chi-square test.

The two-tailed *t*-test showed no significant differences in fire history during the time periods analyzed (Figure 5). The two locations were then compared for synchrony in fire dates to determine if fires observed at the two villages could have been produced by the same fire events. Only during five years (1775, 1783, 1800, 1841, 1864) did $\geq$10% of the samples show potential for being produced by the same fire (Table 5). When the analysis was expanded to $\geq$25% of the samples scarred, no fire year showed the potential for being produced by the same fire.

The high frequency of fires and lack of synchronicity between villages suggests that the fires were spatially small, low-intensity surface fires and not crown fires. Visual observations of the spatial fire-scar data suggest that multiple small patches of 0.1–0.5 ha were burned each year.

DISCUSSION

Modern fire records kept between 1930 and 2002 show no lightning-ignited fires on the floor of Yosemite Valley, creating a modern lightning fire return interval of approximately 70+ y. Discussion of the cause of this lack of lightning-ignited fires on the floor of Yosemite Valley is beyond the scope of this paper. For this study, it is sufficient that there is a significant difference between the number of lightning-ignited fires and the fire return intervals in the dendrochronological fire history.

The fire regime surrounding Native American occupation was frequent, spatially small, low-intensity surface fires. These small fires were probably set in

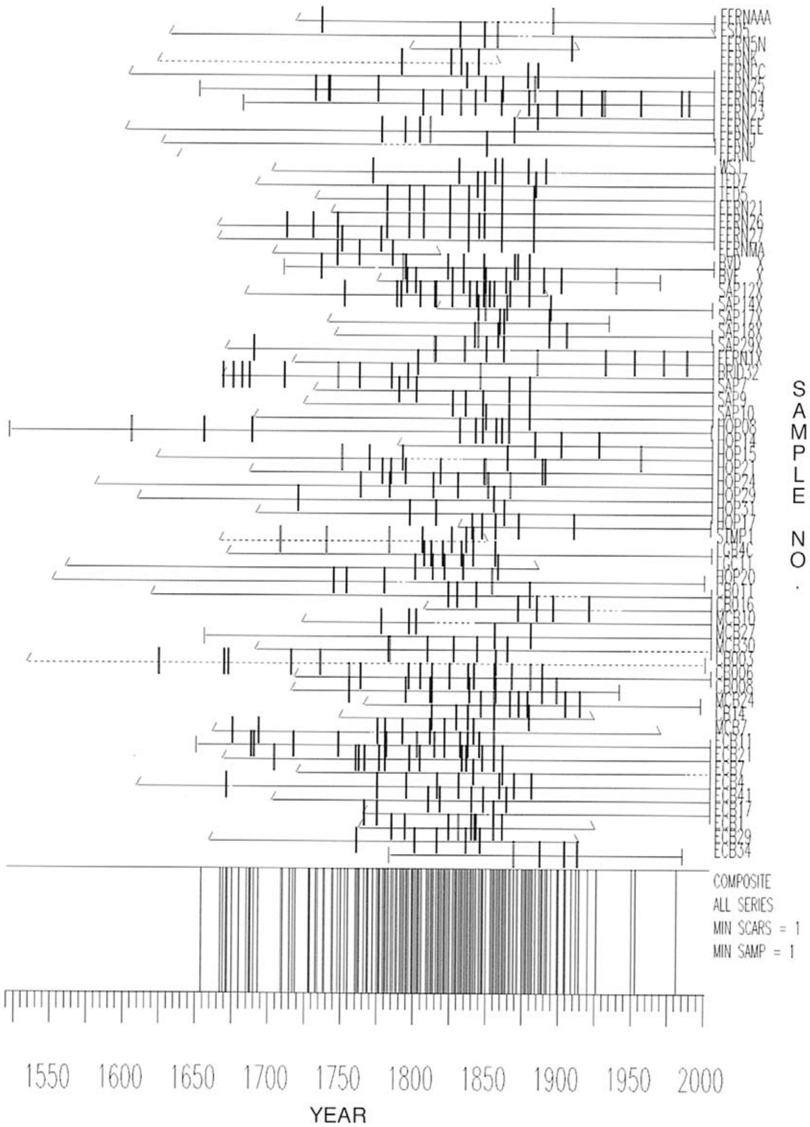

Fig. 4. Fire history for all samples, Yosemite Valley, Yosemite National Park, California.

rotation, creating a highly dynamic patchwork of different vegetation communities and communities in various stages of succession. This pattern was consistent regardless of land-use patterns. The one location that did show a difference, YV-01, had less to do with shifts in Native American fire use than a problem of sample size and proximity to a stable water source. Only five samples could be cross-dated from YV-01. The location was adjacent to the Merced River and a

Table 2. Fire interval analysis by sample size, Yosemite Valley, California.

Variable	Study area	Sample area	Sample
Area (ha)	30	1.5–11	Tree
No. of samples	57	5–14	
Mean fire interval	1.92[a]	4.69–17.83[a]	17.7[b]
Weibull median	1.61	3.33–16.5	
Interval range	1–11	1–43	2–56

[a] Composite interval.
[b] Point interval.

spring, both stable water sources that created highly complacent tree rings. Complacent tree rings showed little variation based on climate and limited the ability to cross-date samples.

The fire frequency changed over time, and these changes were consistent with known cultural time periods and cultural changes observed in the archaeological record. Changes observed included longer fire intervals prior to AD 1800 and shorter fire intervals post–AD 1800. This suggests that, at least for the southwestern portion of Yosemite Valley, something impacted the Native American burning patterns during the late Prehistoric 3 period. The change was likely associated with the cultural change created by Spanish occupation of the California coast.

The decrease in fire return intervals shows that more fire was being applied to the southwestern portion of Yosemite Valley post–AD 1800. Following cultural changes that occurred prior to AD 1800, the use of fire remained stable throughout the early historic periods. This stability remained despite large-scale,

Table 3. Mean fire intervals based on land use during each archaeological time period, Yosemite Valley, California.

Land-use classification	All time periods	Time period				
		Late Prehistoric 3	Protohistoric	Historic 1	Historic 2	Historic 3
All samples	1.92	2.4	1.09	1.5	1.47	5
Gathering areas	4.62	5.13	2.35	2.2	5.75	
Controls	3.12	3.31	1.92	2	1.71	8
Village	3.9	3.96	1.62	1.75	3.29	9.75
Location 1	3.48	3.64	1.68	1.56	1.85	6.5
Location 2	2.71	3.4	1.38	1.86	1.92	5

historically documented changes that occurred in both the region and Yosemite Valley, in particular (e.g., 1849 California gold rush, Mariposa Battalion, Euro-American occupation in Yosemite Valley).

The almost complete cessation of fire after 1890 coincides with the Yosemite Act of 1890 in which Congress set aside areas surrounding Yosemite Valley and created Yosemite National Park when guardianship of these lands surrounding Yosemite Valley fell to the U.S. Cavalry.

By comparing historic lightning ignitions to dendrochronological fire history and archaeological data, I was able to determine that dendrochronological fire history in Yosemite Valley varies dramatically from historical observed lightning-caused fires. In the absence of a dramatic change in climate and lightning-ignition patterns that have not been documented, it can be stated that the modern lightning-ignited fires cannot account for the fire return intervals observed in the prehistoric and early historic dendrochronological fire record. With the archaeological record showing a spatial and temporal overlap of Native American occupation during this period, the fire regime within Yosemite Valley was the product of the human occupants of the valley.

Comparison to Areas Where Lightning Is Not Restricted

To what extent Native Americans influenced prehistoric fire regimes is often debated; but do we know what a Native American fire regime looks like? Would we know it when we see it? Is there a litmus test that geographers, ecologists, and anthropologists can use to determine the amount of human influence? This study showed two variations that could be used as keys for determining if a prehistoric fire regime was created by Native Americans: 1) the dendrochronological fire history varied greatly from the historically observed lightning-ignition pattern, and 2) changes in fire regimes corresponded with some of the known archaeological chronologies.

I sought to determine if those two findings could be used as a litmus test by testing them against previously published fire histories. Dendrochronological fire histories do not regularly compare fire regimes to historically observed lightning-ignition patterns or local archaeological chronologies and the common data provided in the literature do not allow for that level of analysis without large amounts of additional data.

The data commonly provided in fire-history studies are a composite MFI and seasonality. So how do MFI and seasonality of Yosemite Valley's anthropogenic fire regime compare to other areas where lightning ignitions probably are not as restricted? A literature review of fire histories in mixed conifer on the western slope of the Sierra Nevada found seven studies to compare against the Yosemite Valley data. Comparisons of composite MFI show that Yosemite Valley's anthropogenic fire signature does not differ strikingly from that in other locations (Table 6). The MFI across the western Sierra Nevada is 1.7–5.7 (range: 1–28 y). Yosemite Valley with 1.92 MFI (range: 1–11 y) is within this range of variability. When compared to the two nearest sites, South fork of Tuolumne River with a composite MFI 1.5 and the South fork of Merced River with a composite MFI 2.13 (A.E. Scholl, Pennsylvania State University, personal communication), Yosemite Valley's anthropogenic fire signature continues to be within the range of variability.

Comparisons of seasonality also reveal that the anthropogenic fire signature of Yosemite Valley is not outside the historic range of variability (Table 7). The different distribution of dormant to latewood scars ob-

Table 4. Two-tailed *t*-test comparison of fire intervals by time period, Yosemite Valley, California.

Time period	*P*
Prehistoric (AD 1520–1800) vs. Protohistoric (AD 1800–1847)	0.0000*
Protohistoric (AD 1800–1847) vs. Historic 1 (AD 1848–1863)	0.1929
Historic 1 (AD 1848–1863) vs. Historic 2 (AD 1864–1890)	0.9610
Historic 2 (AD 1864–1890) vs. Historic 3 (AD 1891–1944)	0.0001*

* Significant at $P \leq 0.05$.

Table 5. Statistical comparison of village type by time period, Yosemite Valley, California. Two-tailed *t*-tests for MFI difference were not significant ($P \leq 0.05$).

Time period	Sap-pah'sam-mah vs. Kis'-se	
	P	Years with synchrony of ≥10% samples scarred
AD 1520–2004	0.8146	
Late Prehistoric 3 (AD 1700–1800)	0.8576	1775, 1783, 1800
Protohistoric (AD 1800–1847)	0.3171	1841
Historic 1 (AD 1848–1863)	0.9102	
Historic 2 (AD 1864–1890)	0.8402	1864

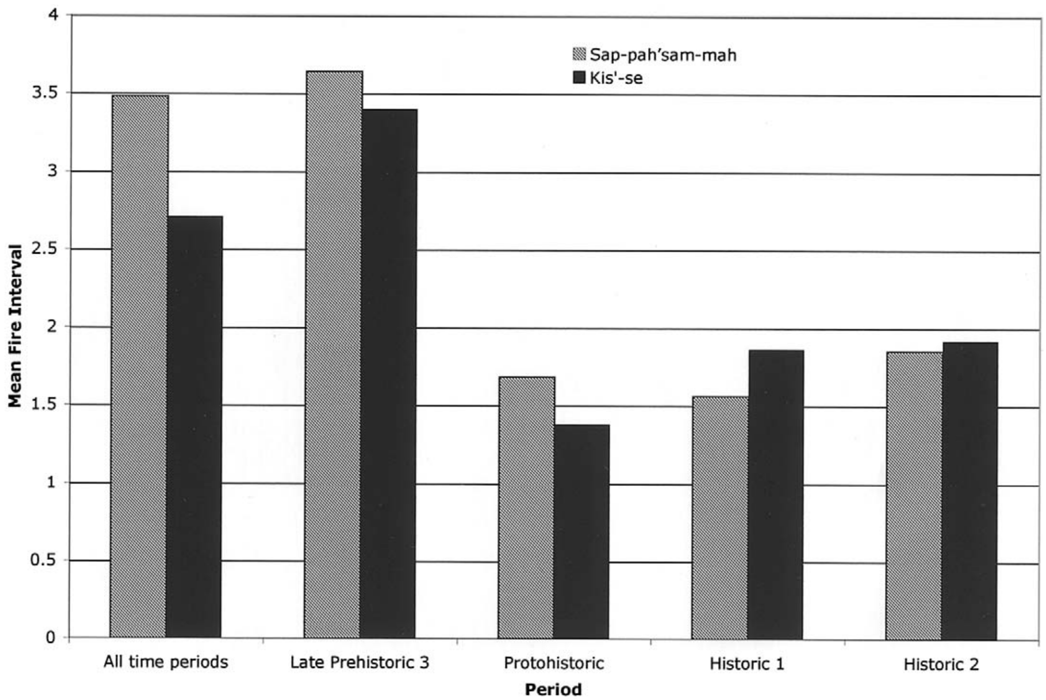

Fig. 5. Mean fire return interval (y) by period for the villages of Sap-pah'sam-mah and Kis'-se, Yosemite Valley, Yosemite National Park, California.

served in Yosemite Valley and other studies is consistent with latitudinal gradients of climate.

Comparison of the anthropogenic fire signature in Yosemite Valley to other studies within the Sierra Nevada shows that Native American fire regimes are not necessarily outside the range of variability of other fire-history studies within the Sierra Nevada. The similarity may be due to a high degree of Native American influence on fire regimes outside of Yosemite Valley, a dependence of fire spread on fuel and climatic events regardless of ignition source, or Native Americans mimicking lightning-fire patterns, or it may be related to data sources and sampling methods. The reasons for the similarity in fire regimes cannot be determined without further research.

Barrett et al. (2005:32) stated ''lightning fires . . . were well capable of maintaining most fire regimes in the West.'' In the case of Yosemite Valley, this is not true: lightning fires could not maintain the prehistoric and historic fire regimes seen in the dendrochronological fire history. Whether this can be said for the rest of the West remains to be tested using site-specific human-occupation data. Most fire-history studies are not designed to determine source of ignition or differentiate between potential amount of lightning and anthropogenic ignitions. Currently, we do not even know what a definitive anthropogenic signature looks like and we do not know if or how much it varies over space, time, or how much it is based on human intent and needs.

We know that Native Americans lived in discrete locations and various times. The similarity of Yosemite

Table 6. Composite mean fire interval (MFI) for locations in Yosemite Valley, California.

Location	Study area (ha)	No. of trees sampled	Composite MFI for study area (y)	Composite MFI range (y)	Source
Blodgett	5	46	4.7	4–28	Stephens and Collins 2004
Pilot Creek	15	15	5.7	3–18	Stephens and Collins 2004
South fork of Tuolumne	2,100	209	1.5	1–16	A.E. Scholl, Pennsylvania State University, personal communication
Yosemite Valley	30	57	1.92	1–11	Gassaway 2005
South fork of Merced	1,625	69	2.13	1–28	A.E. Scholl, Pennsylvania State University, personal communication
Southern-central Sierra Nevada, Yosemite National Park	20–50		2–3	1–25	Swetnam et al. 1998, Stephens and Collins 2004
Sequoia Kings Canyon National Park, Redwood Creek	1,030	37	2.1	1.73–2.35	Kilgore and Taylor 1979
Bearskin Creek	770	183	1.7	1.55–1.86	Kilgore and Taylor 1979
Mountain Home Demonstration State Forest	20–50		3–5	1–12	Swetnam et al. 1998, Stephens and Collins 2004

Table 7. Fire seasonality, western slope of Sierra Nevada, California.

Location	Season[a] (%) D	L	EEW	MEW	LEW	Source
Blodgett	21	79	NR	NR	NR	Stephens and Collins 2004
Pilot Creek	21	79	NR	NR	NR	Stephens and Collins 2004
South fork of Tuolumne	51	24	NR	NR	NR	A.E. Scholl, Pennsylvania State University, personal communication
Yosemite Valley	48	31.5	7.3	5.2	7.3	Gassaway 2005
South fork of Merced	38	32	NR	NR	NR	A.E. Scholl, Pennsylvania State University, personal communication
Southern-central Sierra Nevada, Yosemite National Park	23	54	1	4	18	Swetnam et al. 1998, Stephens and Collins 2004
Mountain Home Demonstration State Forest	20	61	0	1	16	Swetnam et al. 1998, Stephens and Collins 2004

[a] Abbreviations: D, dormant; EEW, early earlywood; L, latewood; LEW, late earlywood; MEW, middle earlywood; NR, not reported.

Valley's anthropogenic fire signature to other fire histories may indicate that mean fire return intervals and seasonality cannot be used alone to determine the amount of lightning versus anthropogenic intervention within a fire regime. In order to determine the amount of influence Native Americans and lightning had on fire regimes, studies have to either explicitly or quantitatively determine ignition sources and use site-specific ethnographic and archaeological data.

Without additional studies that take into account the site-specific ethnographic and archaeological data, our understanding of anthropogenic fire use will be fraught with subjective opinion and bias. We need to test our assumptions.

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LITERATURE CITED

Anderson, M.K. 1988. Southern Sierra Miwok plant resource use and management of the Yosemite region: a study of the biological and cultural bases for plant gathering, field horticulture, and anthropogenic impacts on sierra vegetation. M.A. Thesis, University of California, Berkeley.

Anderson, M.K. 1993. Indian fire-based management in the sequoia–mixed conifer forests of the central and southern Sierra Nevada. Cooperative Agreement Order 8027-2-002, Yosemite Research Center, Yosemite National Park, CA.

Anderson, M.K., and M.J. Moratto. 1996. Native American land-use practices and ecological impacts. Pages 09-01–09-20 *in* M. Barbour (ed.). Status of the Sierra Nevada: Sierra Nevada Ecosystems Project final report to Congress. Volume 2. University of California Centers for Water and Wildland Resources, Davis.

Baisan, C.H. 1990. Fire history of the Rincon Mountain Wilderness, Saguaro National Monument. Technical Report 29, National Park Service, Cooperative Resources Studies Unit, University of Arizona, Tucson.

Barrett, S.A., and E.W. Gifford. 1933. Miwok material culture: Indian life of the Yosemite region. 1976 reprint. Yosemite Natural History Association, Yosemite National Park, Yosemite, CA.

Barrett, S.W. 1981. Relationship of Indian-caused fires to the ecology of the western Montana forests. M.S. Thesis, University of Montana, Missoula.

Barrett, S.W., T.W. Swetnam, and W.L. Baker. 2005. Indian fire use: deflating the legend. Fire Management Today 65:31–34.

Bennyhoff, J.A. 1953. Preliminary report on archaeological excavations in Yosemite National Park. Report to the National Park Service, San Francisco. University of California, Berkeley.

Bennyhoff, J.A. 1956. An appraisal of the archaeological resources of Yosemite National Park. University of California Archaeological Survey 34, Berkeley.

Bibby, B. 1994. An ethnographic evaluation of Yosemite Valley: the Native American cultural landscape. Unpublished document, Yosemite National Park, CA.

Bonnicksen, T.M., M.K. Anderson, H.T. Lewis, C.E. Kay, and R. Knudson. 1999. Native American influences on the development of forest ecosystems. Pages 439–470 *in* N.C. Johnson, A.J. Malk, W.T. Sexton, and R. Szaro (eds.). Ecological stewardship: a common reference for ecosystem management. Elsevier Science, Oxford, United Kingdom.

Broadbent, S.M. 1960. A grammar of Southern Sierra Miwok. Ph.D. Dissertation, University of California, Berkeley.

Byram, S. 1996. On-site lithic analysis manual: prepared for the Malheur National Forest. Malheur National Forest, John Day, OR.

Dieterich, J.H., and T.W. Swetnam. 1984. Dendrochronology of a fire-scarred ponderosa pine. Forest Science 30:238–247.

Gassaway, L. 2004. Reexamination of village sites identified by Merriam and Powers in Yosemite Valley. Proceedings of the Society for California Archaeology 37:67–73.

Gassaway, L. 2005. Hujpu-St: spatial and temporal patterns of anthropogenic fire in Yosemite Valley. M.A. Thesis, San Francisco State University, San Francisco, CA.

Gifford, E.W. 1916. Miwok moieties. University of California Press, Berkeley.

Grissino-Mayer, H.D. 2001. FHX2—software for analyzing temporal and spatial patterns in fire regimes from tree rings. Tree-Ring Research 57:115–124.

Grosscup, G.L. 1954. An archaeological survey of Yosemite National Park, 1954. Submitted to the National Park Service, San Francisco. University of California Archaeological Survey, Berkeley.

Gruell, G.E. 1985. Indian fires in the Interior West: a widespread influence. Pages 69–74 *in* J.E. Lotan, B.M. Kilgore, W.C. Fischer, and R.W. Mutch (technical coordinators). Proceedings: symposium and workshop on wilderness fire. General Technical Report INT-182, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Hull, K.L., and M.S. Kelly. 1995. An archeological inventory of Yosemite Valley, Yosemite National Park, California. U.S. Department of the Interior, National Park Service, Yosemite National Park, Yosemite, CA.

Hutchings, J.M. 1886. In the heart of the Sierras: the Yo Semite Valley, both historical and descriptive: and scenes by the way. Pacific Press Publishing House, Oakland, CA.

Kaye, M.W., and T.W. Swetnam. 1999. An assessment of fire climate and Apache history in the Sacramento Mountains, New Mexico. Physical Geography 20:305–330.

Kilgore, B.M., and D. Taylor. 1979. Fire history of a sequoia–mixed conifer forest. Ecology 60:129–142.

King, J.C. 1991. Douglas-fir chronology, Yosemite Valley, Yosemite National Park. International Tree-Ring Data Bank, IGBP PAGES/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder, CO. http://www.ncdc.noaa.gov/paleo/treering.html [accessed 7 Jun 2007].

Komarek, E.V. Sr. 1967. The nature of lightning fires. Proceedings of the Annual Tall Timbers Fire Ecology Conference 6:5–41.

Lewis, H.T. 1973. Patterns of Indian burning in California: ecology and ethnohistory. Ballena Press, Ramona, CA.

Merriam, C.H. 1917. Indian village and camp sites in Yosemite Valley. Sierra Club Bulletin 10:202–209.

Moratto, M.J. 1999. Cultural chronology 2: the Yosemite data. Yosemite Research Center Publications in Anthropology 21: 17–28.

Napton, L.K. 1978. Archeological overview of Yosemite National Park, California. Submitted to U.S. Department of the Interior, National Park Service, Western Archaeological Center, Tucson, Arizona. In partial fulfillment of Contract No. CX800040032, Institute for Archeological Research, California State College, Stanislaus, Turlock.

Napton, L.K., A.D. Albee, and E.A. Greathouse. 1974. Archeological survey in Yosemite National Park, California: Yosemite Valley (Parts 1–2). Submitted to U.S. Department of the Interior, National Park Service, Western Archeological and Conservation Center, Tucson, AZ.

National Park Service. 2002. Draft Yosemite fire management plan: environmental impact statement. Yosemite National Park, Yosemite, CA.

Pyne, S.J. 1983. Indian fires: the fire practices of North American Indians transformed large areas from forest to grassland. Natural History 92:6, 8, 10–11.

Reynolds, R.D. 1959. Effect of natural fires and aboriginal burning upon the forests of the Central Sierra Nevada. M.A. Thesis, University of California, Berkeley.

Roper Wickstrom, C.K. 1987. Issues concerning Native American use of fire: a literature review. Yosemite National Park Publications in Anthropology 6, Yosemite, CA.

Savage, M., and T.W. Swetnam. 1990. Early 19th-century fire decline following sheep pasturing in a Navajo ponderosa pine forest. Ecology 71:2374–2378.

Stephens, S.L., and B.M. Collins. 2004. Fire regimes of mixed conifer forests in the north-central Sierra Nevada at multiple spatial scales. Northwest Science 78:12–23.

Stewart, O.C. 1956. Fire as the first great force employed by man. Pages 115–133 *in* W.L. Thomas (ed.). Man's role in changing the face of the earth. Published for the Wenner-Gren Foundation for Anthropological Research and the National Science Foundation by the University of Chicago Press, Chicago, IL.

Stokes, M.A. 1980. The dendrochronology of fire history. Pages 1–3 *in* Proceedings of the Fire History Workshop. General Technical Report RM-81, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Stokes, M.A., and T.L. Smiley. 1996. An introduction to tree-ring dating. University of Arizona Press, Tucson.

Swetnam, T.W., C.H. Baisan, K.A. Morino, and A.C. Caprio. 1998. Fire history along elevational transects in the Sierra Nevada, California. Laboratory of Tree Ring Research, University of Arizona, Tucson.

van Wagtendonk, J.W. 1993. Spatial patterns of lightning strikes and fires in Yosemite National Park. Pages 223–231 *in* Proceedings of the 12th Conference on Fire and Forest Meteorology. 26–28 Oct 1993, Jekyll Island, GA. Society of American Foresters, Bethesda, MD.

Wheeler, G.M. 1883. Topographical map of Yosemite Valley and vicinity. Norris Peters, Washington, D.C.

Williams, G.W. 2003. References on the American Indian use of fire in ecosystems. http://www.wildlandfire.com/docs/biblio_indianfire.htm [accessed 8 Feb 2007].

Wilson, D., R. Cromwell, T. Langford, D. Semrau, and G. Kaehler. 2002. Archaeology lab manual. U.S. Department of the Interior, National Park Service, Fort Vancouver National Historic Site, Vancouver, WA.

Yamaguchi, D.K. 1991. A simple method for cross-dating increment cores from living trees. Canadian Journal of Forest Research 21:414–416.