

**NATIVE AMERICAN FIRE PATTERNS IN YOSEMITE VALLEY:
ARCHAEOLOGY, DENDROCHRONOLOGY, SUBSISTENCE, AND CULTURE CHANGE
IN THE SIERRA NEVADA**

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This study explores the use of proxy environmental data — fire-scarred trees — to provide a way for archaeologists to examine a cultural phenomenon normally unavailable in material culture studies, by conducting a dendrochronological fire history study focused on three different land-use types: village sites, gathering areas, and areas of no known use. The study explores whether the Southern Sierra Miwok of Yosemite Valley used fire differently over the landscape. Difference observed between modern lightning igniting patterns and the prehistoric fire history record of Yosemite Valley confirm ethnographic data indicating intensive fire use for proto-agricultural purposes. For this location, the Southern Sierra Miwok appear to have used a rotation system of small, low-intensity ground fires in all areas, regardless of differences in the archaeologically identified occupation intensity. Lack of significant differences between fire return intervals in different land-use areas indicates that fire history data could expand our ability to identify site catchment zones surrounding village sites, thus enabling a greater understanding of hunter-gather subsistence patterns. Two significant changes in fire return intervals suggest that, following cultural change in the Late Prehistoric period, cultural burning practices remained relatively stable from the Proto-historic period until 1890.

Within California and the Sierra Nevada, anthropological studies have shown that Native Californians used fire to manipulate vegetation for various reasons (Anderson 1988; Anderson and Moratto 1996; Gruell 1985; Lewis 1973; Pyne 1983; Reynolds 1959; Roper Wickstrom 1987; 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, fireproofing, insect collection, pest management, warfare or economic extortion, clearing areas for travel, felling trees, clearing riparian areas, “careless campfires,” and ritual use (Anderson 1988; Barrett 1981; Bonnichsen et al. 1999; Lewis 1973; Stewart 1956; Williams 2003).

While archaeologists generally accepted that Native Americans burned the landscape, such burning cannot be determined with standard archaeological methods. The extent of fire in forested environments can be determined using dendrochronological (tree-ring) fire history studies. By comparing historical, dendrochronological, and archaeological data, I show how dendrochronology can be used to increase our understanding of Native Californians’ use of landscape burning. This also expands our knowledge of land use, subsistence patterns, and culture change.

STUDY AREA

As a first step in understanding how one Native American tribal group may have burned the landscape, I sought a location where fire scars could be attributed 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 archaeological data that support the ethnographic data.

Yosemite Valley, in Yosemite National Park, on the western slope of the central Sierra Nevada of California, fits these criteria. Located approximately 250 km east of San Francisco, Yosemite Valley is a

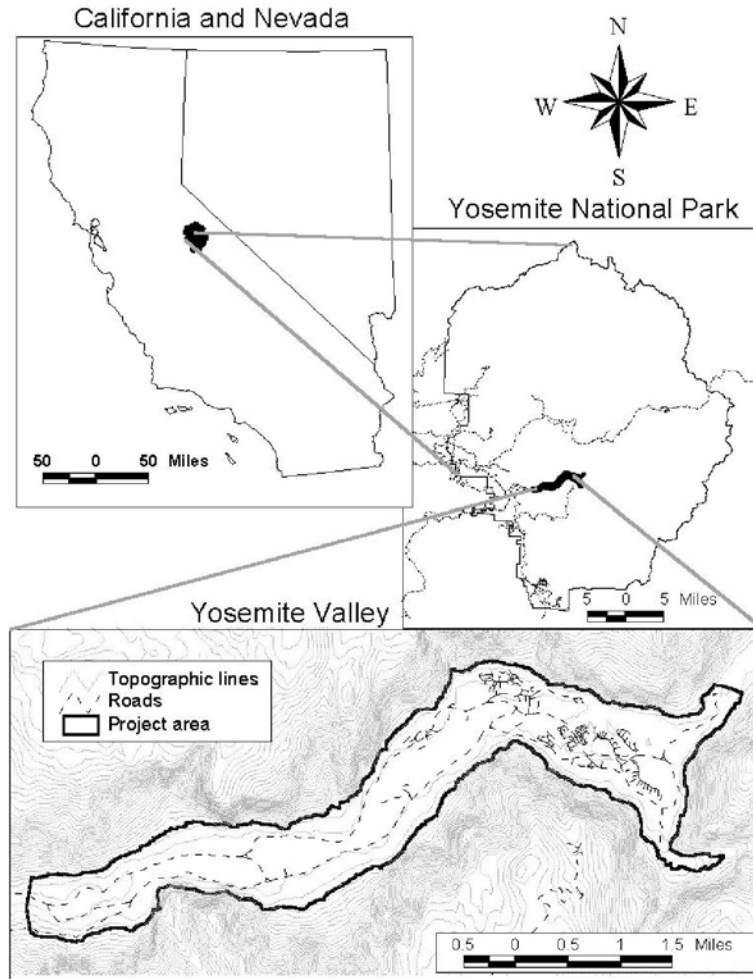


Figure 1. Location of study sites in Yosemite Valley, Yosemite National Park, California.

glacially carved valley approximately 1.6 km wide by 11.4 km long (Figure 1). The valley has a U-shaped cross section, with broad expanses of glacially scoured granite cliffs topped by exposed bedrock domes. The valley floor is at approximately 1,200 m in elevation.

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

Ethnographic studies have shown that the Southern Sierra Miwok, who inhabited Yosemite Valley, used fire for crop management for at least 250 different plants (Anderson 1988, 1993; Barrett and Gifford 1933; 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 topographical limitations of Yosemite Valley and the cultural needs of the Ahwah'-nee (Southern Sierra Miwok of Yosemite Valley) 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 and through 2002, there have been no lightning-ignited fires recorded on the floor of Yosemite Valley (National Park Service 2002). Modern fire-history data indicate that a similar number of lightning-caused fires does not occur in the valley floor as in other areas of similar elevation within the park. Yosemite National Park contains approximately 635,000 vegetated burnable acres and averages 41.5 lightning fires per year from an average of approximately 1,200 lightning strikes (van Wagtenonk 1993). Between 1930 and 2002, 2,877 lightning fires burned 172,379 acres within Yosemite National Park (National Park Service 2002). Yosemite Valley is located within the elevational range of 910-1,830 m, which has a high density of lightning-strike fires (van Wagtenonk 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 is probably 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 midslope 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 percent occurred in either the top or the middle portion of a slope. The high granite walls that surround Yosemite Valley probably receive the vast majority of lightning strikes in the valley area, resulting in more fires occurring on the valley rim, above the valley floor, and outside the study area. The question of why the relatively few lightning strikes that occur on the floor of Yosemite Valley do 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 is 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 (Broadbent 1960; Gifford 1916). Merriam identified the inhabitants of Yosemite Valley as “the Ahwaneech or Ahwah’-nee Mew’-wah” (Merriam 1917). According to Merriam, 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 more than 100 contain evidence of Native American use (Bennyhoff 1953, 1956; Grosscup 1954; Hull and Kelly 1995; Napton 1978; Napton et al. 1974). The archaeological evidence suggests that areas within Yosemite National Park have been inhabited since 7500-6000 B.C. (9450-7950 B.P.). Currently, the earliest occupation observed within Yosemite Valley has been radiocarbon-dated to 5200 B.P. (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 B.P. (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 A.D. 1945 | Historic 4 | |
| A.D. 1891–1944 | Historic 3 | |
| A.D. 1864–1890 | Historic 2 | Rancheria |
| A.D. 1848–1863 | Historic 1 | Tenaya |
| A.D. 1800–1847 | Protohistoric | Yosemite |
| A.D. 1350–1800 (600-150 B.P.) | Late Prehistoric 3 | Mariposa |
| A.D. 650–1350 (1300-600 B.P.) | Late Prehistoric 2 | Tamarack |
| 1200 B.C.–A.D. 650 (3150-1300 B.P.) | Late Prehistoric 1 | Crane Flat |
| 3500–1200 B.C. (5450-3150 B.P.) | Intermediate Prehistoric 2 | Merced Wawona |
| 6000–3500 B.C. (7950-5450 B.P.) | Intermediate Prehistoric 1 | (Unnamed) |
| 7500–6000 B.C. (9450-7950 B.P.) | Early Prehistoric 4 | El Portal |

METHODS

Study Sites 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 topographical 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 areas). These pairings capture the gradient of human land use from human occupation to resource extraction to non-use.

Villages had to correspond with a village site identified in historical 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 period. Traditional gathering areas must have been identified in Bibby (1994), and controls must have lacked evidence of archaeological occupation or use as traditional gathering areas. All areas were required to have 10-30 fire-scarred trees in or immediately surrounding the sampling area.

Historical 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 format. Historic-era and ethnographic maps were scanned and georeferenced using ArcView 3.2a and Arc/Info 8.02 (ESRI, Redlands, California).

Archaeological surveys and excavation data were overlain with the historical and ethnographic data layers to determine the known physical manifestations 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. GPS point locations were converted into a density grid of fire-scarred trees per hectare. The density grid was overlain 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-x-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 screen. I fully analyzed and categorized all collected artifacts based on Wilson et al. (2002), except lithic materials, which were analyzed and categorized based on Byram (1996).

Fire-History Sampling Methods

At each study site, 30-90 “cookies” and wedges from live incense cedar (*Calocedrus decurrens*) and dead ponderosa pine (*Pinus ponderosa*) were collected. This consisted of 10-30 samples from each village, gathering area, and control location. 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 (Dieterich and Swetnam 1984; Savage and Swetnam 1990; Stokes 1980). 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 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 (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 location (Figures 2-3).

RESULTS

Archaeological Excavations

Archaeological excavations were unable to locate any physical manifestations of Native American occupation at one of the study areas; because no occupation was located, this location was dropped from the study. 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 4) and were analyzed.

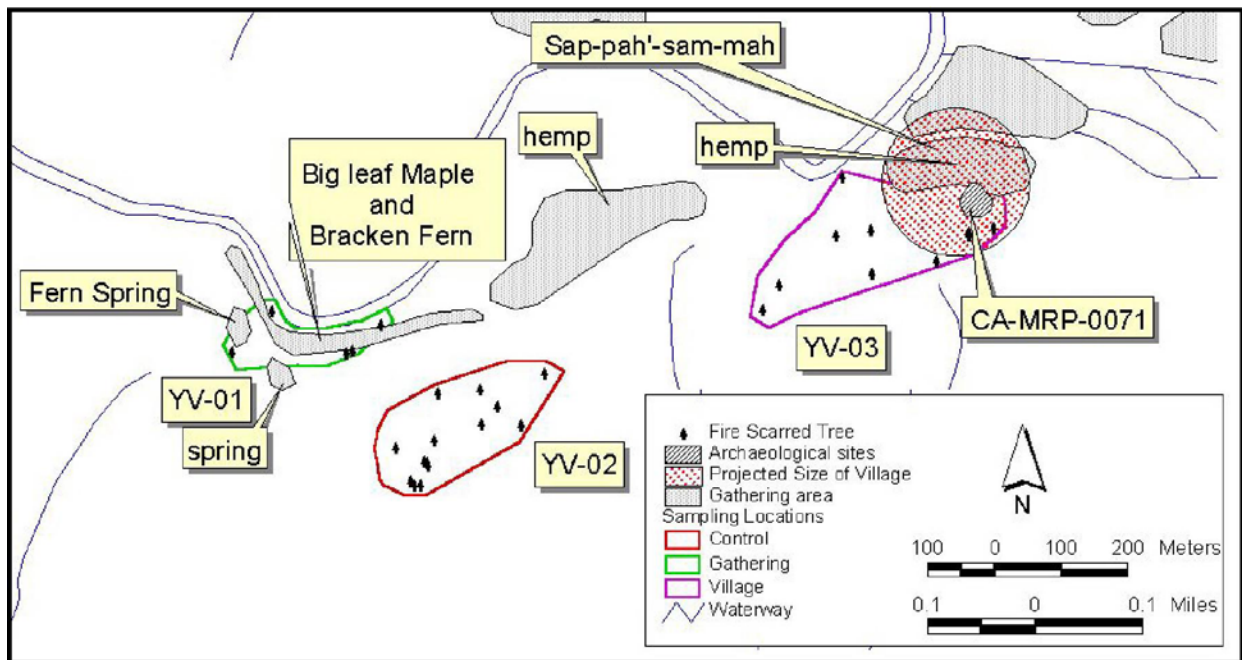


Figure 2. Fire-scar samples from areas associated with the village of Sap -pah'sam-mah (Location 1), Yosemite Valley, Yosemite National Park, California (YV designates fire scar sampling areas).

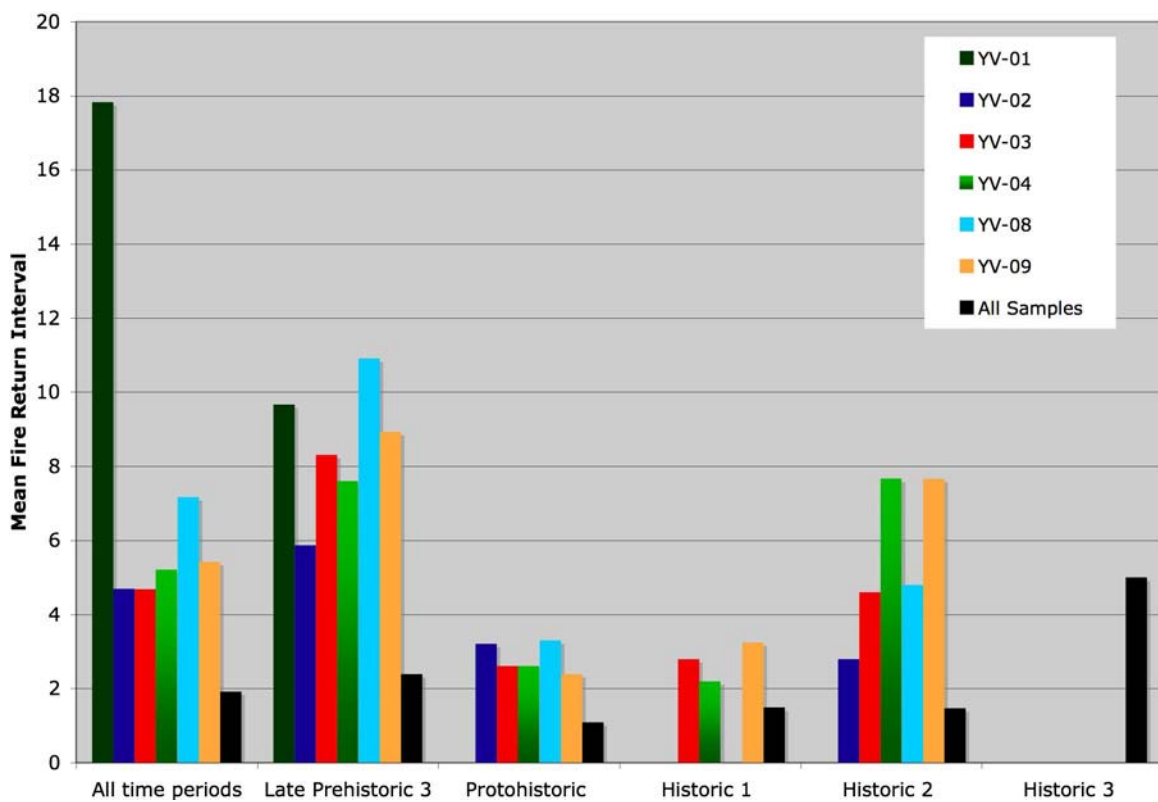


Figure 3. Fire history for all samples, Yosemite Valley, Yosemite National Park, California.

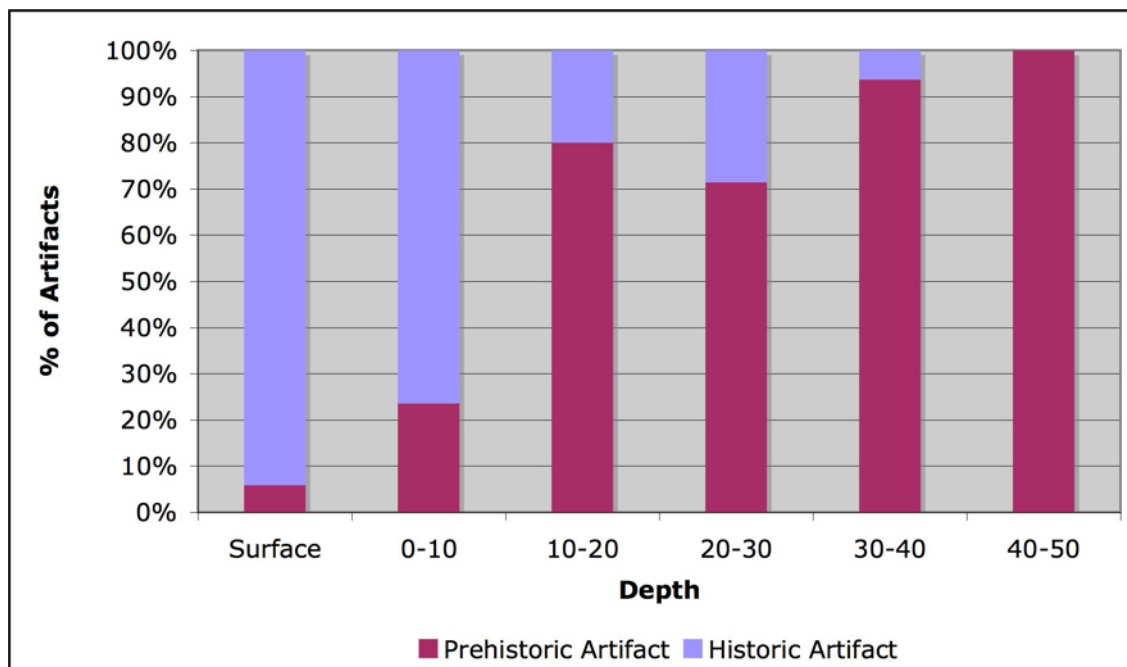


Figure 4. Artifacts by depth, CA-MRP-71.

Location 1

Location 1 (Figure 2), 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). Archaeological evidence for Sap-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 component consisting of small obsidian retouch flakes and debitage, one transverse side scraper, and one blue glass trade bead, was consistent with Merriam's description of a seasonal camp with possibly low-intensity use and with a low diversity of uses. A second period of use consisted of artifacts dating from ca. 1870 to the 1960s, which is consistent with Euro-American occupation and tourism associated with the Wawona Road, which opened in 1875.

The majority of prehistoric artifacts recovered are obsidian flake fragments (51 percent, $n = 35$), complete flakes (19 percent, $n = 13$), and broken flakes (16 percent, $n = 11$). Flake density was low, with one to 14 obsidian artifacts per 0.5 m^3 , and was made up of very small flakes. The presence of the bedrock mortar and one heat-treated, transverse scraper recovered during the excavation hints at the site's use as a center for resource extraction. The best temporally diagnostic artifact for Native American occupation of CA-MRP-71 is the monochrome translucent blue, cylindrical, wire-wound glass trade bead. It likely postdates A.D. 1770. Glass trade beads were probably widespread through the central California interior by A.D. 1800, and groups in the Sierra probably acquired them through trade with native groups of the San Joaquin Valley rather than through direct contact with non-native people.

The distribution of artifacts both vertically and horizontally confirmed two distinct periods of occupation.

Location 2

Location 2, the village of Kis'-se, is located mid-valley, south of the Merced River. The first document that identified use of this area by Native Americans was the 1879 Wheeler Survey map (Hutchings 1886; Wheeler 1883). The map indicates that the area northwest of Kis'-se and its adjacent

Table 2. Fire Interval Analysis by Sample Size, Yosemite Valley, California.

| | STUDY AREA | SAMPLE AREA | SAMPLE |
|--------------------|-------------------|-------------------------|-------------------|
| Area (hectares) | 30 | 1.5–11 | Tree |
| Number 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

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 | 5.0 |
| Gathering areas | 4.62 | 5.13 | 2.35 | 2.2 | 5.75 | |
| Controls | 3.12 | 3.31 | 1.92 | 2.0 | 1.71 | 8.0 |
| Villages | 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 | 5.0 |

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’-se-uh 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 its surface constituents, are consistent with Protohistoric and Historic 1 occupation.

Fire History

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

Significant differences in burning patterns occurred between the Late Prehistoric 3 (A.D. 1350-1800) and Protohistoric (A.D. 1800-1847) periods and between the Historic 2 (A.D. 1864-1890) and Historic 3 (A.D. 1891-1944) periods (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 big leaf maple (*Acer macrophyllum*) and bracken fern (*Pteridium aquilinum*) gathering areas, 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 similar change in fire history over time, as did both study sites (Figure 5).

C. Hart Merriam (1917) suggested that differences existed in the amount and extent of Native American use between the two study sites. Merriam identified Location 1, Sap-pah’sam-mah, as a village

Table 4. Two-Tailed T-Test Comparison of Fire Intervals by Time Period, Yosemite Valley, California.

| TIME PERIODS | P | STATISTICAL DIFFERENCE |
|---|--------|------------------------|
| Prehistoric (A.D. 1520-1800) vs. Protohistoric (A.D. 1800-1847) | 0.0000 | Significant |
| Protohistoric (A.D. 1800-1847) vs. Historic 1 (A.D. 1848-1863) | 0.1929 | Not Significant |
| Historic 1 (A.D. 1848-1863) vs. Historic 2 (A.D. 1864-1890) | 0.9610 | Not Significant |
| Historic 2 (A.D. 1864-1890) vs. Historic 3 (A.D. 1891-1944) | 0.0001 | Significant |

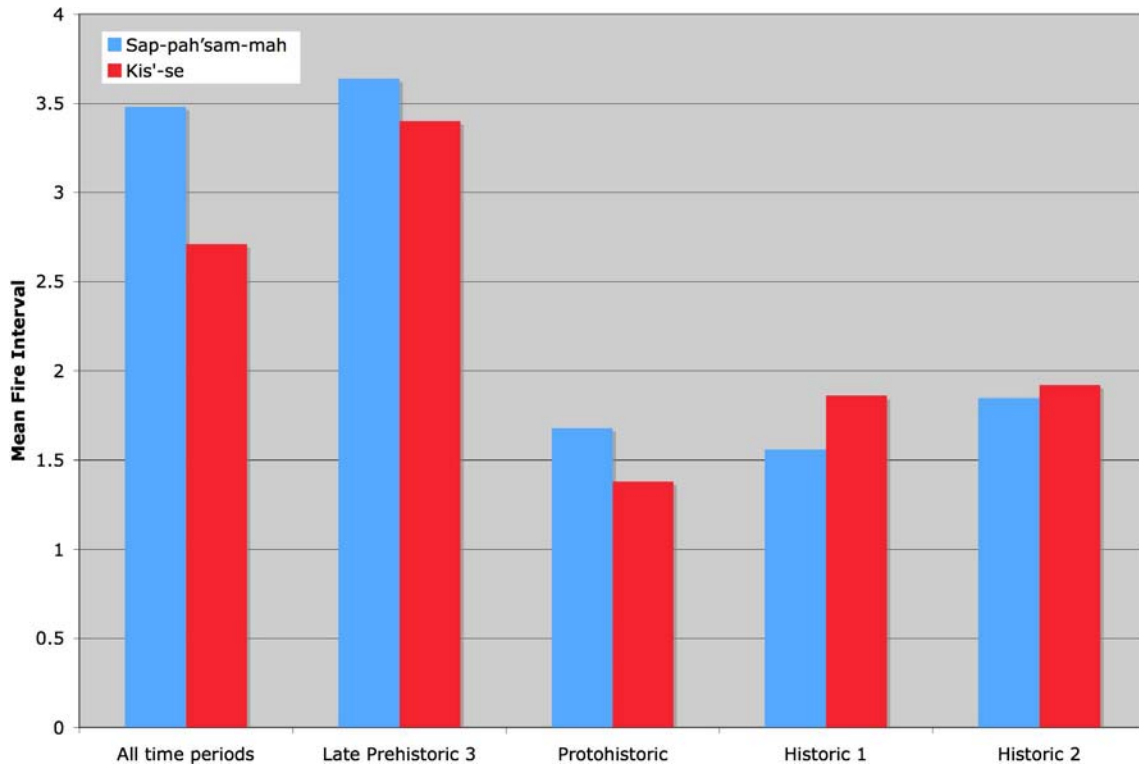


Figure 5. Mean fire return interval by period for the villages of Sap-pah'sam-mah and Kis'-se, Yosemite Valley, Yosemite National Park, California.

or camp, and Location 2, Kis'-se, as a large village. The archaeological remains confirm a difference in the geographical extent of the two villages. Kis'-se (CA-MRP-76) encompasses 1.6 ha, while Sap-pah'sam-mah (CA-MRP-71) extends 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 ≥ 10 percent of the samples show potential for being produced by the same fire (Table 5). When the analysis was expanded to ≥ 25 percent 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 synchrony 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.

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 ² SAM-MAHVS.KIS ² SE | |
|-------------------------------------|--|--|
| | P | YEARS WITH SYNCHRONY OF >10% SAMPLES SCARRED |
| A.D. 1520–2004 | 0.8146 | |
| Late Prehistoric 3 (A.D. 1700–1800) | 0.8576 | A.D. 1775, 1783, 1800 |
| Protohistoric (A.D. 1800–1847) | 0.3171 | A.D. 1841 |
| Historic 1 (A.D. 1848–1863) | 0.9102 | |
| Historic 2 (A.D. 1864–1890) | 0.8402 | A.D. 1864 |

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+ years. 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 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 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. Observed changes included longer fire intervals prior to A.D. 1800 and shorter fire intervals after A.D. 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 after A.D. 1800. Following cultural changes that occurred prior to A.D. 1800, the use of fire remained stable throughout the early historic periods. This stability remained despite large-scale, 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 historically observed lightning-caused fires. In the absence of a dramatic change in climate and lightning-ignition patterns that has 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-era dendrochronological fire record. With the archaeological record showing a spatial and temporal overlap

Table 6. Composite Mean Fire Interval (MFI) for Locations in Sierra Nevada, California.

| LOCATION | STUDY AREA (HA) | NO. OF TREES SAMPLED | COMPOSITE MFI FOR STUDY AREA | COMPOSITE MFI RANGE | 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 | Scholl 2005 |
| Yosemite Valley | 30 | 57 | 1.92 | 1–11 | Gassaway 2005 |
| South Fork of Merced | 1,625 | 69 | 2.13 | 1–28 | Scholl 2005 |
| Southern-central Sierra Nevada, Yosemite National Park | 20–50 | | 2–3 | 1–25 | Stephens and Collins 2004; Swetnam et al. 1998 |
| 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 | Stephens and Collins 2004; Swetnam et al. 1998 |

of Native American occupation during this period, the fire regime within Yosemite Valley was the product the human occupants of the valley.

Comparison to Areas Where Lightning is Not Restricted

The extent to which 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, ecologist, 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 of 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 forests 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 years). Yosemite Valley, with 1.92 MFI (range: 1-11 years), 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 (personal communication, A. E. Scholl 2005), 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 historical range of variability (Table 7). The different distribution of dormant to latewood scars observed in Yosemite Valley and other studies is consistent with latitudinal gradients of climate.

Table 7. Fire Seasonality, Western Slope of Sierra Nevada, California.

| LOCATION | SEASON ^a | | | | | SOURCE |
|--|---------------------|-------|---------|---------|---------|--|
| | D (%) | L (%) | EEW (%) | MEW (%) | LEW (%) | |
| 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 | Scholl 2005 |
| Yosemite Valley | 48 | 31.5 | 7.3 | 5.2 | 7.3 | Gassaway 2005 |
| South Fork of Merced | 38 | 32 | NR | NR | NR | Scholl 2005 |
| Southern-central Sierra Nevada, Yosemite National Park | 23 | 54 | 1 | 4 | 18 | Stephens and Collins 2004; Swetnam et al. 1998 |
| Mountain Home Demonstration State Forest | 20 | 61 | 0 | 1 | 16 | Stephens and Collins 2004; Swetnam et al. 1998 |

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

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) state that “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-era 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 numbers 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 and time, or how much it is based on human intent and needs.

We know that Native Americans lived in discrete locations at various times. The similarity of Yosemite 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 determine ignition sources either explicitly or quantitatively and use site-specific ethnographic and archaeological data.

Settlement Pattern Changes in Late Prehistoric and Protohistoric Periods

The differences in MFI indicate that fire intervals decreased following A.D. 1800, indicating that more fire activity was taking place in the Protohistoric period than in the Late Prehistoric 3 period (Figure 6). This is at odds with commonly held beliefs that the Ahwah’-nee culture was severely impacted during the Protohistoric period. It is often cited that Yosemite Valley was abandoned ca. 1800 and a group under leadership of Tenaya returned in the 1830s or 1840s (Bunnell 1880; Hull 2002; Reynolds 1959). Hull (2002:517) even stated that:

the 16 percent random sample of the residential sites or portions thereof indicates temporary abandonment of the area around AD. 1800 as native people left Yosemite Valley for the eastern side of the Sierra. Relatively few sites (or, more correctly, sub-site areas) were evidently occupied, if indeed any were occupied for about 20 years thereafter.

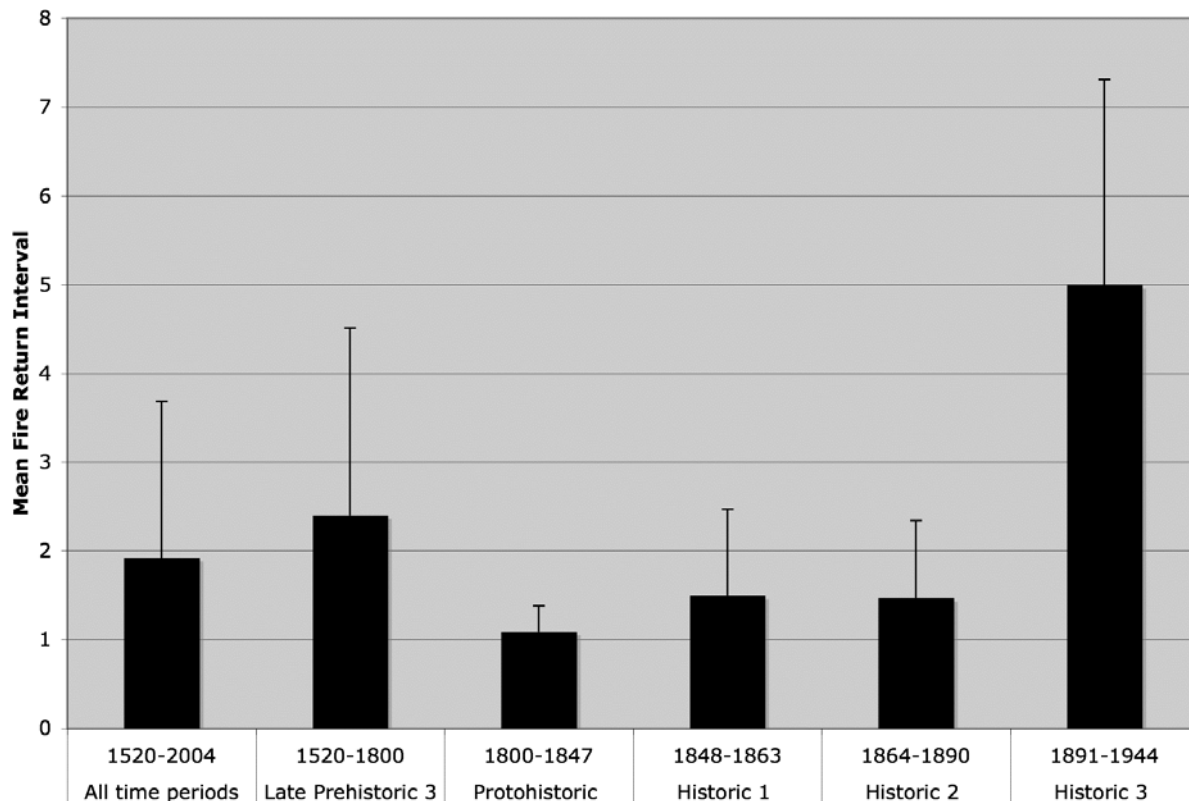


Figure 6. Mean fire return intervals by time period.

Despite Hull's suggestion that the sample indicated a depopulation of the entire valley, excavations within Yosemite Valley are distinctly skewed towards sites occurring in the northeastern portion of the valley. In 2002, of the 104 known sites with a prehistoric component in the valley, only 5 percent ($n = 19$) had been excavated, and of these excavations only one occurred on the south side of the Merced River and none had occurred in the western third of the valley. The small sample size and the disparity in representative samples from both the north and south sides and the upper and lower sections of the valley handicap our ability to detect changes in settlement patterns within the valley.

Changes in fire regimes suggest that subsistence patterns changed substantially in the Late Prehistoric 3 period and stabilized in the Protohistoric and early Historic periods. The decrease in fire return intervals shows that more fire was being applied to the southwestern portion of Yosemite Valley after 1800. The cause of this change is unknown, but two different changes in settlement patterns could account for this: (1) population within Yosemite Valley shifting between villages or from previously occupied villages to new locations (i.e., shifting from the north side to the south side or east to west), thus shifting gathering locations; or (2) expansion of previously marginal populations into the western portion of the valley. Changes in population and changes in tribal relationships caused by influences from Spanish settlement could have caused shifts in settlement patterns for both the Ahwah'-nee and the Pohonichi. The increase in fire use could be caused by a shifting of Pohonichi seasonal movements with increased dependence on plant products from the southwestern portion of Yosemite Valley.

Fire Use during the Early Historic Period

Following the cultural changes that occurred prior to 1800, the use of fire remained statistically stable throughout the early Historic periods. This stability remained despite seemingly large-scale historically documented changes, which occurred in both the region and Yosemite Valley in particular. The relative stability of fire use throughout this period speaks to the relative continuity of subsistence

patterns despite changes in material culture and the influx of Euro-American goods. This may be directly related to the Miwok's restricted access to the White economic system.

Traditional Fire Use during the Historic 2 Period

While it was not unexpected that subsistence patterns remained stable in the Historic 1 period, it is surprising that there was not a substantial change following the signing of the Yosemite Grant in 1864. During the early historic period, while the Ahwah'-nee were chased or removed from Yosemite Valley three times between 1851 and 1853, these periods of removal were short, a few days to a few months. In 1854 tourists began entering the valley but numbers remained low, averaging 70-80 visitors a year between 1855 and 1864 (Hutchings 1886; Taylor 1936). It was not until 1861 that the first Euro-American, James Lamon, stayed the winter in the valley and continuous occupation by non-native peoples began (Taylor 1936).

It was expected that following the California State Legislature Act of 1866, which passed the Yosemite Grant to the State of California, there would be a significant change in broadcast burning. Formal legislation even made it illegal for a person to set fires:

It shall be unlawful for any person willfully to...cut down or carry off any wood, underwood, tree, or timber, or girdle, or otherwise injure any tree or timber, or deface or injure any natural object, or set fire to any wood or grass upon said premises....Any person committing either or any of said acts...shall be guilty of a misdemeanor, and on conviction thereof, shall be punished by fine, not exceeding five hundred dollars, or by imprisonment in the County Jail... [Commissioners 1867:24].

In fact, despite the legislation and ever-increasing tourism (see Figure 7), fire continued to be used on the landscape. The area also highlights native peoples' ability to adapt and maintain practices despite the oversight of the Yosemite Guardians. This may be related to the relationship the early Guardians of the Yosemite Grant had to native peoples. Guardians Galen Clark (1866-1880) and James Hutchings (1880-1884) had both lived among the Miwok and may have been disinclined to interfere with traditional subsistence patterns. Following Hutchings' removal as Guardian, fires began to decrease, with the last substantial burning occurring in 1888.

It is interesting to note that between 1854 and 1900, 49 fires were recorded in the dendrochronological record, yet of the more than 4,200 tourists that visited Yosemite Valley in that time, there is only one first-hand observation of native peoples igniting a landscape burn. This is despite burning in highly visible locations. Fires occurred at Sap-pah'sam-mah until 1891, despite being in full view of the Wawona Road that was constructed in 1875.

CONCLUSIONS

Dendrochronology can give insight into land-use patterns that cannot be seen in the archaeological record. By using dendrochronology and archaeology, we can gain understanding of subsistence and culture change over time.

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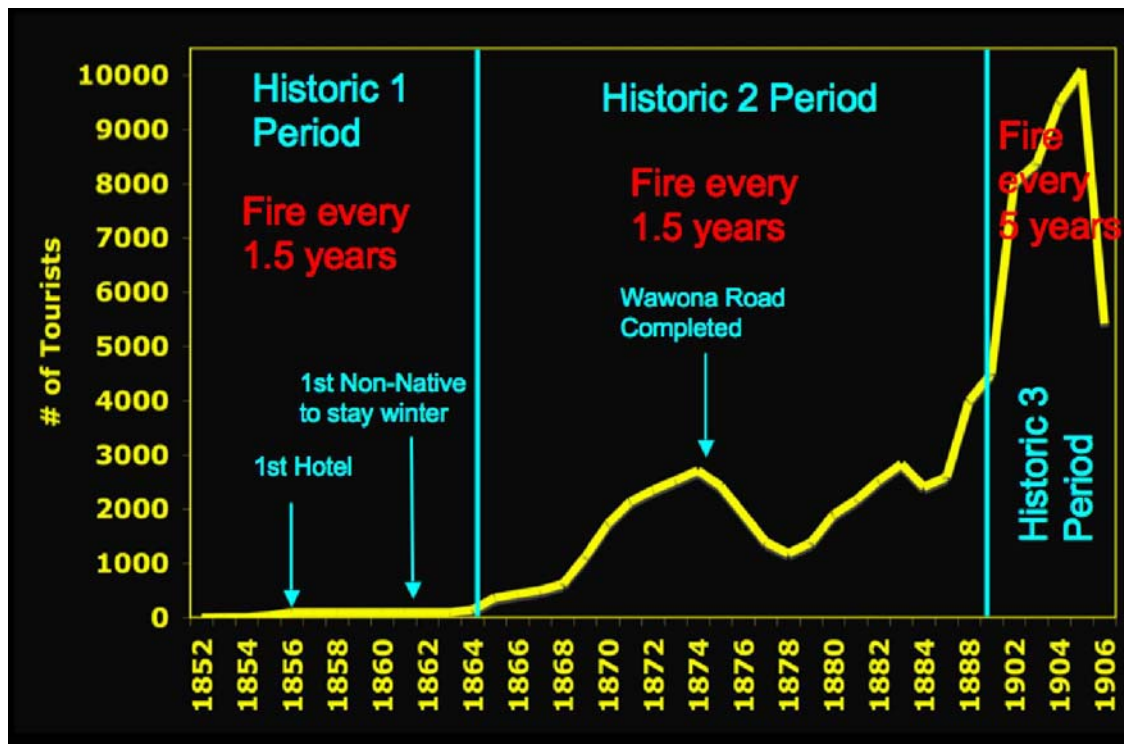


Figure 7. Early tourism in Yosemite Valley by year (Hutchings 1886), and fire return intervals by time period.

Laboratory of Tree Ring Research, University of Arizona; John Sakulich and Andy Scholl at Pennsylvania State University; and David L. Peterson and James Agee at University of Washington.

REFERENCES 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. Unpublished Master's thesis, Department of Anthropology, University of California, Berkeley.
 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, California.
- Anderson, M. K., and M. J. Moratto
 1996 Native American Land-use Practices and Ecological Impacts. In *Status of the Sierra Nevada: Sierra Nevada Ecosystems Project Final Report to Congress*, edited by M. Barbour, Vol. 2, pp. 09-01 to 09-20. University of California Centers for Water and Wildland Resources, Davis.
- Arkush, Brooke
 1993 Yokuts Trade Networks and Native Culture Change in Central and Eastern California. *Ethnohistory* 40:619-640.

- 1995 *The Archaeology of CA-Mno-2122: A Study of Pre-Contact and Post-Contact Lifeways among the Mono Basin Paiute*. Anthropological Records No. 31. University of California Press, Berkeley.
- Baisan, C. H.
1990 *Fire History of the Rincon Mountain Wilderness, Saguaro National Monument*. National Park Service, Cooperative Resources Studies Unit, Technical Report No. 29, University of Arizona, Tucson.
- Barrett, S. A., and E. W. Gifford
1933 Miwok Material Culture. *Bulletin of the Public Museum of the City of Milwaukee* 2:119-376.
- Barrett, S. W.
1981 Relationship of Indian-Caused Fires to the Ecology of the Western Montana Forests. Unpublished Master'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.
1956 *An Appraisal of the Archaeological Resources of Yosemite National Park*. Reports of the University of California Archaeological Survey No. 34. Berkeley.
- Bibby, B.
1994 An Ethnographic Evaluation of Yosemite Valley: The Native American Cultural Landscape. Manuscript on file, Yosemite National Park, California.
- Bonnichsen, T. M., M. K. Anderson, H. T. Lewis, C. E. Kay and R. Knudson
1999 Native American Influences on the Development of Forest Ecosystems. In *Ecological Stewardship: A Common Reference for Ecosystem Management*, edited by N. C. Johnson, A. J. Malk, W. T. Sexton, and R. Szaro, pp. 439-470. Elsevier Science, Oxford.
- Broadbent, S. M.
1960 A Grammar of Southern Sierra Miwok. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Berkeley.
- Byram, S.
1996 *On-Site Lithic Analysis Manual*. Malheur National Forest, John Day, Oregon.
- Bunnell, L. H.
1880 *Discovery of the Yosemite and the Indian War of 1851 Which Lead to That Event*. Fleming H. Revell, Chicago.
- Commissioners
1867 *Report of the Commissioners to Manage the Yosemite Valley and the Mariposa Big Tree Grove*. D. W. Gelwicks, State Printer.
- 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* 17:67-73.
2005 Hujpu-St: Spatial and Temporal Patterns of Anthropogenic Fire in Yosemite Valley. Unpublished Master's thesis, Department of Anthropology, San Francisco State University.

- Gifford, E. W.
 1916 Miwok Moieties. *University of California Publications in American Archaeology and Ethnology* 12:139-194. 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. In *Proceedings, Symposium and Workshop on Wilderness Fire*, pp. 69-74. U.S. Department of Agriculture, Forest Service, General Technical Report INT-182, Intermountain Forest and Range Experiment Station, Ogden, Utah.
- Hull, K. L.
 2002 Cultural Contact in Context: A Multiscalar View of Catastrophic Depopulation and Culture Change in Yosemite Valley, California. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Berkeley.
- 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, California.
- Hutchings, J. M.
 1886 *In the Heart of the Sierras: The Yosemite Valley, Both Historical and Descriptive: and Scenes by the Way*. Pacific Press, Oakland, California.
- 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, Colorado. <http://www.ncdc.noaa.gov/paleo/treering.html>
- 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, California.
- 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*. U.S. Department of the Interior, National Park Service, Western Archeological Center, Tucson, Arizona.
- Napton, L. K., A. D. Albee, and E. A. Greathouse
 1974 *Archeological Survey in Yosemite National Park, California: Yosemite Valley (Parts 1-2)*. U.S. Department of the Interior, National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.
- National Park Service
 2002 *Draft Yosemite Fire Management Plan: Environmental Impact Statement*. Yosemite National Park, Yosemite, California.
- 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. Unpublished Master's thesis, Department of Geography, 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 No. 6.
- 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.
- Scholl, Andrew E.
 2005 *Fire History of South Fork of Tuolumne and South Fork of Merced Rivers*. Pennsylvania State University, State College.
- 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. In *Man's Role in Changing the Face of the Earth*, edited by W. L. Thomas, pp. 115-133. University of Chicago Press, Chicago.
- Stokes, M. A.
 1980 The Dendrochronology of Fire History. In *Proceedings of the Fire History Workshop*, pp. 1-3. U.S. Department of Agriculture, Forest Service, General Technical Report No. RM-81. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- 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.
- Taylor, H. J.
 1936 *Yosemite Indians and Other Sketches*. Johnck & Seeger, San Francisco.

- van Wagtendonk, J. W.
1993 Spatial Patterns of Lightning Strikes and Fires in Yosemite National Park. In *Proceedings of the 12th Conference on Fire and Forest Meteorology, Jekyll Island, GA*, pp. 223-231. Society of American Foresters, Bethesda, Maryland.
- 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. Electronic document, http://www.wildlandfire.com/docs/biblio_indianfire.htm, accessed 8 February 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, Washington.
- Yamaguchi, D. K.
1991 A Simple Method for Cross-dating Increment Cores from Living Trees. *Canadian Journal of Forest Research* 21:414-416.