

Project Title:

Exploring the Traditional Use of Fire in the Coastal Mountains of Central California

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Abstract

This study brought together a team of ecologists, archaeologists, environmental historians, indigenous peoples, and land managers within a research framework combining an ethnographic investigation of traditional practices with cutting-edge paleoecological techniques to answer questions about Indian utilization of fire as an ecological and cultural landscape management tool in Central Coastal California. The study was designed around four key elements: (1) examining fire regimes for research sites using a combination of fire scar dendrochronology, phytoliths, archaeology, historical information, and traditional ecological knowledge; (2) attempting to formalize a methodology for using phytoliths to estimate the fire return interval and intensity in grassland ecosystems; (3) conducting a successful prescribed burn to demonstrate the reintroduction of fire and cultural practices to a rare deergrass field in Pinnacles National Park, and; (4) developing, documenting and disseminating compelling educational materials via a diversity of venues for a wide audience.

Based on ethnographic and dendroecological information, we identified a strong relationship between pre-colonial societies and fire frequency, while our investigations of phytoliths and archaeology supported the need for additional research in these areas. Study results can be used to inform fire management practices (particularly prescribed burning) at sites within the study area and the knowledge gained will be extensively shared with academics, tribes, land managers, and the public.

Background and Purpose

Indigenous peoples throughout the world have employed fire as a tool to manipulate and shape terrestrial vegetation and wildlife populations to benefit human use (Bird et al 2008, Williams 2002). Research conducted in many regions has reconstructed past fire regimes with increasing resolution, but because lightning ignitions often appear to dominate the fire record, few studies have focused on anthropogenic ignitions. The Central California coast region, where the pre-colonial population density was among the highest in North America (Milliken et al 2009), provides an ideal setting for examining landscape level effects of anthropogenic fire on ecosystems because there are very few lightning ignitions but considerable evidence of frequent fire (presumed anthropogenic) prior to European settlement. Several researchers have suggested that during the mid-Holocene in this region, California Indians intentionally used fire to create the mosaic of landscape patches comprising the prairie/oak savanna ecosystem that exists today, targeting taxa and communities of cultural and/or subsistence significance, and maintained them into the historic period through frequent burning (Keeley 2002, Stephens and Fry 2005, Anderson 2006, Lightfoot and Parrish 2009). At the same time, there has been increasing recognition among land managers concerned with fire management and weed abatement that burning needs to be reintroduced into many ecosystems as a tool for ecological improvement, but knowledge of long term effects of particular burning regimes is lacking. This study represents an effort to add information and clarity to traditional Indian fire regimes in this region, and directly apply this knowledge as a tool for modern land management.

Study description, Methods, and Locations

This study took place in two primary locations: Pinnacles National Park in San Benito County, CA; and in the watersheds of Whitehouse, Waddell, and Scotts Creeks in Santa Cruz and San Mateo Counties, CA (Figure 1) – all within the aboriginal territory of the Amah Mutsun Tribal Band.

A third location originally proposed, the Bureau of Land Management’s Clear Creek Management Area, was eliminated from the study for lack of available data after careful, multi-day assessments by our multidisciplinary team.

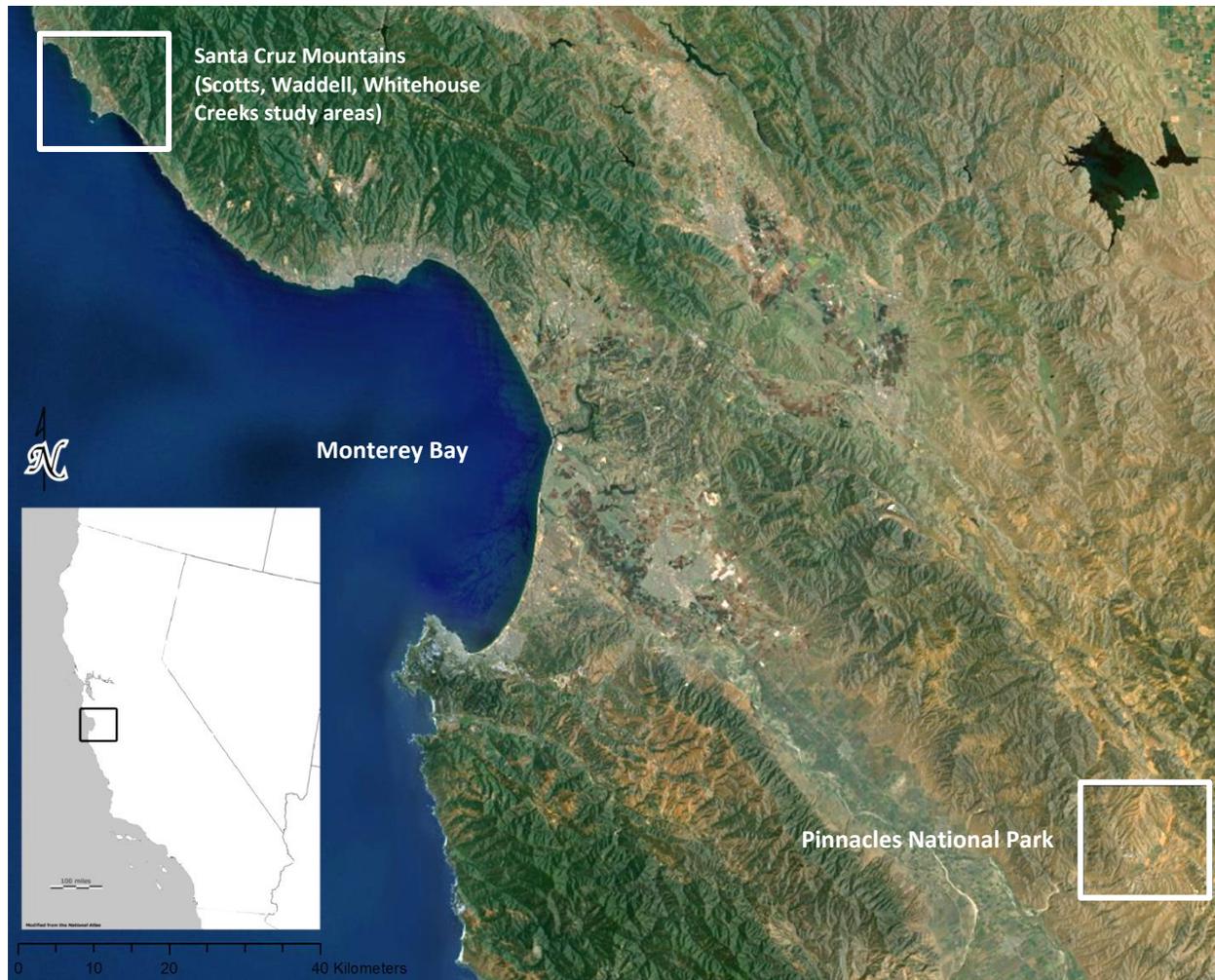


Figure 1: Central California Coast Study Area

Fire scar dendrochronology study (Santa Cruz Mountains)

Funding from the Joint Fire Science Program allowed us to expand our original Quiroste study area to two adjacent basins in Santa Cruz Mountains north of Davenport, California, approximately 65 miles (101 km) south of San Francisco and 16 miles (26 km) northwest of Santa Cruz. The study area focuses primarily on the Whitehouse Creek, Waddell Creek, Scotts Creek watersheds, but also includes select locations in the Gazos Creek and San Vicente Creek watersheds (Figure 2). The Whitehouse Creek watershed encompasses 5 mi² (1,294 ha), Waddell Creek is 24 mi² (2,822 ha), and Scotts Creek is 30 mi²

(7,700 ha). Elevations in the study area range from 37m nearest the coast to 655m near the headwaters of Waddell Creek.

Fire scar dendrochronology is a well-established methodology for reconstructing fire regimes. This approach uses scars which form on some tree species when cambial tissue is damaged by the heat from fire (Agee 1993). Fire scars provide annual and often seasonal temporal resolution, and provide an excellent record of fire in areas where species that are conducive to recording scars occur. Fire histories based on fire scar dendrochronology can date back thousands of years if long-lived tree species are used (e.g. Swetnam et al. 1993).

Our sampling strategy was designed to assemble a representative inventory of fire scars over the longest time frame possible from individual sites or plots that represent the topographic, climatic, and structural diversity of the study area (Swetnam and Baisan 2003; Stephens et al. 2003; Stephens and Fry 2005). Where possible, clusters of well-preserved fire-scarred stumps, snags, or downed logs that contained approximately 5 samples in an area of 20 ha or less (with generally homogeneous vegetation and topography) were prioritized for sampling. Our aim was to structure sampling to encompass the gradient of land use patterns in the study area (Gassaway 2007).

Fire scar specimens were identified and sampled on an opportunistic basis. Such targeted sampling has been demonstrated to yield comparable results to random or grid-based sampling (Van Horne and Fule 2006) and has often been necessary in prior studies to obtain adequate data sets for this forest type (Brown and Baxter 2003; Stephens and Fry 2005). Entire or partial cross sections (approximately 5 to 8 cm thick) were extracted from remnant wood and live trees using a chainsaw (Arno and Sneek 1977; McBride 1983; Agee 1993). Both young (<150 years) and old specimens (>150 years) were selected in order to maximize the length and completeness of the temporal record (Farris et al. 2010), but adequately preserved stumps with intact bark and sapwood, downed logs, and trees that were not significantly decayed or degraded were prioritized. In Scotts Creek, stands that were recently logged in the post-Lockheed Fire (2009) salvage operation were preferentially selected to increase the prospect of having intact bark and sapwood to facilitate the assignment of accurate calendar dates (Norman 2007). Sections were occasionally removed from multiple locations and heights on the basal flutes and tree boles to capture accurately the most complete scar record possible (Stokes 1980; Dieterich and Swetnam 1984), but great care was taken to collect samples from as close to the root-trunk transition as possible (Norman 2007). Care was taken to avoid damage to redwood regeneration. The following information was recorded for sample specimens: sample identification code and number, date sample collected, tree species, location and elevation (UTM coordinates), condition (snag, stump, log, or live tree), height and depth of the cross-section on the bole, vegetation cover (i.e. visual estimate of species dominance), diameter, aspect, percent slope, position on slope, fire scar orientation, and harvest date (if known). Sampling locations were recorded using Global Positioning System (GPS) technology and photographed, but were not be permanently marked in most cases. All fire-scarred samples were labeled and transported to the University of California, Berkeley (Richmond Field Station), for preparation and laboratory analysis.



Figure 2: Map of Study Watersheds, Santa Cruz and San Mateo Counties, CA

Specimens were prepared and analyzed using standard dendrochronology techniques (Stokes and Smiley 1968; Orvis and Grissino-Mayer 2002). Samples were air-dried and sanded to a high sheen starting with 40 grit and progressing to 400-600 grit sand paper, until the cellular structure within each annual growth ring and the position of the fire scars within the ring series could be viewed clearly under a stereo microscope with 7-45X magnification. Counting annual rings on all samples commenced inward from the bark, with the outermost ring being the year the tree was sampled or died (Year 0).

Samples were counted at least once, with many counted several times to account for complacent rings. Each sample was inspected for regions exhibiting ring complacency, and accounted for by making multiple counts along different radii. Fire affected ring numbers were assigned based on the longest radial count.

Fire scars were identified by the overlapping curvilinear growth in post-fire growth rings that is characteristic of the tree's healing pattern (McBride 1983). The fire season was determined by the position of the scar within the annual growth ring. Although some dendroecologists have established six different seasonal categories (e.g. Baisan and Swetnam 1990), this study makes use of only three general categories; earlywood, latewood, or dormant season.

Accurate dating of redwoods has proven notoriously difficult due to anomalies in the ring patterns such as locally absent, missing, false, wedging rings, and complacency (lack of sensitivity to limiting environmental variables; Fritz 1940; Brown and Swetnam 1994; Waring and O'Hara 2006; Lorimer et al. 2009). Fire return intervals, the number of years between successive fire events in a designated area, are based on ring counts between consecutive fire events (Jacobs et al. 1985; Finney and Martin 1989; Stephens and Fry 2005). Attempts were made to corroborate common fire dates between trees within individual plots, and between plots where large historic fires could be documented.

The following events and information were also used to calibrate calendar dating and date bracketing:

- Fire scars from known fires, including 2009 (3,163 ha), 1962 (1,310 ha), 1948 (6,400 ha), 1936 (10,400 ha), 1919, and others.
- Timber harvest dates from Big Creek Lumber, Swanton Pacific Ranch, and CalFire timber harvest plan data (furnished by the Sempervirens Fund).
- Timber harvest, blow-down, and Rx burn dates from Big Basin State Park.
- Presence of sapwood on samples.

To be included in the analysis, a tree must be considered a 'recorder' tree (i.e. a tree that has scarred at least one time, thus becoming more susceptible to future scarring on the exposed sapwood), and have at least one additional scar. Only scar to scar intervals were recorded (i.e. the period from the tree origination date to the first fire scar is not considered an "interval", thus not included in our analysis, see Baker and Ehle 2001). For each cross-section from recording trees, the point minimum, maximum, median, mean, and range of fire return intervals were calculated. The point mean fire return interval is the statistical average of all fire intervals in each individual sample and is calculated by recording the number of annual growth rings between each fire scar, summing the intervals, and then dividing this result by the total number of recorded intervals.

Verifiable harvest dates were established for 20 of the sample trees. Fire interval information for this subset was analyzed using FHX2 (Grissino-Mayer 1996). Analyses reported via FHX2 include Mean Fire Intervals (MFI), median fire interval, Weibull modal and median intervals, standard deviation, coefficient of variation, skewness, kurtosis, Kolmogorov-Smirnov Test for Goodness-of-Fit, and seasonality information (percent of fires in each season class, % of early vs. late vs. dormant season fires).

Floating Chronologies

Since firm harvest dates for the balance of the sample set (n= 50) were not able to be established, these samples were handled as “floating chronologies.” These are defined as intervals between discernible fire events based on rings for which absolute calendar dates cannot be reliably established (Clark and Renfrew 1972). Numerous approaches have been used to align floating chronologies with known or established chronologies, usually by crossdating focal samples with regional master chronologies, or developing a 14C calibration curve from existing master chronologies and linking floating ring series to the resulting radiocarbon age/tree-ring age curve (Yamaguchi 1986, Roig et al. 1996, Kromer et al. 2004). Even if permanent temporal gaps in the tree-ring record exist, wiggle-matching (Baillie 1995) of high precision carbon dates and the 14C record can allow for dating of floating chronologies to within a few decades (Stambaugh and Guyette 2009).

Regional master chronologies for coast redwoods (or the associated 14C calibration) have yet to be established for the study area, so an attempt was made to detect patterns in fire frequency with respect to known cultural and physiographic variables using a novel statistical model.

During sample collection, in addition to individual specimen and sample variables collected (e.g. diameter at breast height [dbh], depth of cut, height of cut, etc.), physiographic measurements were recorded for each contributing stand. These included the following:

- percent slope (using a clinometer);
- position on slope (valley bottom to bottom 1/3 of slope = bottom; middle third of slope = middle; and top third of slope to ridgeline or significant topographic crest = top);
- elevation (in meters, recorded in field using Garmin GPS);

Additionally, several GIS-based measurements were determined once the positions of individual sample trees were incorporated into the project geodatabase. These included:

- distance from coast (in meters);
- northness/eastness (refinement of aspect);
- distance from “culturally significant zone” (derived from known site information, proximity to water, topography, etc.);
- distance from known (recorded) archaeological sites;
- distance from (pre-colonial) residential site (a subset of known sites);
- and watershed/zone (incorporates standard continuous variables for all areas, i.e. slope, aspect, elevation, distance from coast).

Generalized linear mixed model (GLMM)

For floating chronologies, we worked with Melissa Eitzel (PhD Cand., UC Berkeley/ESPM) to construct a generalized linear mixed model (GLMM) to detect possible patterns in the annual probability of fire (Bolker et al. 2009). For the purposes of this study, we utilized a binomial probability model where each annual growth ring represents a “trial”, and each fire scarred ring is defined as a “success.” Unscarred rings are therefore defined as a “failure.” We require a mixed model framework because we treat plots as random effects. We aggregated the return interval data to obtain the number of fire scars per sample in order to estimate this binomial model.

These data possess a number of attributes which made it desirable to use such a model in this case. We chose the binomial successes/failures model to account for the highly variable lengths of the records (ring counts; “trials”). We favor this model of the number of fire scars per sample rather than the fire return interval because the latter is Weibull distributed, and developing a mixed model with a Weibull distribution is beyond the scope of this study. To incorporate spatial autocorrelation in the model, plot designations were treated as random effects. In addition, to account for the unbalanced nature of the overall sample set (varying number of samples per plot), we used likelihood ratio tests to establish significance.

Model estimation and significance testing

For this model, R (R Core Team 2013) facilitates the use of independently scripted functions which were utilized here to model annual probability of fire as a function of continuous and explanatory variables using an unbalanced, non-normally distributed sample set. To estimate the GLMM described above we used `glmer` (“generalized linear mixed effect regression” in the `lme4` package; Bates et al. 2013). This package is traditionally used to fit generalized (non-Gaussian) linear mixed models which have random effects (in this case, plot).

We separately tested the significance of the random effect for plot by fitting the model without the plot effects using the function “`glm`” and ensuring that the `glmer` models used maximum likelihood estimation (not restricted maximum likelihood estimation). We tested the significance of the plot effect with all the other fixed effects in the model to account for the potential explanatory power of all the fixed effects (Zuur 2009); once it was determined to be significant, it was included in all other models. To evaluate the significance of the fixed effects, we used a likelihood ratio test: for each predictor variable we estimated a reduced model, calculated the likelihood ratio between the reduced and full models, and obtained p-values using a chi-squared approximation for the likelihood ratio. Likelihood ratios are valid even in cases with an unbalanced design and therefore our tests should be robust given the varying number of samples per plot. We used a backward-selection approach (Crawley 2005) to eliminate non-significant variables and produce a reduced model.

Using Fire-Altered Phytoliths to Examine the Indigenous Fire Regime at McCabe Canyon

The investigation was centered in McCabe Canyon, a recently acquired area within Pinnacles National Park, focusing on two areas within the canyon with sizable patches of two species likely favored by Native Americans and maintained by regular burning: deergrass (with saddle-shaped short cells found only in *Muhlenbergia* among common native California grasses) and whiteroot sedge (with conical cells only found in *Cyperaceae*). Intensive sampling of plants and soil was undertaken at the deergrass patch both prior to and following the prescribed burn performed December 2011. Phytoliths previously

extracted from samples in both archaeological and natural contexts at Quiroste Valley were also examined for evidence of burning (Evetts and Cuthrell 2013).

Despite considerable qualitative information regarding Indian fire regimes in CA grasslands and shrublands, primarily derived from ethnographic interviews of tribal elders, obtaining quantitative data to test hypotheses of fire frequency and intensity has been problematic because a lack of trees and lakes in these environments renders typical approaches such as fire-scar dendrochronology and charcoal analysis of lake sediments unfeasible or inconclusive (Stephens et al. 2007). Recent advances in the paleoecological technique of phytolith analysis have provided the framework for a promising, but to this point incomplete and untested, new approach to reconstructing rangeland fire regimes. We tested several approaches to produce a phytolith-based estimate of a fire regime in CA.

Opal phytoliths are microscopic particles of amorphous silica that are formed when soluble silica taken up by plants from the soil solidifies within cells (often taking the shape and incorporating the nucleus and other contents of the cell) and between cell walls (Piperno 2006). Phytoliths tend to be highly resistant to decomposition, often persisting for hundreds or thousands of years (Wilding 1967). We examined three phenomena associated with changes that occur in phytoliths when they are heated or exposed to fire:

- 1) Phytoliths (normally transparent) change color, becoming dark or opaque (Parr 2006)
- 2) The refractive index increases (Elbaum et al. 2003)
- 3) The chemical nature of elements such as carbon occluded in phytoliths, measured by spectra from Raman, FT-Infrared, and fluorescence spectroscopy (focusing a laser beam on individual phytoliths), permanently changes as a function of maximum temperature exposure (Pironon et al. 2001).

To examine the effects of heating and burning on phytoliths of deergrass and whiteroot sedge, we conducted both laboratory and field experiments. Laboratory work involved heating vegetative samples of each species in a muffle furnace to temperatures at 100°C intervals from 100-600°C. Additional samples were burned using an open flame in a beaker under the laboratory hood. Heated and burned samples were further processed in household bleach for two days to remove residual organic matter and then rinsed several times in distilled water.

To examine evidence of burning through changes in phytolith color or opacity, a drop of phytolith solution from each sample was placed on a microscope slide and examined under a microscope at 400x magnification. The proportion of phytoliths showing evidence of burning was estimated by counting 300 phytoliths for each sample.

To investigate changes in the refractive index of phytoliths occurring as a result of heating, a portion of each phytolith extract was dried then re-suspended in Cargille Refractive Index Liquid with refractive index 1.44. A drop of each suspension was placed on a slide and examined under the microscope (Elbaum et al. 2003). By observing the nature of the Becke line (Elbaum et al. 2003; Wyche 2012), 200 saddle short cell phytoliths from each sample were counted and classified as either above or below 1.44 RI, and the percentage of phytoliths above 1.44 RI was calculated.

Raman spectrometry was performed using two instruments, a Renishaw RM1000 at the Spectral Imaging Facility at University of California, Davis, and a confocal Horiba LabRAM HR at the Analytical Chemistry Instrumentation Facility at University of California, Riverside. A drop of aqueous suspension of

each phytolith sample was placed on a piece of aluminum foil taped to a slide (to avoid contamination with the spectrum of the glass slide, which is composed of amorphous silica similar to phytoliths), allowed to dry, and then placed under the microscope. Individual phytoliths were located on each slide and the laser beam focused within the phytolith at 1000x. Samples were examined using two laser light wavelengths, 523 nm and 784 nm. Raman spectra were obtained for dozens of phytoliths from each sample using exposure times ranging from 10 seconds to 2 minutes. Raman spectra of individual phytoliths were closely examined to identify predictable spectral patterns that manifest with increasing temperature.

The field portion of the study had several components. At the deergrass site in McCabe Canyon, soil samples and specimens of major plant species that occur in the area were collected prior to the prescribed burn in December 2011 and phytoliths were extracted following established phytolith sampling procedures (Evetts et al. 2006; Evetts et al. 2007) to establish a baseline soil phytolith assemblage with interpretation based on a modern phytolith reference collection. Prior to the burn, aluminum tags painted with temperature-sensitive lacquers from 79-204°C (Tempilaq) were placed in NPS delineated sample plots in order to estimate the range of maximum temperatures occurring during the burn. Samples of ash were collected from each plot immediately following the burn. These were examined under the microscope at 400x before and after treatment with bleach to determine the proportion of visually darkened phytoliths resulting from the burn. To estimate the rate of incorporation of burned phytoliths into the soil after the occurrence of two rainy seasons following the burn, soil samples were collected from each plot late spring 2013 and phytoliths extracted.

To determine the extent of long-term native grasslands in Pinnacles National Park, soil samples were collected from sites currently dominated by California annual grassland. Phytoliths were extracted and the presence of long-term grassland determined using the 0.30% soil phytolith content threshold (Evetts et al. 2013). In an attempt to estimate vegetation change over time, phytoliths were also extracted from undated chronologically stratified sedimentary layers from several cut bank sites located in streambeds.

Rather than assume the proportion of burned to total phytoliths in a soil phytolith assemblage produces a reasonably accurate quantitative estimate of long-term fire frequency, we attempted to test and calibrate this approach by extracting soil phytoliths from ponderosa pine-bunchgrass sites along a fire frequency gradient on NPS lands in the Rincon Mountains of southern Arizona. These sites were chosen because there are fire frequency maps constructed from well-documented historical and dendrochronological fire histories extending back several hundred years that document relatively stable fire frequency continuing through the present, a highly unusual situation given the introduction of fire suppression in most forests 100+ years ago (Farris et al. 2010). Sample sites were located within patches of grass in the forest (because the assumed long-term grass understory in the pine forest was expected to produce abundant burned phytoliths for analysis) along a gradient ranging from <10 yr fire return interval (with frequent fires that continue today) to >100 years since the last fire; 2 soil samples were collected at each site and soil phytoliths were extracted.

Archaeological Research at McCabe Canyon

The archaeological investigation of McCabe Canyon was undertaken as a collaborative research and educational project involving the National Park Service, the Amah Mutsun Tribal Band, the University of California, Berkeley, and Vassar College. The project, implemented as a field school class (Anthro 134A: Field Course in Archaeological Methods) offered through UC Berkeley's Summer Sessions

Program, provided an exceptional pedagogical experience for 11 undergraduate students and one graduate student from the University of California. An additional four students from Vassar College also participated in the first two weeks of the field school.

Members of the Amah Mutsun Tribal Band played a critical role in the research and teaching mission of the field school. In formal lectures at the campground, as well as informal discussions over the nightly campfire, tribal elders discussed the history of the tribe and the contemporary revitalization movement among tribal members. They also sang songs, recounted oral traditions and tribal stories, and even sponsored a traditional dance as part of the field school program. Four high school/college students from the tribe, serving as paid interns during the field school, were taught the basics of archaeological field methods.

The post-field research was undertaken in the California Archaeology Laboratory at UCB. Laboratory work involved the flotation of soil samples and the recovery and identification of paleoethnobotanical and micro-faunal remains. Organic samples were submitted to the Center for Accelerator Mass Spectrometry (CAMS) at the Lawrence Livermore National Laboratory in Livermore, California for radiocarbon (AMS) assessments.

In designing the field methodology for the McCabe Canyon survey, we developed a multi-stage field program that balanced coverage of the canyon land with the detailed inspection of specific places to detect buried archaeological remains. Archaeological visibility is a critical variable in McCabe Canyon. Archaeological visibility is defined as the likelihood of detecting archaeological remains on the ground surface. High visibility refers to conditions where the probability of observing cultural materials on the ground surface is excellent. In contrast, in areas of low visibility archaeological remains may not be readily observable on the ground surface due to heavy vegetation and/or depositional or post-depositional processes.

We recognized from the outset that the major drainages of McCabe Canyon are characterized by low archaeological visibility. Historical observations for the Pinnacles region (Babalis 2009:27-30, 88, 125) and recent eyewitness accounts of McCabe Canyon (e.g., Mark Francis pers. comm. 2011) chronicle periodic flooding events, resulting in the deposition of significant quantities of sediments from the surrounding ridge system into the canyon lands. Consequently, in areas of low archaeological visibility it is best to employ methods of subsurface inspection. The surrounding ridges and upper terraces above the drainages exhibit evidence of higher archaeological visibility. However, the survey of these upland areas is impeded by thick chaparral vegetation in many locations.

We employed the following three stage field methodology to detect and record archaeological resources in McCabe Canyon: surface pedestrian survey, shovel probe testing, and geophysical investigations (using a gradiometer instrument) (see Figure 3).

Surface Pedestrian Survey

We used the standard surface pedestrian survey to investigate the ground surface along the lower canyon lands and along the lower terraces that follow the major drainages. We also surveyed a small sample of the upslope ridge systems on both sides of McCabe Canyon (Figure 3). Surface pedestrian survey is a relatively rapid, effective method for locating cultural remains in areas of high archaeological visibility. We acknowledge that its effectiveness decreases dramatically in areas of low

archaeological visibility. Our strategy was to employ this method as a first pass through the canyon lands and along a sample of the surrounding ridge slopes and ridge tops.



Figure 3: McCabe Canyon Archaeological Survey Blocks

Shovel Probe Survey

In some areas of low archaeological visibility in the canyon lands, we instituted shovel probe investigations to search systematically for subsurface archaeological remains that may be buried or covered by dense vegetation. Similar to the surface pedestrian survey, crew members worked as a team walking separate lines in a transect unit. In addition, each crew member excavated shovel probes at set intervals along their line. Each shovel probe measured about 25 by 25 cm in size and was typically excavated to a depth of 30-50 cm, although a few went as deep as a 1 m. All sediments were screened through ¼" mesh for the rapid detection of cultural materials.

Geophysical Survey

In a few of the places where we believed the likelihood of archaeological remains was high based on Paul Engel's predictive model and past research in the park, but where archaeological visibility was poor, we implemented geophysical magnetometer survey. A critical factor in the employment of geophysical survey, in contrast to the shovel probe investigations above, is that the target area had to be relatively flat and not covered by thick woody vegetation that impedes the use of survey instruments. Magnetometry is a passive method for measuring the local magnetic field of an area in gammas (γ) or nanoteslas (nT). Magnetometer survey can be used to detect anomalies represented by higher or lower than normal magnetic readings, indicating objects, features, or deposits with induced or remnant magnetism. Magnetic anomalies may be created by natural features, such as rocks with high iron content. Anomalies are also produced by cultural features, such as ferrous metals, ceramics and fire-cracked rock (with iron oxide) associated with hearths and ovens. Magnetic anomalies may also be produced by house pits, middens, hearths, and underground ovens where the matrix of the site has been altered with the addition of new materials and the mixing of stratigraphic deposits.

We employed a Geometrics G-858 Cesium Gradiometer in undertaking the magnetometer survey. The specific areas designated for geophysical survey were divided into grid systems, with grid lines staked out at 0.5 m intervals using nylon guide ropes. The operator walked the G-858 Cesium Gradiometer along the grid system with the aid of the nylon guide ropes. The dual sensors of the instrument were positioned 1.0 meters apart in a vertical configuration. The G-858 Cesium Gradiometer collected readings continuously along the grid y-axis at ca. 0.1 second intervals (one reading every ca. 0.02-0.05 m). The output from the gradiometer survey was downloaded into a spatial mapping program (SURFER) to compute isopleths and produce color contour maps showing the configuration of magnetic fields.

We then selected a sample of the magnetic anomalies for field testing. For each magnetic anomaly chosen, we excavated a 50-by-50 cm unit over the anomaly location to determine whether anomalies were produced by cultural materials or features. We employed a combination of shovels and trowels in the excavation. Sediments were screened using ¼" mesh. In a few cases, we collected column samples of sediments from the most promising units for flotation and fine screening. Stratigraphic profiles and photos were produced for one or more unit sidewalls. Magnetic anomaly units were geo-referenced using the Trimble GPS.

Fire and Environmental History

Historical research methods included evaluation of written documents such as homesteading-era land records, private journals, and newspaper accounts of settler activities, fires, industrial development (mining, logging, etc.), and other significant events with potential to affect the landscape. Family and local traditions from tribal members, surviving descendants of early laborers and settlers were also examined. These sources included oral histories, photographs, and selected ephemera. Historic maps, aerial photos, surveys and survey narratives were incorporated into a project GIS. In sum, detailed investigation of domestic life among households directly associated with the study areas, and of industrial practices where resource extraction was the predominant mode were conducted in order to reveal the prevailing patterns of resource use, land management activities, and terrestrial vegetation change during the late pre-colonial and historic period at each study site. Information on historic fires, suppression response and vegetation patterns were compiled and incorporated in fire regime analyses.

During fiscal year 2011, the project environmental historian Timothy Babalis conducted preliminary research in primary sources relating to McCabe Canyon and the Sandy Creek bottomlands at Pinnacles National Park, one of two study areas in the current project. This research was conducted during a week-long site visit to San Benito County (where Pinnacles NM is located) during the month of June and consisted of an extensive review of county records—especially tax assessment rolls—from the 1870s to recent times. Tax assessment rolls contain an annual itemized account of household wealth. This information can be used to infer agricultural production and related land use activities in a given area and by known individuals, especially when it is correlated with other official documentation (also examined) such as homestead patents, agricultural and population census records, mining claims and proofs of labor, and property deeds.

During fiscal year 2012, Mr. Babalis continued analysis of data collected from tax assessment rolls during the previous year. However, the majority of work done this year consisted of research on Native American tribes associated with study area. Much of this work was conducted orally through interviews with tribal members of the Amah Mutsun and Chalon bands. Formal oral histories were conducted with members of both groups. These interviews were then transcribed and the information correlated with written historical records and synthesized into existing research.

Historical GIS

In order to compare historical data sources in GIS, historical maps of Pinnacles National Monument were located, scanned, and georeferenced. Six historical maps were located that depicted different and compelling information, including dates from 1873 to 1933 (including early General Land Office [GLO] survey maps). Several of these maps offer detailed views of the Bear Valley portion of the Park. In addition to historical maps, historical aerial photos of the study area were orthorectified into photomosaics covering Pinnacles National Park and the Scotts, Waddell, and Whitehouse Creek watersheds. For the Pinnacles, 26 aerial photos from 1939 were orthorectified, encompassing the entire extent of the Park. For the Santa Cruz Mountains watersheds, aerial photos from 1941 and 1948 were orthorectified in order to provide complete coverage of the study area. The 1941 photos covered the entirety of Waddell Creek, but provided only partial coverage of the Scott Creek watershed. The 1941 photos were added to a photo dataset produced in an earlier project to create a mosaic covering Waddell Creek watershed and the adjacent Whitehouse and Gazos Creek watersheds, as well as Point Año Nuevo. Ten additional photos from 1948 were orthorectified and mosaicked in order to cover the remainder of Scott Creek Watershed. In total, 69 early aerial photos were orthorectified and mosaicked

into 3 separate datasets (1939, 1941, and 1948) to cover the study area. Comprehensive metadata was generated for all GIS layers and, along with the GIS itself, has been supplied to the National Park Service and California State Department of Parks and Recreation.

Key findings

Fire scar dendrochronology study (Santa Cruz Mountains)

A total of 109 coast redwood samples were collected from 19 sites within the study area. All sites were of predominantly redwood overstory, with a variety of stand and understory characteristics. Twenty-six of the samples were discarded for lack of usable fire interval information (excessive rot, or <1 fire intervals), and harvest dates for 50 of the samples could not be firmly established. The analysis of those samples with a generalized linear mixed model (GLMM) is discussed below. For sample trees with >1 samples recovered, those with the most reliable count were included in the analysis such that only one count per sample tree was analyzed.

Most sites were located on relatively steep slopes (mean 35.1%), with the majority of samples collected from stumps (76%). Other samples were retrieved from downed logs (4.6%), standing snags (8.3%), living trees (10.1%), one sample from a fallen lateral limb, and one sample was included for which origin stand only was known.

Dated samples

The approximate time period described by the overall fire scar samples is 1600-2013, though the lack of crossdating does not allow for precise estimation of this period. Some samples extended several hundred years beyond 1600, but verifiable harvest dates could not be established for most of those samples, and sample density was quite low for older dated samples. For instance, sample WHC3034 had a record of approximately 1,224 years, but this sample was retrieved from a top-killed standing old growth snag never subject to harvest, and there was no documentary information or local knowledge that would indicate a firm mortality date for this tree. The owner of this stand, who has logged the area continuously since the 1940s, indicated that it has been a snag as long as the family has owned the property (F. McCrary, pers comm.). However, given the sound condition of the wood, it was likely killed in the early 20th century, putting its record of fires back into the 1st century AD.

Summaries of fire frequency and seasonality information were estimated for dated samples going back to 1350 in order to capture a greater proportion of the fire information for this region. Composite fire information for dated samples by plot was also estimated for the focal management eras: the Native and Mission eras (1600-1850), the intensive commercial logging era (1850-1950), and the modern fire suppression/sustainable harvest era (1950-2013).

The fire return intervals recorded from the dated redwood samples in this study were relatively frequent (see Figure 4). For all sites combined, mean FRI was 6.97 years; the median FRI was 4.0 years for dated samples. The grand mean FRI for single trees (point) was 39.9 years (range of means 7–518 years). The grand median FRI (point) was 25 years. The mean number of fire scars on an individual sample was 4.12 (range 2-12 scars). For all samples, including floating chronologies, the composite mean interval frequency was 14.1 years (SE=4.13), with a median of 4.0 years. The median may be a better indicator of the central tendency than the mean for this positively skewed frequency distribution. Even

though there are several fire return intervals between 51 and 200+ years, the majority of the intervals range between 1 and 50 years in length (Figure 4). The earliest recorded fire in dated samples was in 1351 (sample COT001), and the most recent fire recorded in many of these trees was the 2009 Lockheed Fire. Several of our samples survived that extreme fire event, only to suffer mortality due to high winds in subsequent years.

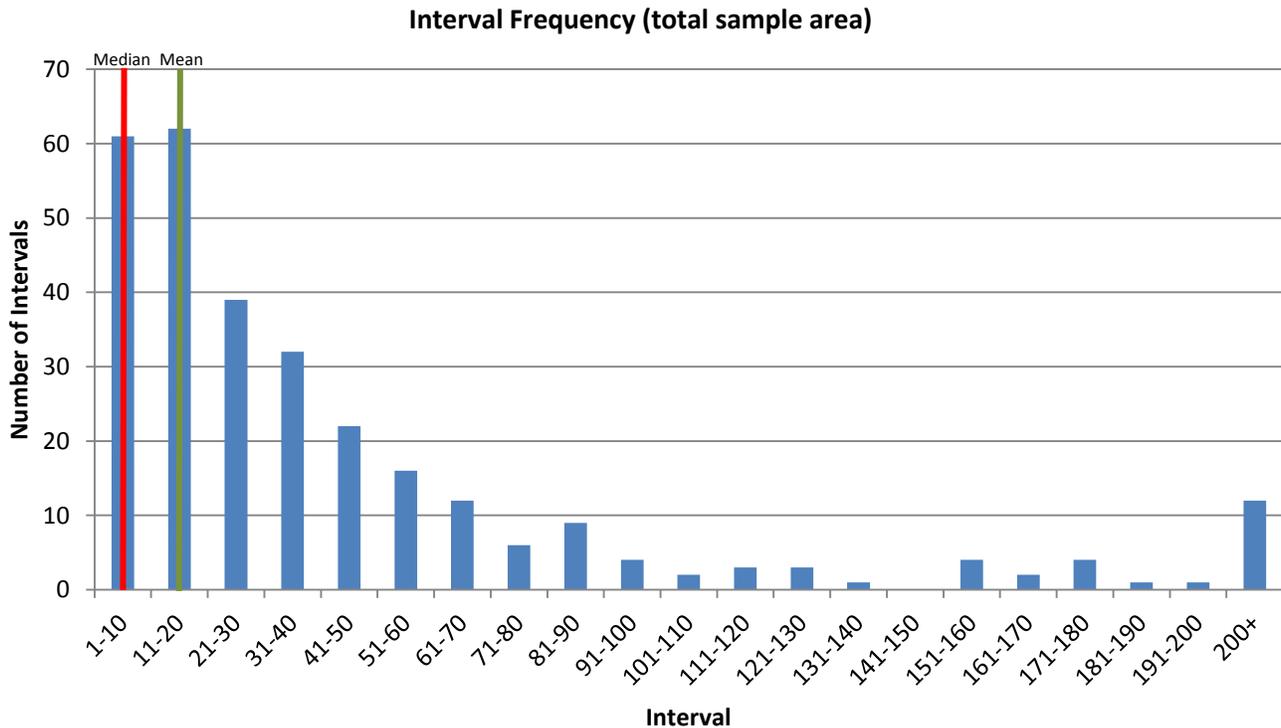


Figure 4: Fire Interval Frequency for Santa Cruz Mountains study area (n=71)

In several locations, nearby plots within zones were composited where dated sample density was insufficient for analysis in FHX2, and where local physiography does not present significant physical barriers to fire spread. As evidenced by the behavior of many historic and modern fires, the vast majority of the project area, in fact, presents few significant physical barriers to fire spread in the dry season, except in the very lower reaches of the basins.

Though some plots did not contain enough data for analysis for some management periods, when viewed at the plot level, most stands tended to exhibit similar patterns of fire frequency: fires were slightly less frequent in the Native and ranching period (mean FRI 7.6 years; range 1-29) than the intensive logging period (mean FRI 3.1 years; range 1-11), as well as the modern period (mean FRI 4.6 years; range 1-12). It should also be noted that there is some contention about the use of fire scar composite chronologies (see Dieterich 1980) to estimate how often a sample area burns (e.g. Baker and Ehle 2001). Our study area and plot sizes are large, at least by comparison to other studies. As such, we caution direct comparisons to other studies in the redwood region until further data can be developed for this area.

The season of fire occurrence was determined for 84.8% of the fire scars. As a percentage of those with known seasonality, dormant or late season fires accounted for a combined total percentage

of 87.3% of all fires for the entire period of record (1350-2013; 54.7% dormant, 32.6% late) – indicating that historic fires most likely took place between the months of July and February. Early season (March – June) fires accounted for 12.6% of fires. In the 1600-1850 period, combined dormant and late season fires accounted for 91% of fires (63.6% and 27.3%, respectively), with 9.1% of fires occurring in the early season. During the intensive logging period (1850-1950) combined dormant and late season fires accounted for 85.2% of fires (55.6% and 29.6%, respectively), and 14.8% in the early season. In the modern era (1950-2013), dormant and late season fires still account for the majority of fires (85.8%), but with a marked shift in the proportions into the drier late season (July – September), which now account for 42.9% of fires. Early season fires represent 14.3% of fires in this period.

Floating Chronologies

Using a backward selection process, only 3 independent variables ultimately proved significant in terms of predicting the probability of the occurrence of fire in the study area: the combined watershed/zone variable ($p= 0.04$), the distance to native residential site ($p= .04$), and position on slope ($p= 0.002$). P-values were similar between the default p-values produced by R’s ‘summary’ function and the explicit likelihood ratio test. In addition, the plot random effect is significant ($p<<.001$)

Estimates of the probability of the occurrence of a fire scar in a given year are shown in Table 1. Probabilities are summarized by the combined watershed/zone variable, and are displayed for slope position and linear distances to residential sites.

Parameter estimates for all other predictor variables, including percent slope, distance to coast, aspect, elevation, proximity to site (broadly defined), proximity to “C-Zone”, and watershed were not significant.

Table 1. Parameter estimates* for significant predictor variables

Watershed/Zone	<i>Position on Slope</i>		
	bottom	middle	Top
Scott-2	1.3	1.5	3.0
Scott-3	32.5	36.0	53.9
Waddell-2	57.1	60.9	76.4
Waddell-3	58.5	62.3	77.4
Whitehouse-1	50.3	54.2	71.1
Whitehouse-2	31.7	35.2	53.1

Watershed/Zone	<i>Distance to Native Residential Site</i>		
	min	mean	Max
Scott-2	1.9	1.3	0.6
Scott-3	42.6	32.5	17.5
Waddell-2	67.2	57.1	37.0
Waddell-3	68.5	58.5	38.3
Whitehouse-1	61.0	50.3	30.9
Whitehouse-2	41.8	31.7	17.0

* probability (as a percentage) of fire in any given year

Using Fire-Altered Phytoliths to Examine the Indigenous Fire Regime at McCabe Canyon

None of the approaches tested in this study and purported in the literature to distinguish individual burned phytoliths from unburned phytoliths were reliable enough to be useful to accurately estimate past grassland fire regimes in typical soil conditions.

1. The Raman spectroscopic approach, distinguishing individual burned phytoliths through heat-induced changes to occluded carbon, was only able to identify phytoliths that were visually darkened from burning in an open flame, suggesting the carbon measured by the Raman instrument is externally adsorbed during a fire rather than internally altered by heating.

2. The refractive index approach, distinguishing heated or burned phytoliths through changes in the RI due largely to decreased water content, is dependent on fire intensity and not accurate at the relatively low temperatures typical of grassland fires, as well as sensitive to rehydration and phytolith aging effects.

3. The phytolith coloration approach, distinguishing burned phytoliths through their altered color, successfully identified as burned the vast majority of phytoliths from plant leaf material burned with an open flame, both in the lab and from a recent prescribed burn in the field. Phytoliths that were heated in a muffle furnace to grassland fire temperatures but not exposed to direct flame could not be distinguished. However, there were few obviously darkened soil phytoliths found at the deergrass site in McCabe Canyon or at other grassland sites sampled in Pinnacles NP, or indeed at any of the hundreds of grassland sites examined for phytoliths anywhere in California, even at sites expected to have had a long history of frequent native burning. Instead, many soil phytoliths have altered, rather than darkened, color and/or texture. This suggests that darkened, burned phytoliths may be visually altered, either becoming slightly yellowed, light brown, more opaque or with granular texture as they weather after they are deposited in the soil. This approach holds some promise for reconstructing grassland fire regimes if weathered burned phytoliths can be reliably distinguished from weathered unburned phytoliths; considerable additional research is required to determine whether this is possible.

Most areas in Pinnacles NP that are currently covered with California Annual Grassland (CAG) were likely grass-dominated grassland prior to European settlement. Based on previous research in California, sites with soil phytolith percentage >0.30% are considered long-term grass dominated grasslands. Many upland sites that are currently CAG patches in a matrix of other vegetation along the High Peaks Trail and the Bushwack Saddle grass patch showed elevated phytolith percentages, suggesting they have been stable and grass-dominated for hundreds to thousands of years. Percentages consistently above this threshold in samples from the large grassland area near the eastern entrance to the Park suggest this area was likely dominated by grasses prior to European settlement, not surprising because the relatively high water table there likely contributed to elevated soil moisture that probably favors grasses over forbs in California (Evetts and Bartolome 2013).

Temperatures achieved during a prescribed burn of a grassland plot dominated by deergrass were highly variable and patchy, ranging from unburned to ~700°C.

Since the technique was first suggested almost 30 years ago (Piperno 2006), visual identification of burned phytoliths has been increasingly used in the literature to document fire in a variety of environments (Kealhofer 1996; Boyd 2002; Gu et al. 2008; Morris et al. 2010). However, no researchers to date have adequately addressed the issue of distinguishing burned from unburned phytoliths in a typical soil phytolith assemblage that includes phytoliths with a wide range of ages and degree of

weathering. Publications associated with phytolith research usually have photographs of a typical darkened phytolith that appears exactly like phytoliths extracted in our study from ash resulting from laboratory burning and prescribed burning of leaf material. Unfortunately, very few phytoliths found in California soils fit this idealized image. It is not clear whether current researchers are counting only those phytoliths that are clearly darkened or whether they are also counting those phytoliths that have some alteration of color or texture. The inability to confidently and reliably identify a burned phytolith in a soil assemblage was a big stumbling block for this study; it is difficult to believe previous researchers did not face similar challenges. There needs to be an explicit examination of this issue, including more research to clarify which weathered phytoliths should be counted as well as a survey of previous authors to determine which altered phytolith types were included in their counts, with publication of results. Recent research with sponge spicules (Wyche 2012) has highlighted problems with using the refractive index to reliably identify heating of amorphous silica at temperatures below 700°C. At the same time, this research suggests there may be predictable changes, not related to water content, occurring to the fluorescence spectra of biogenic silica when exposed to lower temperatures.

Archaeological Research at McCabe Canyon

Pedestrian Surface Survey

Field crews observed significant differences in the environmental characteristics of McCabe Canyon walking from south to north. The southern half of McCabe Canyon is relatively open and level canyon land, which during the month of June contained standing water in McCabe Creek and water seeping from at least two artesian springs in Blocks A and D. The majestic valley oaks, whiteroot sedge, and deergrass in the southern canyon soon give way to sporadic annual grasses, shrubs, and increasing numbers of grey pine in the north. The northern half of McCabe Canyon, particularly north of the extensive deergrass patch in Block G, is much drier, narrower, and steeper in terrain.

A strong association exists between the distinctive environmental patterns in McCabe Canyon and the presence/absence of archaeological remains. We did not observe any clear evidence for archaeological remains in the drier, northern half of McCabe Canyon, nor did we observe indigenous material culture along the three side canyons walked by survey crews or up the chaparral-covered ridge slopes or ridge crests on both sides of McCabe Canyon. The archaeological remains discovered during the pedestrian survey are almost entirely associated with the better watered canyon land comprising the six southern most survey blocks (A, B, D, E, F, G) situated on either side of McCabe Creek (Figure 3). In addition to detecting surface material in the southern survey blocks, the survey reconnaissance provided field crews with the opportunity to mark areas that looked promising for archaeological remains that may be buried and/or difficult to see because of dense vegetation. We designated these as “areas of special interest” that we would return to for further subsurface investigation. All of the “areas of special interest,” as defined by members of the survey team, are situated in the six southern survey blocks of McCabe Canyon.

The surface pedestrian survey produced the following results. One lithic scatter on the low bench at the entrance of McCabe Canyon near Highway 146 was detected. It is situated on the west bench directly across the canyon from CA-SBN-222. The site consisted of a scatter of lithic artifacts and other materials situated within a 55 by 50 m area on the top and sides of the slight ridge. No artifacts were collected. Artifacts included 8 red chert flakes, one red chert core, one worked glass flake, and one tin can stamped with a “United States Tobacco Company” emblem.

Survey crews also detected isolated chipped stone flakes and tools from chert, basalt, and rhyolite, and white tuff, and a possible pestle fragment in the floodplain between the two benches associated with A-1-2 on the west side of McCabe Canyon and CA-SBN-222 on the east side. Survey crews also recorded a small, portable mortar in the channel of McCabe Creek in the southern boundary of Block. It appears that a low density scatter of artifacts is dispersed between the two sites in the southern most area of McCabe Canyon. We defined this area as a “non-site manifestation.”
Shovel Probe Survey

We completed shovel probe surveys in seven “areas of special interest.” Little cultural material was encountered, but subsurface charcoal, as well as what we postulate to be fire-associated sediment color and texture were observed. A discrete charcoal lens and fire-cracked rocks were detected in Shovel Probe 5 (G-1-2).

Geophysical Survey

We completed geophysical investigations in three areas (B-1-1, B-1-2, D-1-2).

B-1-1 Summary. The field testing suggests that the dipolar anomalies observed during the gradiometer survey were created by pieces of surface metal or possibly buried rocks with high iron content. This area is situated only a short distance to the north of a private residence inholding, thus the discovery of barbed wire and metal link chain is not surprising. No other cultural materials were observed during the field testing of the five geophysical anomalies. The findings of the geophysical survey did not reveal a broader archaeological manifestation associated with the portable mortar. The geophysical results do not suggest that the low density surface scatter of lithics observed to the south extends northward into this area of the canyon land.

B-1-2 Summary. The detailed investigation of the McCabe Spring area indicates that both historic ranchers and native peoples used this place in the past. It is not clear what materials may have created the high magnetic readings for Mag Anomalies 1, 3, and 4. Mag Anomalies 1 and 3 may have been caused by iron rich rocks detected in the units, whereas rodent disturbance in Mag Anomaly 4 may have been a factor. Mag Anomaly 2, situated 5 meters from the bedrock milling station, appears to be the product of past cultural activities. It is the location of a possible pit feature with charcoal and fire-cracked rock. One lithic artifact was collected above the feature, while a chopping tool was recovered in the feature, along with charcoal and unburned gopher remains. Flotation samples collected from Mag Anomaly 2, as well as the BMS unit, were transported to the California Archaeology Laboratory at UC Berkeley for flotation and analysis.

D-1-2 Summary. The subsurface testing of the D-1-2 area, situated near the spring and wetlands in Block D, indicates that most of the magnetic anomalies may have been produced by noncultural processes and materials, such as the presence of gravel lenses or rocks. However, the high magnetic readings for Mag Anomaly 3 appear to be caused by cultural remains, including fire-cracked rocks, charcoal, lithic artifacts, and faunal remains. Flotation samples collected from deposits in Mag Anomaly 3, as well as Mag Unit 6, were transported to the California Archaeology Laboratory at UC Berkeley for analysis.

LABORATORY ANALYSES

Radiocarbon Assessments

To evaluate the temporal components of B-1-2 and D-1-2, we selected four organic samples for radiocarbon dating. The two dates from B-1-2 indicate a relatively late use of the site. One sample (CAM# 160102) from the pit feature in Mag Anomaly 2 (63-64 cm) yielded an age of cal. A.D. 1470-1639 (all dates are given in 2 sigma ranges). A second sample (CAM# 160103) from the BMS Unit (30-35 cm) produced a similar date of cal. A.D. 1451-1529 (.500) and cal A.D. 1543-1634 (.499). The two radiocarbon assessments from D-1-2 indicate this location may have been used in late prehistoric and protohistoric times. The organic sample (CAM# 160101) recovered from the lowest level in Mag Anomaly 3 (50-70 cm; below the fire-cracked feature) generated a date of cal. A.D. 1289-1400. The other sample (CAM# 160100) recovered from within the fire-cracked rock feature in Mag Anomaly 3 (30-50 cm) yielded a date of cal. A.D. 1487-1604 (.757) and cal. A.D. 1608-1649 (.243).

Macrobotanical Analysis

Twenty-one flotation samples were collected from four excavation units at B-1-2 and D-1-2. The twelve flotation samples from B-1-2 included seven from the excavation of Mag Anomaly 2. Bulk and scatter samples were taken from above, within, and below the pit feature, as well as from an 80 cm column sample along the unit's north wall. Field crews also collected five bulk samples from an 80 cm column sample from the BMS unit. The investigation of D-1-2 yielded nine flotation samples. These consisted of six bulk and scatter samples from the fire-cracked rock feature and a column sample in Mag Anomaly 3. The depth of the deposits ranged from 10-70 cm below surface. Another three flotation samples were gathered from a column sample in Mag Unit 6 that extended 10-70 cm below surface. Samples ranged in volume from 1.9-4.2 liters, with an average of 3.0 liters.

Macrobotanical data are reported as densities, with counts and weights standardized to quantities per liter of soil or sediment. Macrobotanical density was generally low in the overall assemblage. Wood charcoal was sparse, averaging 7.6 specimens/liter and 77.5 mg/liter. Fourteen of seventeen samples contained <10 macrobotanical specimens/liter identified to the level of family or better (Figure 5).

Five taxa comprise 91% of the assemblage identified to genus level (Figure 6): oak acorn (*Quercus* sp., 55%), elderberry (*Sambucus* sp., 12%), clover (*Trifolium* sp. cf., 9%), star thistle (*Centaurea* sp., 8%), and bedstraw (*Galium* sp., 7%). The overwhelming majority of specimens are grasses (Poaceae, 92%) or probable grasses (Poaceae cf., 3%), with some small-seeded sunflower family specimens (Asteraceae, 4%). Nearly three quarters (74.3%) of identified macrobotanical remains in the overall assemblage come from the three samples with the highest macrobotanical density (Flots #13, 16, and 17).

The four AMS date determinations collected from flotation samples from B-1-2 and D-1-2 indicate that most charred materials >30 cm in depth are from the period prior to Euro-American colonization, despite vertical mixing that has incorporated some more recent material into deeper levels. Botanical remains in samples >30 cm in depth primarily represent the vegetation that would have been present under indigenous land use practices, which may have included an anthropogenic management fire regime.

Analyses of Other Cultural Materials (Artifacts, Faunal Remains)

Our general policy was to not collect cultural materials observed on the ground surface during surface pedestrian survey. These remains were left in situ in the field. We did collect cultural materials (artifacts, faunal specimens and charcoal samples) that were recovered in subsurface contexts from shovel probe units and magnetic anomaly excavation units. These remains were transported to the California Archaeology Laboratory at UC Berkeley for analysis and preparation for curation. UC Berkeley also prepared an archaeological catalogue for all subsurface materials. Using an Excel spreadsheet, we assigned each specimen (or cluster of charcoal pieces, faunal remains) a catalogue number for which the following fields of information were recorded: provenience information, artifact type, raw material, dimensions, weight, count, and any further remarks. Twenty-two catalogue numbers were assigned: 2 faunal (FA), 2 charcoal (CH), 4 lithic groundstone (LG), and 11 lithic flakes (LF). For lithic flakes, we also recorded flake type, termination type, evidence for heat treatment, cortical stage, and evidence for edge modification.

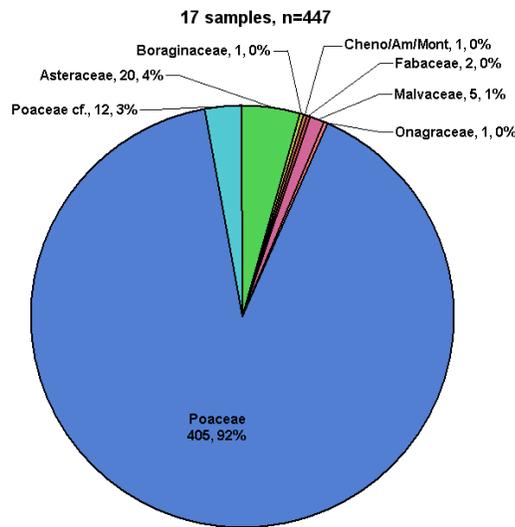


Figure 5: McCabe Canyon Charred Macrobotanical Samples Identified to Family

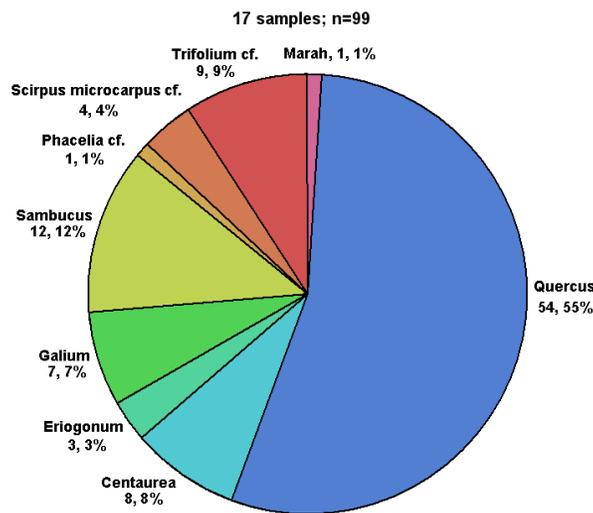


Figure 6: McCabe Canyon Charred Macrobotanical Samples Identified to Genus

The majority of artifacts are unretouched flakes with no evidence of edge modification or use. They include lithic flakes manufactured from andesite (AN, n=3), basalt (BA, n=2), rhyolite (RH, n=2), sandstone (SA, n=2), and chert (CH, n=1). One formal lithic flake tool (PNP-UCB-2011-4) was identified from Mag Anomaly 2 in B-1-2. It is a large, hand held chopper made from chert with evidence for both retouch and use. The four groundstone artifacts included two recycled basalt (BA) milling stone fragments from the fire-cracked feature in Mag Anomaly 3 in D-1-2. The other two groundstone objects were the milling handstones associated with the surface of the mortar unit in B-1-2. The two “chunks” of charcoal were recovered, respectively, from Mag Anomaly 2 in B-1-2 and Mag Anomaly 3 in D-1-2. The faunal remains consisted of the unburned gopher bones recovered from Mag Anomaly 2 in B-1-2, and the broken, unburned, long bone of a small mammal from the fire-cracked rock feature in Mag Anomaly 3 in D-1-2.

The analysis of the heavy fraction from the 17 flotation samples from B-1-2 and D-1-2 yielded an additional 83 faunal fragments. Eighty-one of the 83 faunal fragments are tentatively identified as rodent remains (analysis ongoing). They were found in all of the excavation units in B-1-2 and D-1-2. Two of the elements are small mammal remains. They include one charred element from Flotation 21 >1, D-1-2, Mag Anomaly 3, 50-70 cm, and another charred small mammal remains from Flotation 16 >4, D-1-2, Mag Anomaly 3, 10-30cm.

In conclusion, the findings of the archaeological investigation provide some tantalizing indications that anthropogenic burning may have supplemented the natural (i.e. lightning) ignitions previously reported by Greenlee and Langenheim (1990), thus altering and providing diversity to the spatial and temporal extent of fire in this landscape. This interpretation that both natural and cultural ignition sources were probably at work is based on the following three observations from the archaeobotanical findings from B-1-2 and D-1-2.

First, the taxa recovered from the macrobotanical analysis indicate the presence of plants from oak woodland and grassland communities, including oak acorn (*Quercus* sp.), elderberry (*Sambucus* sp.), clover (*Trifolium* sp. cf.), bedstraw (*Galium* sp.), borage family plants (Boraginaceae), grasses (Poaceae), with some small-seeded sunflower family specimens (Asteraceae), wild cucumber (*Marah* sp.), and a charred seed in the Amaranthaceae or Montiaceae families. Given the vertical mixing of deposits at B-1-2, it not clear to what degree the charred plants may have been brought to the site by people or deposited there after nearby landscape fires. In either case, it suggests that the floral resources growing in the nearby environs were from oak woodlands and grasslands. The archaeological remains from the more intact deposits at D-1-2 appear to be the result of intentional gathering of plants from nearby habitats, which may have been initially processed in association with at least one hearth feature. It is noteworthy that we found no evidence in either site of chaparral vegetation that may have been deposited from nearby landscape fires or transported there by people who were harvesting shrubland taxa for food, medicine, or crafting materials, such as manzanita berries, hollyleaf cherry nuts, scrub oak nuts, and toyon berries.

Second, the discovery of floral taxa from the oak woodlands and grasslands at B-1-2 and D-1-2 suggests that frequent valley burns at a sub-decadal interval may have taken place. The maintenance of extensive grasslands in the bottomlands would be best sustained by regular anthropogenic burning. Our findings do not dispute such an interpretation. In contrast, the current natural fire regime of 30-40 years or more would be much less conducive to the long-term upkeep of grassland habitats over a period of several centuries (A.D. 1300-1650, Greenlee & Langenheim 1990).

Third, the discovery of oak woodland and grassland species at B-1-2 and D-1-2 suggests that type conversion of chaparral shrubland to grassland may have been taking place in the adjacent uplands of McCabe Canyon in late prehistoric times. Both sites are situated on the eastside of the canyon land on either the upper terrace or lower ridge slope. Today the eastern boundary of both sites is comprised of thick chaparral vegetation (e.g., stands of chamise) which extends down the ridge slope close to the bottom of McCabe Valley. However, the findings indicate that the immediate neighborhood of both sites consisted of oak woodland and grassland habitats in prehistoric times, and that the chaparral vegetation must have been situated farther upslope. If shrubland vegetation had been growing near the sites during the period of A.D. 1300-1650, then it would be expected that nearby landscape fires would have deposited taxa from chaparral vegetation into the archaeological deposits at one or both of the sites. The scarcity of shrubland taxa, in combination with the oak and grassland plant remains recovered at the sites, supports the possible interpretation that the chaparral ecosystem may have been pushed farther up the ridge system by frequent fires radiating out from the McCabe bottomlands.

Fire and Environmental History

Based on evaluation of written documents such as homesteading-era land records, private journals, and newspaper accounts of settler activities, fires, industrial development (mining, logging, etc.), this study examined the relationship between specific communities and the region in and around Pinnacles National Park, with a special focus on fire. This examination focused on six major eras: The Indigenous Context; European Contact and Colonization; Settlement during the American Period; Post-War Rangeland Management (1946-1977); Prescribed Burning at Pinnacles National Monument (1977-1982); and the Pinnacles Bottomlands during the Post-War Years (1946-2006). The study also addresses the Consequences and Effects of Land Use Practices within these periods.

Through conducting comprehensive historical analysis, we were also able to evaluate the effectiveness of several fire management approaches in the Park. It appears now that the fire regime which would best maintain chaparral habitats at Pinnacles should represent a fire-return interval of at least 30 to 40 years, the frequency which Greenlee and Moldenke (1982) found to be average for the period they investigated. See Babalis' Supplemental Report for complete findings. However, as interior climate conditions continue to change, likely resulting in periods of prolonged drought, deluge, and increased summer temperatures (NPS 2012), it will likely be necessary to manage chaparral habitats in ways that will enhance their resilience in the face of certain future firestorms (e.g. diversifying stand age complexity via prescribed burning, restoration of grassland/forb patches in high country and slopes, etc.).

McCabe Canyon Prescribed Burn: Restoring Traditional Management Practices

This component of the JFSP integrates traditional Native American tending practices with contemporary management techniques in an effort to restore, protect, and understand the natural and cultural processes of a unique California grassland system. Our efforts culminated in a prescribed burn that took place in December 2011. In the field of restoration ecology, there is an increasing awareness as to the significant role that Native Americans historically played in shaping the landscape. Traditional ecological knowledge teaches that both deergrass and white root sedge respond favorably to intermediate human disturbance. This collaborative restoration project allows the park and the tribe to research, test and re-learn appropriate traditional management techniques in a way that is mutually beneficial to all parties.

Background

An extensive deergrass field (*Muhlenbergia rigens*) and expansive beds of white root sedge (*Carex barbarae*) occupy a site within Pinnacles National Park, called McCabe Canyon. Botanically, large stands of deergrass and white-root are extremely rare in California. Culturally, deergrass and white root have deep meanings for past and present Mutsun and other California Indian peoples. Pinnacles partnered with the UC Santa Cruz Arboretum and the Amah Mutsun Tribal Band to restore both natural and cultural processes in this unique site. This project has provided an opportunity for resource management collaboration that is unprecedented in the park's 100 year history.

McCabe Canyon is botanically significant because it maintains native grassland, oak woodland, and riparian ecosystems. Valley oak savanna and riparian ecosystems are plant communities vulnerable to degradation and are considered threatened habitats by the California Native Plant Society and the California Department of Fish and Wildlife. The area's large populations of deergrass, covering two acres, and white root sedge, stretching 3 acres, are rare remnants of native grasslands that centuries ago were widespread.

McCabe Canyon is also culturally significant. Deergrass and white root sedge provide key materials for California Indian basketweaving. Both species were traditionally and are still managed or tended by Native peoples. Other ethnobotanically significant species in the area include valley oak (*Quercus lobata*), coast live oak (*Quercus agrifolia*), and gray pine (*Pinus sabiniana*), all traditional food plants. A perennial stream runs through the canyon, and the combination of permanent water, plentiful food and abundant basketry material provides a probable case that this site may have been historically managed by Native peoples. The application of fire maintains healthy stands of deergrass and encourages new growth and flower stalk production. Outside the Park, California Indians still carry on the tradition of gathering and tending these species today.

Traditional Burn

On December 8, 2011 the park conducted a small prescribed fire as part of this Joint Fire Science Program research project. National Park Service Fire Management staff completed the burn operations with cooperators from the Cal Fire San Benito-Monterey Unit, the Amah Mutsun Tribal Band, and the Bureau of Land Management. The burn was approximately two acres in size (Figure 7).



Figure 7. Traditional deergrass burn at Pinnacles National Park (12/8/11). Photo by Rick Flores

The burn was located in the 2-acre grassland dominated by deergrass (*Muhlenbergia rigens*), highly valued by California Indian tribes. The burn was ignited by a representative of the Amah Mutsun Tribe. The effects of burning deergrass are compared with mechanical clipping to stimulate the growth of flower stalks which are used in the foundation of coiled baskets.

Discussion

Fire regime changes are now being observed in western North America (Cohen and Miller 2001). Longer fire seasons and more frequent and severe wildfires are already having large-scale impacts on landscapes and resources in California (Duguy et al 2013). These changes are also impacting cultural use and the availability of tribally valued resources throughout the state (Voggesser et al 2013). However, current utilization and preservation of publicly-owned parks and open spaces is still largely based on how these systems developed under past climatic conditions (Spittlehouse & Stewart 2004).

Adaptation to and mitigation of these changes requires planning for change such that a suite of management alternatives is available whenever needed (Spittlehouse & Stewart 2004). We contend that in order to develop realistic conceptual models of desired future conditions, and to maximize the effectiveness of management alternatives, both culturally and ecologically, 1) a greater understanding of historical ranges of variability, resilience, and landscape function must be developed, 2) the cultures involved in creating, maintaining, or modifying those historical conditions must be central to efforts to synthesize that information, and 3) ultimately become full partners in its use, interpretation, and implementation.

As exemplified by this study, as well as by a wide range of global efforts to incorporate indigenous knowledge systems into contemporary land use planning (Uprety et al 2012), proper respect and deference must be shown to the individuals, tribes, communities, and governments which steward those knowledge systems. Once those relationships are achieved and time-tested, a greater range of information needed to inform historical (and future) conceptual models of landscape change and adaptation can be cooperatively developed.

This study brought together a disparate team of subject specialists and tribal peoples with the aim of adding clarity to our understanding of the relationship between humans and fire in the Central Coast of California. Physical, historical, ethnographic, and experimental information was developed around this theme, as were the relationships necessary to ultimately utilize the findings to improve environmental quality through better informed and more representative land use decision-making.

In Central California, several studies indicate the presence of a higher than expected frequency of fire with respect to the only natural source of ignitions: lightning. Greenlee and Langenheim's (1990) study of historic fire events in the Monterey Bay area estimated that the mean fire interval based on lightning strikes alone would have been about 135 years – and that with the advent of native-managed burning, the fire intervals dropped to roughly 50 years (Greenlee and Langenheim 1990:245). Another recent fire history study of redwoods from several locations in the Santa Cruz Mountains found even shorter fire-return intervals, ranging on average from nine to 16 years during ~1650 to 1860 (Stephens and Fry 2005).

This study is now one of just three investigations in California (with Norman 2007 and Gassaway 2009) to indicate a strong statistical relationship between pre-colonial societies and fire frequency

(Table 1). Together with a tree ring-based frequent fire return interval (median FRI 4.0 years) for the northern portion of the study area, and compelling land and resource utilization insights based on our historical, archaeological, and phytolith work at the Pinnacles - these findings suggest a culturally and spatially complex relationship between tribal societies, fire, and terrestrial resources in Central California.

Cultural fire regimes emerged as a result of time-tested, collective community knowledge on the effects of climate and fire on culturally valued resources (Lightfoot and Parrish 2009). Tribes utilized fire to increase the predictability of resource yields and cycles, as well as to increase ecosystem resilience (Anderson 2005). Tribes used fire for crop management, basketry, range improvement, defensible space around valued resources, clearing travel routes, driving game/prey, clearing riparian areas, increasing water yield, communication/signaling, warfare, rituals, heat, and cooking (Stewart 2002; Williams 2002). The behavior, severity, and extent of major wildfires in “natural” (lightning driven) regimes versus that of major fires in landscape mosaics created by cultural regimes also differ (Kofinas et al. 2010). In addition, the size and spatial configuration of fires under cultural regimes were likely controlled to some degree by legacy fire effects that produced patchy distribution of recently burned parcels, potentially impeding the progress of subsequent, low-intensity fires. This patchwork quilt of past fires, when combined with natural barriers, may have facilitated the creation of relatively small burn areas with definable boundaries – in other words, an anthropogenic, pyrodiverse landscape (Lightfoot and Parrish 2009).

Management Implications

New Science Initiative projects are not required to demonstrate immediate relevance to managers; however, this research identified several management implications suggested by the research findings above.

Dendroecology-based fire history

1) Our data support a growing number of studies in California and the Pacific West indicating that fire was historically more frequent in the redwood region than earlier studies have indicated. Our study also indicates a potentially close linkage between the frequency of fire and pre-colonial human habitation (implying human ignitions). This information can be used to support and inform expanded prescribed burning efforts in these systems, and further research using this information could improve landscape-level conceptual models of desired future conditions with respect to publicly-owned open space, the wildland/urban interface, and ecotone areas.

Phytolith research

2) Because it is not yet possible to use phytoliths or any other paleoecological approach as a proxy to determine grassland fire regimes in Pinnacles NP prior to European settlement, ethnographic information and the accounts of early explorers to the region, indicating that grassland fires were frequently intentionally burned, remain the most accurate sources of prehistoric fire regimes and should remain the guide for current grassland management.

3) High phytolith content in soils currently covered by grasslands in Pinnacles NP suggests these areas supported grass-dominated grasslands prior to European settlement. Since native grasses were dominant, it is highly appropriate to attempt to restore native grasses and forbs to areas in the park currently dominated by CAG vegetation.

Archaeological Research

4) The findings of our archaeological investigation provide some support that both lightning ignited fires and anthropogenic burning were probably taking place in McCabe Canyon during the period of A.D. 1300 to 1650. We believe that a cycle of regularized prescribed burns may have been initiated by native peoples, as a sub-decadal fire interval would have been ideal to maintain the oak woodland and grassland habitats that existed in the canyon lands over at least three centuries. Our findings also suggest that the spatial distribution of chaparral vegetation may have been pushed farther up the ridge slope in late prehistoric times from burns radiating out of the valley. This spatial patterning is in sharp contrast to the current extension of chaparral vegetation to the immediate edges of the McCabe bottomlands.

5) The paucity of significant residential sites or logistically-organized processing camps in McCabe Canyon is an important finding. This suggests that people were extracting resources from the canyon lands and transporting them elsewhere for processing, consumption, and possibly storage. We suspect that these more intensively used settlements, while not found in McCabe Canyon proper, may have been located nearby by people inhabiting the local region. If hunter-gatherers were exploiting McCabe Canyon directly from more distant places, such as the Salinas Valley or San Benito Valley, we expect that they would have established logistically-organized camps in the McCabe area, which would have served as temporary bases of operation for harvesting and processing resources for transportation back home. Since these kinds of sites were not found, a more parsimonious explanation is that the people exploiting McCabe were residing in residential settlements or logistical based camps situated in the nearby Pinnacles bottomlands. Native people who founded settlements here would have been ideally situated to not only exploit the rich riparian, oak woodland, and grassland communities of the bottomlands, but they were in excellent spatial proximity to harvest the many resources of the nearby upland canyon lands, such as McCabe Canyon.

We contend that native peoples who established residential bases in the nearby Pinnacles bottomlands would have included McCabe Canyon in their daily catchment or foraging range. By walking a relatively short distance northward out of the Bear Valley corridor, native peoples could have effectively harvested resources from the oak woodlands, deergrass patches, whiteroot sedge plots, and other grassland habitats in the well watered, southern McCabe canyon lands. The exploitation of more distance locales in the McCabe Canyon area, such as hunting for deer in the uplands, would still be in the catchment or foraging range of some of the nearby bottomland settlements. In this scenario, resources exploited in McCabe Canyon would have been transported directly to nearby residential sites for processing, cooking, consumption, and even preparation for storage. An excellent candidate for this kind of residential/processing site, which was ideally situated to dispatch people into McCabe Canyon, is one of the known (recorded) sites in Bear Valley. It is the largest and most complex of all the known Pinnacle sites, consisting of multiple loci of midden deposits, chipped stone, ground stone, and fire-cracked rocks, and a bedrock milling station. It is also located along the westernmost segment of the Bear Valley corridor.

This information will allow the Park to devise a more nuanced regime for protection and study of important cultural resources within the Park, as well as allow the Park to better facilitate public access.

McCabe Canyon Prescribed Burn

6) This component of the JFSP project is allowing us to better understand traditional management processes and restore the condition of botanically and culturally significant vegetation communities to a reference state that is inclusive of cultural management, reintroduce traditional resource management techniques, determine flora and fauna response, and form lasting working relationships with project partners. Prior to 2009, the area was not managed, was impacted by exotic pigs, invasive weeds, and traditional tending practices were absent. Now, the pigs have been removed, many of the invasive plants have been controlled, and we have begun to reintroduce traditional practices back to the land.

Relationship to other recent findings and ongoing work

Table 2. Related projects		
Project/Funding Source/Year	Description/Project elements supported	Status
<p>“Central Coast Ethno-ecology Studies” (Quiroste Valley)</p> <p>California State Department of Parks and Recreation 2007-2008</p> <p>Moore Foundation 2010-2013</p>	<ul style="list-style-type: none"> • Archaeological Fieldwork • Fire Scar Analysis • Charcoal/Pollen Study • Isotopic Analysis • Microbotanical Analysis and Materials • GIS Development • Computer Software • AMS Dates • Native American Consultation 	Complete
<p>“Cooperative Habitat Restoration of a California Grassland”</p> <p>National Park Service 2009-2012</p>	<ul style="list-style-type: none"> • Documented desired future conditions (DFC) for the deergrass and white-root populations within the study site. • Plot design and establishment to test vegetation response to various approaches to achieving DFCs. • Initiation of baseline flora, fauna and physical surveys to gain a better understanding of ecosystem structure and function within McCabe Canyon. • Control of targeted invasive plant species within McCabe Canyon using non-chemical techniques. • Treatment Plan for populations that may include prescribed burning, clipping of target plants, thinning of native plants, harvesting, and outplanting. • Begin developing interpretive material and documenting project with video and still photography. 	Ongoing

<p>“Valley Oaks: A Cultural and Ecological Journey Through Time”</p> <p>Christensen Fund Yahoo Employee Fund</p> <p>2010/2011</p>	<ul style="list-style-type: none"> Partnership between California Academy of Sciences, SFEI/ASC, and local tribes to interpret the ecology and cultural relationships of Valley oaks 	<p>Complete</p>
<p>“San Francisco Estuary Institute/ Aquatic Science Center Tribal Initiative”</p> <p>Switzer Foundation</p> <p>2012-2013</p>	<ul style="list-style-type: none"> New programmatic initiative designed around Joint Fire project elements to expand similar work with tribes throughout California 	<p>Ongoing</p>
<p>“An Integrative Approach to Developing Sustainable Land Use Plans to Serve Diverse Stakeholders through Traditional Resource and Environmental Management Practices”</p> <p>National Science Foundation</p> <p>2014-2016</p>	<ul style="list-style-type: none"> Expansion of work supported by JFSP to <ul style="list-style-type: none"> 1) incorporate archaeological biological data into the “Predictive Biosystems Informatics Engine” (PBIE), an integrative database that synthesizes ecological, environmental, and historical data sets. 2) conduct integrative historical ecological research on indigenous resource use and TREM practices in California by applying methods developed in prior research 3) develop, implement, and evaluate the sustainability implications of TREM-based management on California public lands 	<p>Ongoing</p>

Future Work Needed

Dendroecology-based fire history

1) We recommend expanding dendroecological research in the Santa Cruz Mountains. Current efforts to develop a master ring chronology for the Santa Cruz Mountains (Sillett et al 2010) could dramatically improve efforts to crossdate Coast Redwoods in the study area, and facilitate greatly improved conceptual models of fire behavior, frequency, spatial extent, and terrestrial vegetation. Greater investment will be needed to recover samples from large, roadless areas in some watersheds, but our surveys indicate that there is sufficient data in the region to warrant such an effort.

2) We recommend expanding work to define the cultural landscape of the Santa Cruz Mountains. Given the relationship between pre-colonial habitation sites and fire frequency indicated by our findings, further historical and ethnographic research on the distribution of cultural activity in the area would improve our understanding of this relationship. Based on existing information, coastal tribal communities in this area arranged themselves on the landscape in complex patterns not yet fully

understood – likely having effects on forest stand composition, vegetation mosaics, water sources, and wildlife populations. Better informed models incorporating this information could expand alternatives for restoration and management.

Phytoliths

3) To make the phytolith coloration approach viable for reconstructing past fire regimes by using fire-altered soil phytoliths, considerable research must be done to document changes that occur in burned phytoliths compared to unburned phytoliths due to weathering and aging in the soil environment. In every soil phytolith assemblage examined, many phytoliths show substantial changes in color, opacity, and texture but very few appear darkened in the same manner as those observed in recently burned leaf material. It is suspected that some of these phytoliths are burned and weathered, but there is currently no method to reliably distinguish them from unburned, weathered phytoliths. If this method is developed, the approach outlined in this study to estimate past fire regimes based on the proportion of burned phytoliths in the soil phytolith assemblage should be viable.

4) The results of the Raman portion of this study should be reconciled with the results of the Pironon et al. (2001) study. This will require a trip to France to observe Pironon's procedures. Phytoliths extracted from samples collected for this study can be brought to Pironon (who is still involved with Raman research but has not worked with phytoliths in more than 12 years) in France to run on his Raman instrument to see if it is possible to replicate his published results using our samples. If the results can be replicated and it is determined how to achieve positive results on our instruments, the Raman approach, which has a sound theoretical basis if there is enough occluded carbon in phytoliths to be detected, could be resurrected and applied as envisioned to reconstruct past fire regimes.

5) Other spectroscopic approaches that could distinguish a heated and/or burned phytolith from an unheated phytolith should be tested. While FTIR spectroscopy is probably not useful for this purpose because the signal is dependent on phytolith water content, approaches such as fluorescence spectroscopy should be investigated further (Wyche 2012)

6) Quantitative morphotype analysis of soil phytoliths can potentially provide species specific information, particularly for grasses, that can be used to determine which species to target when attempting to restore pre-European settlement grassland plant communities in Pinnacles NP and elsewhere.

Archaeological Research

7) Selected loci in the McCabe bottomlands should be examined for evidence of past landscape fires. The shovel probe survey conducted in the canyon lands yielded some deep deposits of gravel lenses, sand, and clay that were probably produced by periodic flood events. We also noted in a number of shovel probe units evidence of charred plant remains. We recommend the placement of off-site units near or in the deergrass and whiteroot sedge patches. Our survey of the perimeters of these patches in blocks D, G, and E, using a combination of surface pedestrian and shovel probe survey methods, failed to detect any associated archaeological remains. We propose shifting our focus to the excavation of the bottomland deposits themselves to determine if we can recover direct evidence of past landscape fires based on the recovery of in situ charred macrobotanical specimens, phytoliths, charcoal particles, radiocarbon samples, and possibly pollen and faunal remains. Landscape fires burning chaparral vegetation in the uplands may have facilitated periodic flood events during winters with heavy precipitation (i.e., Quinn and Keeley 2006). These episodic flood events may have generated

a series of buried, intact vertical deposits in the McCabe bottomlands. If such laminated deposits can be detected, then the recovery and dating of the organic remains may provide a vertical chronology of landscape fires, which may shed more light on the frequency of fires in historic and late prehistoric times, and the kinds of floral taxa that were consumed by these burns.

8) We recommend that a concerted effort be made to search for archaeological remains in the Pinnacle bottomlands along the Bear Valley Corridor. We recognize that historic agricultural practices and developments, such as the construction of the Pinnacles campground, have probably seriously impacted many of these cultural resources. But a careful examination of the bottomlands may yield some intact components of sites. The search for bottomland sites is necessary to test our prediction that the principal residential settlements of PNP will be concentrated in this area. If such sites can be detected, then a detailed eco-archaeological study, as exemplified by the investigation of CA-SMA-113 in Quiroste Valley, may provide information about the kinds of resources being exploited, the occupation sequence of the bottomlands, and the nature of local landscape management practices (see Cuthrell 2013; Cuthrell, et al. 2012; Gifford-Gonzalez, et al. 2013). In addition to searching for additional Pinnacle bottomland sites, we recommend that a rigorous low-impact investigation of CA-SBN-123/H be undertaken. This site is the largest and most complex indigenous site yet found in the park. Consisting of several separate loci, including a bedrock milling station, lithic scatter, and midden deposit, it is found in the westernmost segment of the Bear Valley bottomlands close to McCabe Canyon. We believe that a detailed investigation of the site would provide information on its chronology and the kinds of cultural practices and resources associated with a residential base in the park.

9) We recommend that a low impact archaeological investigation of one or more of the rock shelters in the Pinnacles uplands be undertaken. This work may be crucial in evaluating a possible Mission Period occupation of Pinnacles National Park. The research we conducted in McCabe Canyon appears to focus on the period (A.D. 1300-1650) prior to the establishment of the Franciscan missions in the greater San Francisco Bay Area. The investigation of the rock shelters in the remote areas of the park may provide one avenue for evaluating whether the PNP was being used as a refuge by Indian people hiding from the Spanish and/or by fugitive neophyte escaping from the missions (Babalis 2009:67; Greenlee and Moldenke 1982:44). If the Pinnacles were occupied by Native people in the Mission Period (late 1700s to 1830s), then the settlement distribution and resource management practices they employed may have differed significantly from those used in the pre-mission and post-mission times. We propose that during the Mission Period, native residential settlements would have shifted from the open and accessible Pinnacle bottomlands to more remote and less accessible upland areas, such as where the known rock shelters are found. During the Mission Period, native people may have curtailed the regular burning of the grasslands and oak woodlands in the Pinnacles, since this may have sent a clear smoke signal to the Spanish that people were residing in the area. Furthermore, evidence of burned grasslands would also be a clear indicator to missionaries and soldiers traveling through the Pinnacles that people still occupied the area.

10) We recommend additional survey work in the Chalone creek drainage downstream of the Sandy Creek/Chalone Creek confluence. This area has the potential as an ideal travel corridor to access the Salinas Valley, in addition to the existence of perennial water in some creek reaches. Minimal surface surveys have been conducted, but little else. This area would have potentially connected Bear Valley and the Salinas Valley.

11) Based on the success of the prescribed burn in McCabe Canyon, given its community and ecological benefits, we recommend that this approach be expanded in the Park. This activity will facilitate related cultural, interpretive, and management goals, and could serve as a model for similar activity in the region. Long term monitoring and continued analyses (i.e. of physical and biological effects) should be continued.

Table 3. Deliverables table

Deliverable proposed	Delivered	Status
Articles in peer reviewed journal	<ul style="list-style-type: none"> - Lightfoot, KG, RQ Cuthrell, CJ Striplen, and MG Hylkema. 2013. Rethinking the Study of Landscape Management Practices Among Hunter-Gatherers in North America. <i>American Antiquity</i> 78(2): 285-301 - [Multiple authors – Special Issue], 2013. The Study of Indigenous Management Practices in California. <i>California Archaeology</i> (5)2:197-390 - Cuthrell, RQ, CJ Striplen, M Hylkema, & KG Lightfoot, 2012. A Land of Fire: Anthropogenic Burning on the Central Coast of California in TL Jones & JE Perry (Eds.), Contemporary Issues in California Archaeology. Left Coast Press, Walnut Creek, CA - Evett, RR & RQ Cuthrell, 2013. Phytolith Evidence for a Grass-Dominated Prairie Landscape at Quiroste Valley on the Central Coast of California. <i>California Archaeology</i>, 5(2): 319-335. - Evett, RR & JW Bartolome, 2013. Phytolith evidence for the extent and nature of prehistoric Californian grasslands. <i>The Holocene</i>, 23(11): 1644-1649. 	Complete
Professional presentations	<ul style="list-style-type: none"> Soc. for California Archaeology 2008/2013 – special sessions Soc. for Conservation Biology 2012 NPS Science Symposium 2012 CA Native Plant Society 2012 Ecological Soc. of America 2012 	Complete
Field workshop	1 day field workshop held Nov 23, 2013 at Pinnacles National Park	Complete
Press releases	<ul style="list-style-type: none"> Pinnacles Partnership 2013 (attached) National Park Service 2011 (attached) 	Complete
Website development	Tribal and NPS Website update: Amahmutsun.org	Complete

	http://www.sfnps.org/landuse/cooperative_restoration_briefing	
Visitor Center displays	Pinnacles West Side Visitor Contact Station April 2012	Complete
Summary paper and rack cards	In progress	2014
Video documentary	Video (~6 min) documentary https://vimeo.com/44969222 password: deergrass	Complete
Popular articles	San Francisco Chronicle http://www.sfgate.com/news/article/Grass-is-burned-to-study-Indian-culture-2396204.php Bay Nature Magazine, http://baynature.org/articles/pinnacles-tests-out-tribes-fire-tradition/ National Radio Project http://www.radioproject.org/2012/09/the-burning-issue-americas-war-on-fire/ California Magazine http://alumni.berkeley.edu/california-magazine/spring-2011-articles-faith/unearthing-california News from Native California http://www.sfei.org/sites/default/files/News%20from%20Native%20CA_Spring%2009.pdf	Complete

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Pinnacles National Monument
Fire Management News

November 22, 2011
For Immediate Release
Contact: Brent Johnson, 831-389-4486 ext. 259

Prescribed Fire at Pinnacles Renews Traditional Practice

Pinnacles National Monument is planning to conduct a small prescribed fire during the week after Thanksgiving as part of an interagency research project to learn about the traditional use of fire in central California. National Park Service Fire Management staff will complete the burn operations with cooperators from the Cal Fire San Benito-Monterey Unit, in consultation with the Amah Mutsan tribal band. The burn will be approximately two acres in size and is scheduled for Wednesday, November 30, but the date could change based on weather conditions. Smoke may be visible in Paicines and vicinity, or from trails within the Monument. Caution is advised if smoke is present, but no roads or trails will be closed.

The burn is located on the east side of Pinnacles in an area rich in two culturally important plants – deergrass (*Mulenbergia rigens*), and white root sedge (*Carex barbarae*), both highly valued by California Indian tribes. Pinnacles has initiated research for the purpose of restoring traditional land management techniques to these plant communities. The central research questions are, “How did the use of fire and other practices by California Indians influence the vegetation of central California, and what techniques best achieve cultural goals for plant use?”

The effects of burning deergrass will be compared with mechanical clipping to stimulate the growth of flower stalks which are used in the foundation of coiled baskets. Fire temperature will be measured during the burn and silica particles

known as “phytoliths” (or plant stones) will be collected from the ash to learn about the fire history of the site. Fire scars in tree rings will also be studied at two other sites -- the Quiroste Valley, a cultural preserve in Ano Nuevo State Park, 65 miles south of San Francisco, and another site yet to be determined. Additional research at Pinnacles National Monument will determine what techniques promote longer, straighter rhizomes in the white root sedge, characteristics which enhance their use for basket-making.

The native plant populations at Pinnacles National Monument will also be a propagation source for development of the Amah Mutsun Relearning Garden at the University of California Santa Cruz Arboretum. The Relearning Garden is part of a 55-acre area known as the California Native Gardens that is owned by the University and will provide plant material for research, cultural use and education. The Relearning Garden has begun a series of “Work and Learn Parties” which have included demonstrations of fire-making, pine needle basket-weaving and herbalism. Three events are planned at the Relearning Garden for 2012. Several research tours will also be offered next year at Pinnacles National Monument. For information about these educational opportunities contact:

- Rick Flores, Curator of California Native Plant Collection, rflores@ucsc.edu
- Brent Johnson, Botanist, Pinnacles National Monument, brent_johnson@nps.gov

To be notified when the burn date is confirmed for the upcoming prescribed fire at Pinnacles National Monument, contact:

Denise Louie, Chief of Research and Resource Management at 831-389-4486 ext. 222 or denise_louie@nps.gov.

-NPS-

Pinnacles Partnership

A Special Opportunity from Pinnacles National Park



Greetings!

Pinnacles National Park has asked us to pass along the special opportunity below to our members. Please note that there are two components - a Panel Presentation and a Field Trip. You may participate in either or both of the activities.

Panel Presentation and Field Trip:

Exploring the Traditional Use of Fire in the Coastal Mountains of Central California

Panel Presentation

Date: Wednesday, November 20, 2013 from 7:00-8:30 pm

Place: Archaeological Research Facility, Room 101, University of California, Berkeley

Participants: Timothy Babalis (National Park Service), Rand Evett (UC Berkeley), Brent Johnson (National Park Service), Kent Lightfoot (UC Berkeley), Valentin Lopez (Amah Mutsun Tribal Band), Chuck Striplen (San Francisco Estuary Institute, UC Berkeley)

The members of the panel will discuss the results of an eco-archaeological project, funded by the Interagency Joint Fire Science Program, which is examining the hypothesis that local tribes influenced patterns of fire occurrence and resulting vegetation in the coastal mountain regions of Central California. The project brings together a team of ecologists, archaeologists, environmental historians, indigenous peoples, and land managers within a research and educational framework that combines the methods of paleoecology, historical research, and archaeology with indigenous knowledge to address issues concerning traditional methods of prescribed burning as a management tool for enhancing biodiversity and ecosystem health and vigor. While the project is investigating three separate study areas within the traditional tribal territory of the Amah Mutsun Tribal Band, this panel will focus on findings from the Pinnacles National Park study area. Panel participants will outline the findings from five interdisciplinary techniques employed in the study of past anthropogenic burning: fire scar dendrochronology, phytolith analysis, archival research on fire history, traditional knowledge of landscape management practices, and archaeology.

Field Trip: Saturday November 23, 2013 1100 AM -3:00 PM

Place: Pinnacles National Park, East Side Visitor Center & Campground.

We will take a walk up to one of our study sites with all of the primary research participants. Bring sturdy walking shoes, water, sun protection, and a lunch. Meet at 11:00 AM in front of the East Side Visitor Center.

For more information or directions, please contact Brent Johnson, 831-389-4486 extension 259.

Thank you for your support and for subscribing to the Pinnacles Partnership Newsletter. Our quarterly newsletter is **back** and will be sent out on December 1!

Sincerely,

Rochelle Fischer

Executive Director

Pinnacles Partnership

Ensuring Excellence in Education, Resource Stewardship, and Visitor Experiences at Pinnacles National Park