Anthropogenic Burning on the Central California Coast in Late Holocene and Early Historical Times: Findings, Implications, and Future Directions

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Abstract In this final paper, we summarize the results of the eco-archaeological project, address five research questions concerning anthropogenic burning on the central California coast in Late Holocene and early historical times, and outline plans for future research.

Resumen En este artículo final, resumimos los resultados del proyecto eco-arceologico, discutimos cinco cuestiones que concentran con fuegos antropológicos en la costa central de California desde el tiempo tarde holoceno hasta el tiempo temprano histórico, y formamos planes para investigaciones en el futuro.

California is an ideal place to undertake eco-archaeological studies that can make important contributions to our understanding of indigenous landscape management practices in Holocene and historical times. This special issue of *California Archaeology* illustrates the tremendous potential that exists for archaeologists to better comprehend the ecosystem-engineering capabilities of Pacific Coast complex hunter-gatherers through the investigation of anthropogenic burning. Central coastal California, for example, has relatively low natural ignition rates (few lightning strikes), wide swaths of public land where eco-archaeological studies may be implemented, and local tribal groups and government agencies who are receptive to undertaking collaborative research programs that may provide broader benefits to local communities and the greater public. There is growing recognition among many tribal peoples, resource managers, and restoration ecologists that lessons learned from the past about traditional resource and environmental management (TREM) practices can have beneficial applications in our modern world.

In this collection of articles and elsewhere (Cuthrell et al. 2012; Lightfoot and Parrish 2009; Lightfoot et al. 2013), we argue that studies of anthropogenic burning in California are both timely and relevant not only to the field of archaeology, but to a wide range of scientists, managers, and policy-makers. As we develop more refined and sophisticated understandings of past TREM practices in specific regions of California, we may provide new insights for improving the management of open spaces, for enhancing the biodiversity and the vitality of local habitats, and for mediating the effects of firestorms in the face of global warming. However, to undertake this ambitious research program, California archaeologists must begin a concerted effort to address a suite of basic questions about the ecosystem-engineering practices of complex hunter-gatherers.

As put forth in the introductory article for this special issue, we identify five questions that should drive future archaeological research in the Golden State: Is there empirical evidence for anthropogenic burning in the diverse regions of the state? When did people first initiate sustained anthropogenic burning? What were the characteristics of the anthropogenic fire regimes and what potential impacts did they have on local ecosystems (e.g., is there evidence for transformation in the structure of local habitats, enhanced biodiversity, etc.)? How extensive were the areas burned by Native Californians? Can we address whether anthropogenic burning activities were simply incidental to other foraging behaviors, such as hunting game, or more systematically managed by individuals, family groups or broader communities to produce intended landscape-scale outcomes?

The articles in this special issue present the findings of an integrated eco-archaeological study that we designed and implemented to address these five questions in central coastal California. This project is being conducted in two study areas (Quiroste Valley Cultural Preserve near Point Año Nuevo and Pinnacles National Park) within the traditional territory of the Amah Mutsun Tribal Band and the Muwekma Ohlone Tribe. Our study is dependent on the advice, support, and participation of tribal scholars and elders, the collaboration of resource managers and scientists from the California Department of Parks and Recreation and the National Park Service, and the contributions of a plethora of scholars from local universities and non-profit organizations. In this collection of articles, we detail the results to date from our investigations of Quiroste Valley, while subsequent publications will focus on Pinnacles National Park.

Quiroste Valley Cultural Preserve is an ideal place to initiate our project. In detailing the findings of previous archaeological research in the peninsular coast and northern Monterey Bay region, Hylkema and Cuthrell (this issue) situate our landscape management study within a broader context that incorporates more than 6,000 years of changing subsistence practices, trade relationships, technological innovations, and settlement and mobility patterns. This was also the homeland of the powerful *Quiroste* polity, who were well documented in the initial years of Spanish colonialism. Spanish accounts of the *Quiroste* people provide us with a temporal baseline for the presence of extensive anthropogenic burning which we can use to examine evidence of landscape management practices moving back into pre-colonial times.

Most of our archaeological work has focused on CA-SMA-113, a large *Quiroste* site that appears to be the Casa Grande village described by members of the Portola expedition in the fall of AD 1769. The Spanish explorers observed burned grasslands in the village's hinterland that they attributed to fires ignited by local peoples to enhance the yields of grassland plant seeds. The research program initiated at CA-SMA-113, as summarized in Cuthrell et al. (this issue), featured a low-impact field strategy designed specifically to define the spatial structure of the site and to detect subsurface anomalies. Excavations of 22 1-m^2 units unearthed midden contexts, non-discrete deposits, and discrete deposits (features), including an elongated shallow pit, three hearths, and two fire-affected rock concentrations. We employed a robust flotation sampling strategy to systematically collect large quantities of archaeobotanical remains, as well as micro-artifacts and archaeofaunal specimens, from excavation units across the site. Twenty-four AMS dates indicate that the site was occupied from AD 1000 to at least the time of the Portola expedition in 1769. The upper levels of the site have been impacted by agricultural activities, but the earlier deposits dating between AD 1000 and 1300 are relatively intact below the plow zone.

The archaeological investigations revealed an extensive, possibly year-round village community occupied in late Holocene and early historical times from which people collected Monterey chert from nearby outcrops, traded whole olivella shells and other goods to interior groups, and harvested a diverse range of resources from tide pools, the surf zone, the rocky intertidal, and a range of terrestrial ecosystems, particularly grasslands. The primary resources described in the articles herein include mussel (*Mytilus californianus*), turban snail (*Tegula* sp.), limpet (Acmaeidae), mule deer (*Odocoileus hemionus*), various lagomorphs, voles (*Microtus* spp.), wood rats (*Neotoma* spp.), marine fishes from nearshore habitats (northern anchovy [*Engraulis mordax*] and surfperches [Embiotocidae]), and intertidal habitats (pricklebacks [Stichaeidae] and sculpins [Cottidae]), tobacco (*Nicotiana* sp.), and a diverse range of grassland plants (see below).

The Investigation of Anthropogenic Burning

In evaluating the five research questions concerning anthropogenic burning in the study area, we implemented an interdisciplinary eco-archaeological program involving the intensive study of floral and faunal remains from CA-SMA-113, as well as the carefully coordinated collection of fine-grained paleoecological data sets from off-site contexts.

Archaeobotanical Data Set

As Cuthrell (this issue) details in his article, the macrobotanical assemblage strongly suggests that grassland seed foods were an important component of foodways for CA-SMA-113 inhabitants. The most common taxa include grasses (Poaceae), panicled bulrush (*Scirpus microcarpus*), coast tarweed (*Madia* sp.), clovers (*Trifolium* spp.), composites (Asteraceae), bedstraws (*Galium* spp.), hazel (*Corylus cornuta* ssp. *californica*), phacelias (*Phacelia* spp.), tanoak (*Notholithocarpus densiflorus*), and wild cucumber (*Marah* sp.). The analysis of wood charcoal specimens at CA-SMA-113 indicates a dominance of redwood (*Sequoia sempervirens*), followed by California lilac (*Ceanothus* spp.), alder (*Alnus* spp.), and the merest presence of Douglas fir (*Pseudotsuga menziesii*). The detection of a high proportion of woody plants compatible with frequent, low-intensity fires (redwood, California lilac, alders) and few specimens of woody taxa incompatible with these conditions (e.g., Douglas fir, coyote brush) supports the interpretation of a fire regime characterized by frequent, low-intensity burns that sustained an open landscape.

Cuthrell shows that the results of the archaeobotanical study (i.e., high proportions of grassland-associated food plants, relatively high density of hazelnut remains, and the dominance of fire-enhanced shrubs and trees) compare favorably to descriptions of the area when it was being maintained by landscape fires during the time of the Portola expedition in AD 1769, but are in sharp contrast to the fire-suppressed north coast scrub and Douglas fir woodlands that populate the valley today. These findings also indicate that the inhabitants of CA-SMA-113 had developed specialized and intensive seed gathering foodways by about AD 1000–1300, a set of practices consistent with an anthropogenic management system in which areas between the Coast Range foothills and the coastal strand were regularly burned to maintain grassland vegetation.

Archaeofaunal Data Set

The results of the analysis of archaeofaunal remains from CA-SMA-113 by Gifford-Gonzalez, Boone, and Reid (this issue) corroborate the existence of grasslands near the village. Recovery of a high ratio of voles (*Microtus* spp., which are specially adapted to grassland habitats) to wood rats (*Neotoma* spp., which prefer dense woodland or forest environments) at CA-SMA-113 is a strong indicator of this interpretation. Reid's findings from live-trap rodent samples demonstrate that wood rats are found almost exclusively in closed, inland habitats, while modern voles prefer more open environments. It may also be significant that about 45 percent of taxonomically identified mammals from the site consisted of mule deer (*Odocoileus hemiomus*) and various lagomorphs, which would have thrived in a mixed mosaic of grassland and open woodland environments.

Phytolith Data Set

The detailed study of phytoliths from both landscape and archaeological contexts by Evett and Cuthrell (this issue) demonstrates the untapped potential of this kind of research in California archaeology. Analysis of near-surface sediments in Quiroste Valley yielded extraordinarily elevated phytolith content, ranging from ca. 0.75 to 1.75 percent soil dry weight. These findings are substantially higher than the current phytolith content threshold of ca. 0.30 percent that has been used as an indicator for long-term grassland vegetation in California. Although there are significant uncertainties in the dynamics of phytolith pools in soils, the phytolith content in Quiroste Valley soils is much too high to be the result of historical land use practices involving agriculture. Even without accounting for phytolith dissolution, the size of the phytolith pool in Quiroste Valley soils suggests grassland vegetation cover from hundreds of years to over a thousand years. Phytolith density data from CA-SMA-113 are spatially and temporally heterogeneous across the site, a possible indication of distinct activity areas where food, crafting, and construction-related practices took place. Phytolith content from discrete ash deposits at CA-SMA-113 suggest high variability in the amount of grasses and/or sedges burned in fires. While some ash deposits showed no evidence of grass burning at all, others had sufficiently high phytolith content to indicate intentional burning of grasses, and possibly of winnowed grass chaff.

Pollen and Charcoal Data Sets

The investigation of pollen and charcoal by Cowart and Byrne (this issue) from the Skylark Pond sediment core, located 1.8 km from CA-SMA-113, records evidence for pre-colonial and colonial-era fires in the Quiroste Valley area. Five AMS radiocarbon dates establish a chronology and define changes in deposition rates for this 3,200-year paleoecological record. Charcoal/pollen ratios calculated for the period from about AD 1400 to 1750 (132–116 cm) indicate two major charcoal peaks at ca. AD 1425 (130–131 cm), followed by a section of low organic content (129–125 cm), which appears to have resulted from a significant erosion event. This was followed by smaller charcoal peaks at 124, 120, 118, and 117 cm. Cowart and Byrne interpret these data as the consequences of frequent, low-severity fires in the area.

This interpretation is supported by an associated increase in RRA pollen (Rhamnaceae, Rosaceae, and Anacardiaceae families), which could represent California lilac (*Ceanothus* spp.), California coffeeberry (*Rhamnus californica*), toyon (*Heteromeles arbutifolia*), and holly-leaf cherry (*Prunus ilicifolia*), all of which regenerate rapidly after fires. The upper section of the Skylark core dating to the historic period (ca. AD 1750–1950, 116–104 cm) also exhibits considerable evidence for fires and vegetation changes associated with logging, ranching, and farming.

Plant Population Genetics Data Set

Fine, Misiewicz, Chavez, and Cuthrell (this issue) present an innovative genetic study of contemporary California hazel (*Corylus cornuta* ssp. *californica*). Interestingly, while hazel is a common constituent in the archaeobotanical assemblage from CA-SMA-113, as well as being described as a managed taxon by the Portola expedition in AD 1769, it is very scarce in the Quiroste Valley landscape today. Fine et al. hypothesize that the current rarity of hazel in our study area may be the consequence of historical practices that outlawed native burning and promoted fire suppression policies. To evaluate this hypothesis, they implemented a program of research that is examining the genetic diversity of hazel from Quiroste Valley compared to seven other study areas in California and one in Washington. By extracting DNA from 189 hazel plants, and using data from 11 nuclear microsatellite loci, the authors show that the Quiroste

Valley population exhibits high values of genetic variation, indicating considerable gene flow with other hazel populations in California.

These results suggest that anthropogenic burning could have promoted a more substantial, genetically diverse population of hazel plants that had branched out across much of the central California coast by the time of the Portola expedition. Hazel populations with distinct genetic markers in Quiroste Valley and nearby Butano may represent refugial pockets of populations that had spatially dynamic ranges during the Holocene. The authors believe that insufficient time has passed for the isolated hazel plants at Quiroste Valley to exhibit a bottleneck indicating reduced genetic variation resulting from recent fire suppression practices.

Dendroecological Data Set

Research on the fire history of coast redwood forests using fire-scar dendroecology is well developed in California. The basic methodology, as outlined in detail elsewhere (e.g., Brown et al. 1999; Stephens and Fry 2005), involves the careful analysis of fire scars observed within the annual growth rings of long-lived trees such as redwoods. Fire return intervals (FRI) are calculated by counting the number of annual rings between successive fire scars. As summarized by Stephens and Fry (2005:3), the pioneering investigations of the fire histories of redwood forests initially suggested long FRIs on the order of 50 to 250 years, while recent studies are now recording FRIs that span only 6 to 15 years.

Dendroecological studies of central California coast redwood forests in the general vicinity of our study areas follow this trend. In their initial study of the broader Monterey Bay region, Greenlee and Langenheim (1990:245) calculated a mean fire interval (MFI) of about 50 years during late Holocene times, which was considerably shorter than their estimated MFI of 135 years based on lightning ignitions alone. They argued that the discrepancy found between the observed MFI and the expected MFI based on natural ignition rates was probably the consequence of burning by native peoples. Stephens and Fry's (2005) recent investigation of redwood forests in four study areas in the northern Santa Cruz mountains yielded a much higher frequency of fires. Based on the analysis of 48 redwood samples, they calculated MFIs ranging between nine and 16 years, and a grand MFI of 12 years for the four study areas combined. The time span covered by the fire scar samples is approximately AD 1650–1850. Stephens and Fry (2005:12–13) concluded that the high fire frequency could not be produced by natural ignition sources alone, but that a significant contributing factor was anthropogenic burning by Native Californians and Spanish-American ranchers and loggers.

We are currently undertaking additional dendroecological research focusing on three coastal watersheds in the peninsular coast and northern Monterey Bay region: Whitehouse Creek (including Quiroste Valley), Waddell Creek, and Scott Creek. The purpose of this research is (a) to increase the number of analyzed fire scar samples on the central California coast, (b) to expand the spatial coverage of dendroecological research sites, and (c) to extend, if possible, the time depth from which FRIs can be calculated in the late Holocene. This work is being conducted by Chuck Striplen, Gregory Jones, and Scott Stephens. Subsequent publications will detail the results of this component of our project.

Evaluating Questions about Anthropogenic Burning

The above findings can now be employed to address the five major research questions that structured our eco-archaeological study of indigenous landscape management practices in central coastal California.

Is there evidence for anthropogenic burning in the study area? In summarizing the results of the eco-archaeological investigation, we believe there is strong empirical support for anthropogenic burning in the study area. Our findings differ significantly from the baseline predictions for natural fire regimes. In generating the null hypothesis, Cuthrell et al. (2012) and Cuthrell (this issue) synthesized extant data that indicates lightning-ignited fire regimes along the central California coast are characterized by extended FRIs of ca. 50 to 100 or more years. Under these conditions, we would expect the vegetation on coastal terraces and hillsides to be dominated by woody vegetation types, such as north coast scrub and Douglas fir forests. Woodland and shrubland communities would have thrived in Quiroste Valley, as they do today under the modern system of fire suppression. In contrast, significant increases in fire frequencies will lead to type conversions of the local vegetation. Coastal prairies are disturbance-dependent communities requiring regular grazing, tillage, or burning to persist. Consequently, we believe that the detection of long-term grassland vegetation may signal regular prescribed burning along the central California coast.

Our investigation found that an extensive grassland community thrived in the valley from AD 1000–1300 based on floral and faunal remains recovered from CA-SMA-113. This finding is bolstered by the phytolith investigation that indicates grasslands prospered in the valley from hundreds of years to over a thousand years. As Cuthrell (this issue) details, coastal prairies free of woody vegetation (such as those described by early explorers) could only have been sustained by very frequent fires on the order of sub-decadal return intervals, most likely with fires ignited every one to five years (see also Greenlee and Moldenke 1982:41).

Other lines of evidence suggest that frequent fires continued to be ignited after AD 1300. The investigation of pollen and charcoal from the nearby Skylark pond suggests frequent, low severity burns during the period of ca. AD 1400 to 1700, followed by recurrent fires and vegetation transformations in early historic times. Dendroecological research based on fire-scar data from redwood forests in the nearby northern Santa Cruz mountains suggest FRIs of about nine to 16 years during the period of AD 1650–1850. Finally, journal entries of Spanish explorers beginning in AD 1769 provide a number of eyewitness accounts of smoke from fires, charred patches, extensively burned landscapes, and lush grasslands that they attributed to the burning practices of local native peoples living on the central coast and in the vicinity of Quiroste Valley (Hylkema and Cuthrell, this issue).

While we contend that the extensive coastal grasslands in the study area were generated primarily by anthropogenic burning, other hypotheses need to be considered. One alternative explanation is that climatic change may have increased the frequency of lightning strikes (and potential fires) in late Holocene times. Sprugel (1991:13) emphasized that relatively slight changes in temperature (1–2°C) can influence fire regimes and the structure and distribution of vegetation communities over time, as warmer temperatures may increase the frequency of fires and cooler temperatures may reduce their occurrence. The period of AD 1000–1300, when disturbance-dependent grasslands prospered in Quiroste Valley, is associated with the Medieval Climatic Anomaly (MCA) in California, a climatic regime marked by prolonged intervals of decreased precipitation, "epic" droughts, and warmer summer temperatures, which were punctuated by interludes of cooler and wetter years (Jones et al. 1999; Kennett and Kennett 2000; Stine 1994).

The intervals of warmer temperatures and droughts associated with the MCA may have increased the frequency of lightning strikes (and possible natural fire ignitions) in the study area. For example, in his analysis of 1500 years of fire-scars from giant sequoia trees (*Sequoiadendron giganteum*) on the western slopes of the Sierra Nevada Mountains, Swetnam (1993:887) found that fire frequency was highest during the period of AD 1000–1300, with fire occurrences declining afterwards and a few short episodes of increased fire frequencies in the AD 1600s and AD 1700s. He calculated that the longest fire-free intervals during the AD 1000–1300 period were always less than 13 years, while fire-free intervals in other periods ranged from 15 to 30 years.

In considering the impacts that the MCA had on coastal California, exemplary research has been undertaken for the south coast, including a high resolution record of oxygen isotopic values serving as proxies for sea-surface temperature (SST) and dendrochronological investigations of precipitation trends evidenced in *Pseudotsugo macrocarpa* sections extending back more than 1600 years. The paleoecological studies (see Kennett and Kennett 2000:384–385) indicate that the period of AD 1000–1300 was distinguished by cool marine conditions and regional decreases in precipitation that were punctuated by intervals of greater precipitation. These climatic conditions fostered greater marine productivity at the expense of deteriorating terrestrial resources produced by prolonged droughts, which in turn had significant implications for the subsistence practices, settlement distributions, exchange systems, and incidence of violence among local hunter-gatherer groups from Big Sur to the Channel Islands (Jones et al. 1999; Kennett and Kennett 2000).

We are currently examining the consequences that the MCA may have had on the people and environment in the vicinity of Quiroste Valley. In considering the effects that the MCA climatic conditions had on lightning-ignited fires, the data are still inconclusive. Greenlee and Langenheim (1990) employed a fire-spread modeling technique using the ignition points of lightning fires from 1930–1979 to predict the distribution in time and space of lightning in the greater Monterey Bay area in Holocene times. They suggested that the MFI in local redwood forests during most of the Holocene, *without* any human disturbances, would have varied around a mean of 135 years (Greenlee and Langenheim 1990:241–245). In discussing why lightning-ignited fires in this area are rare, Keeley (2002:305) noted that the coastal foothills are cooled in the summer, which impedes convective lightning storms, and lightning ignitions from winter storms typically fail to ignite because of high fuel moisture. He stated the importance of distinguishing lower elevation coastal places, such as Quiroste Valley, where lightning strikes are rare, from the coastal mountains where summer lightning, when present, will tend to cluster.

Unfortunately, we do not currently have access to high resolution dendroecological data for the Monterey Bay area and Santa Cruz Mountains that predate about AD 1600, so evaluating the effects of changing climate on FRIs for the period of AD 1000–1300 is not yet possible. We hope that our ongoing fire-scar investigation of redwood trees in the study area will increase the time depth of fire-scar samples. However, our analysis of pollen and charcoal from the Skylark Pond did *not* produce evidence for a greater frequency of fires during the MCA when compared to later periods. If climate alone was influencing the fire regimes of the study area, then we would expect the exact opposite. The evidence for more frequent fires after AD 1300, derived from both the Skylark Pond core (AD 1400–1700) and the dendroecological study of the Santa Cruz Mountains (AD 1650–1850), correlates with the climatic episode of the Little Ice Age (ca. AD 1350–1850), a period of overall cooler temperatures that should have decreased the frequency of lightning strikes and lightning-ignited fires, all other factors remaining equal.

In sum, it appears that the climatic conditions of the MCA would probably have increased the frequency of lightning in the study area. But we do not yet know the magnitude of change in the incidence of naturally ignited fires. We remain skeptical that the estimated 50 to 100 years (or more) return interval for natural fires in the study area would have been reduced during the MCA to the sub-decadal interval necessary to maintain extensive coastal prairies on marine terraces and foothills west of the Santa Cruz Mountains. Given the major fluctuations in temperature and precipitation that took place during the MCA on the south coast (see Kennett and Kennett 2000:384), we do not think that natural ignitions alone could have sustained the coastal prairies for more than three centuries without some regular intervention by local people.

We hope to explore this issue in more detail through a new dynamic fire-vegetation model that is being created to examine the interaction of fire, alternative stable states (grasslands, woodlands, scrublands), and climate change in California. Implemented through the Berkeley Initiative for Global Change Biology at UC Berkeley and funded by the Gordon and Betty Moore Foundation, this research is being undertaken by David Ackerly, Max Moritz, and Enric Batllori Presas. It will provide a sophisticated framework for examining changes in vegetation patterns in relation to changing climatic conditions and fire regimes, including modifications in ignition rates based on our findings of anthropogenic burning in late Holocene and early historical times.

When did people first initiate sustained anthropogenic burning in Quiroste valley? The findings of our eco-archaeological study indicate that the burning practices of native peoples increased the frequency of landscape fires in Quiroste Valley by at least AD 1000. The diverse lines of evidence employed in our investigation suggest that regularized burning took place over the next eight centuries, continuing until the Spanish began their exploration and settlement of the area, which ultimately led to significant changes in local fire regimes. However, we do not yet know when this practice of prescribed burning first commenced. Our evidentiary record is limited by the occupation span of CA-SMA-113 (deposits no earlier than AD 1000 and a lack of intact deposits post-dating AD 1300), the record of charcoal/pollen peaks from the Skylark Pond that begin in earnest in the AD 1400s, and the fire scar data from redwood samples that currently only date back to about AD 1650. The measured phytolith content in the surface deposits of Quiroste Valley indicates that grasslands resulting from prescribed burning probably prospered in the area for hundreds of years, but this type of research is still developing and it is not yet possible to determine when regular landscape burning may have been initiated.

In the next phase of our research, we seek to push back the time depth of our eco-archaeological data sets to evaluate when anthropogenic burning first commenced in the study area. One approach involves the testing of other known archaeological sites in the Año Nuevo Point area for evidence of anthropogenic burning from late Holocene and middle Holocene times. This will provide the long-term chronology necessary to examine landscape management practices over several thousand years. Another line of work is the investigation of pollen and charcoal in a sediment core from Laguna de las Trancas, a landslide-dammed pond situated 10.9 km southeast of Quiroste Valley. A seven-meter core, currently undergoing analysis by Cowart and Byrne, shows major changes in vegetation and fire frequency over the last ca. 50,000 years. This record is interrupted by several hiatuses, but the lower part of the core extends back beyond the period of human settlement. Preliminary findings indicate changes in pollen frequencies and charcoal abundance that suggest significant increases in fire frequencies beginning about 6500 BP. The full results of this analysis will be available in a subsequent publication.

What were the characteristics of the anthropogenic fire regimes and What potential impacts did they have on local ecosystems? The results of our research suggest that more than 950 years ago, people were contributing to a regime of frequent, low-intensity fires in Quiroste Valley. We argue that this fire regime had significant repercussions for the structure, diversity, and vitality of local terrestrial communities. The extensive grassland environments created by frequent fire disturbances represented maintenance of a seral vegetation type, distinct from the north coast scrub and Douglas fir woodlands that become expansive when coastal landscapes in this area are not frequently burned (e.g., through fire suppression or natural fire regimes). Sustaining extensive and enduring grassland communities in much of the central California coast likely requires subdecadal FRIs, and we believe it is not unreasonable to suggest that an FRI of one to five years was probably maintained.

The *Quiroste* people derived many benefits from the creation of this anthropogenic landscape. As Cuthrell (this issue) emphasizes, the diversity, quantity, and predictability of floral resources available for human subsistence is substantially greater in coastal prairies than in the coastal scrublands or forests that would have developed in the absence of disturbance. Gifford-Gonzalez, Boone, and Reid (this issue) also highlight some of the changes in faunal populations that take place when dense scrublands/woodlands are transformed into a landscape of mixed coastal prairie and open canopy forest, particularly when burned patches exist adjacent to "islands" of more mature vegetation where birds, deer, rabbits and other game animals can still hide and rear their young.

How extensive were the areas burned by native Californians? The results of our eco-archaeological study suggest that people regularly ignited fires in Quiroste Valley over many centuries. But what was happening outside the valley and in other regions of California? Was Quiroste Valley an isolated case or part of a broader pattern of ecosystem-engineering practices instituted by Pacific Coast hunter-gatherers? Interestingly, recent research along the northwest coast of North America suggests that an extensive swath of anthropogenic prairies may have once paralleled the coastline, extending from southern British Columbia into northern California (Weiser and Lepofsky 2009:185–186). Eco-archaeological studies at Ebey's Prairie on Whidbey Island and the Ozette Prairies of the Olympic Peninsula in Washington State indicate that these prairies were maintained by indigenous burning practices beginning about 2,300 to 2,000 years ago (Weiser and Lepofsky 2009:203–204).

Clearly, California archaeologists will need to undertake eco-archaeological research in other regions of the state to evaluate the kinds of landscape management practices employed by hunter-gatherer groups and the impacts they had on local ecosystems. We are currently finishing the analysis of some preliminary fieldwork at Pinnacles National Park and planning to conduct future work to address whether the late Holocene grassland communities detected at Quiroste Valley were part of a larger ecological manifestation of coastal prairies created by Pacific Coast hunter-gatherers in central and northern California. Under an initiative of the Society for California Archaeology, we are proposing to undertake future eco-archaeological fieldwork with local tribes and government agencies along the central and northern California coastlines where sites are being threatened by inundation and erosion as global warming drives sea level rise.

Were anthropogenic burning activities incidental to other foraging behaviors, such as hunting game, or were they systematically managed by individuals, family groups, or broader communities to produce intended landscape-scale outcomes? From the outset, in evaluating this question, it is important to recognize that the social relations and organizations that people employ in anthropogenic burning practices can vary markedly in their level of planning, coordination, and community participation. We find it useful to conceptualize the social dynamics of anthropogenic burning along a continuum that incorporates a diverse range of immediate-return activities and more coordinated landscape management practices.

At one end of the continuum are fires people set to promote immediate-return subsistence goals and/or to enhance foraging efficiency, such as hunting game, removing brush to facilitate movement through densely vegetated areas, controlling pests that compete for food resources, or preparing areas for harvesting nut crops. Fires may be ignited by individuals with little coordination among members of the broader community. These burns may involve little prior planning and there may be no intended consequences beyond the immediate subsistence goals. However, the cumulative effect of people lighting multiple fires over a period of time may be a significant transformation in the local ecology, resulting in major changes in the diversity and structure of biotic communities. Yet at this end of the continuum, the landscape-scale ecological changes associated with anthropogenic burning may be purely incidental to the immediate foraging goals of the hunter-gatherers.

The potential consequences of immediate-return burning at the landscape level are exemplified by ongoing field research in Western Australia. Here the hunting of burrowing animals by aboriginal women has produced fine-grained mosaics of habitats with greater biodiversity and less susceptibility to climate-driven catastrophic fires than other nearby places where this kind of hunting is not being practiced (Bird et al. 2008, 2012). Thus, one scenario that needs to be considered for Quiroste Valley is that the late Holocene and historic coastal grasslands and hazel groves may have been created by native people igniting fires for immediate-return purposes, such as burning dense vegetation to hunt deer and to expose the elusive wood rats or to clear underbrush in anticipation of hazel nut or tanoak acorn harvests. Individuals may have executed these burns with minimal planning or coordination with other members of the community. While there may not have been any intended design to generate ecological changes at the landscape-scale, the cumulative consequence of many small-scale burns may have been the conversion of the north coast scrub and Douglas fir forests into coastal prairies.

At the other end of the continuum are anthropogenic burns integrated within community-level resource management practices that are intentionally designed to enhance the diversity, productivity, and predictability of resources on the landscape-scale. These kinds of burns would involve planning, collective action, and the coordinated participation of community members. As outlined in more detail elsewhere (Lightfoot and Parrish 2009:99–108), these practices may involve the synchronized lighting of small, low-severity surface fires calculated to burn moderately sized patches in a staggered succession over a series of years. The intended design of this management program would be to facilitate greatly the biodiversity and availability of floral and faunal resources in the local region.

Thus, another scenario that needs to be considered for Quiroste Valley is that the people from the CA-SMA-113 village created and maintained the grasslands and hazel groves through some kind of rotational system of frequent burns. They may have employed a coordinated program of landscape management practices that was intentionally devised to produce patchy mosaics of grasslands and shrublands that greatly augmented the quantity, diversity, and predictability of vegetable foods, game, and crafting materials.

In evaluating the above scenarios for Quiroste Valley, we recognize that the disturbance-dependent grasslands may have been maintained for many centuries through a combination of infrequent lightning-ignited fires and a diverse array of anthropogenic burning practices. We further emphasize that it is tough enough to try to document anthropogenic burning using multiple lines of eco-archaeological data sets, but it is even tougher to address the various kinds of social relations and organizations that may be associated with past anthropogenic burning practices. However, recent studies on intentionally designed resource management systems characterized by community participation, collective action, property rights, and temporal discounting (i.e., incurring short-term losses for long-term gains) provide excellent sources from which expectations can be generated for examining the organizational parameters of anthropogenic burning in Native California (e.g., Bowles and Choi 2013; Hunn et al. 2003; Lertzman 2009; Smith and Wishnie 2000).

For example, Smith and Wishnie (2000:504) emphasized that the critical features of successful collective action systems involving the exploitation/production of common-pool goods are "socially regulated access, management rules governing harvests, means of monitoring compliance to these rules, and sanctions to punish those that violate them." Thus, the development of collective action systems should be associated with changes in property rights and restrictions in the access of common-pool resources to primarily members of the collective. In examining the adoption of farming among hunter-gatherers in early Holocene times in Southwest Asia, Bowles and Choi (2013) emphasized the importance of changing property rights that restricted access to productive patches and the cultivated resources derived from them to members of the farming group. One manifestation of these changing property rights among collective action systems is the construction of storage facilities designed to limit entry to only members of the collective. Bowles and Choi (2013) identified the transformation of communal sharing systems (which characterize most mobile foraging groups) to new kinds of collective systems where the fertile lands and resulting yields are now limited only to members of the social group, as a critical variable in the development of resource management systems involving crop cultivation.

Based on the above discussion, we may expect that anthropogenic burning practices that were scrupulously managed by community collectives to produce intended landscape-scale outcomes would be associated with evidence for increasing territorialism, greater defense of resource patches, secure storage facilities, and restricted access of goods to people outside the collective. While we are only in the initial phase of evaluating these expectations for the study area, our preliminary thinking suggests that the *Quiroste* people probably fall somewhere in the middle of the above continuum of anthropogenic burning practices, as outlined below.

We believe that CA-SMA-113, as the primary village in the local region, was probably embedded within a logistically organized collector settlement system. As noted by Hylkema and Cuthrell (this issue), the site appears to have been occupied during the Bonny Doon Phase (ca. AD 900 to Spanish colonization), a time when local populations exhibit evidence of greater social complexity, regional trade, and territorial circumscription. The founding of sedentary residential bases, such as CA-SMA-113, would represent known places where members of local polities could periodically come together for communication and planning, as well as for securely storing bulk harvested goods, for collective food gathering and food processing events, and for performing mortuary practices, ceremonies, and feasts. These villages may have served as bases from which specialized task groups and family units might tend nearby habitats or bulk collect resources from previously burned patches. These work parties may have been dispersed out across the landscape during some part of the annual cycle, setting up a series of small camps and work places in the near and far hinterlands of the residential bases.

In undertaking our ongoing eco-archaeological research at other sites in Quiroste Valley that date to late and middle Holocene times, we propose to examine the broader settlement patterns of the local region to evaluate whether the commencement of anthropogenic burning was associated with evidence for transformations in mobility patterns, logistical practices, territorialism, collective action organizations, and restricted access of goods. We will also identify other outlying sites that may have been part of the Bonny Doon Phase regional subsistence/settlement associated with CA-SMA-113.

Conclusion

In concluding this special issue of *California Archaeology*, we turn to the broader implications of our findings for making future decisions and policies about the management of resources in Quiroste Valley Cultural Preserve and beyond. Clearly, significant changes to the local environment have taken place over the last thousand years. The valley now being encroached by dense woody vegetation was once an open landscape supporting a diverse array of fire-enhanced grassland and woodland plants and animals. We will work closely with the members of the Amah Mutsun Tribal Band, the Muwekma Ohlone Tribe, and the resource managers from the California Department of Parks and Recreation in considering how the knowledge we have gained from our eco-archaeological research about anthropogenic burning may be productively incorporated into contemporary management practices.

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