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Changing Palates and Resources: Regional and Diachronic Trends in Plant Use in Prehistoric California

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Despite considerable differences in plant communities across western California, the region's hunter-gatherers often have been viewed as having a broadly similar plant resource orientation. The paper re-assesses this perspective by explicitly examining spatial and temporal variation in plant use west of the Sierra Nevada. In doing so, the study capitalizes on a growing body of paleoethnobotanical data to explore similarities and differences in plant food resource emphasis across six main regions in western California. Discussion emphasizes trends in the relative reliance on exploited resources, focusing on three main plant food groups—seeds, nuts, and geophytes—the 'Sister Trilogy of California.' The results provide an archaeological baseline to explore to what degree observed spatio-temporal patterns in plant use are primarily a function of resource distribution and density, and in what contexts social factors (such as investment in labor, risk assessment, population density, settlement organization, and cultural preference) play a more prominent role.

California has long impressed, fascinated, and challenged scholars interested in characterizing its natural history and indigenous lifeways. Owing to its sheer size and staggering variation in topography and rainfall, California is not surprisingly characterized by a tremendous range of climatic zones, vegetation communities, and potential food resources. This variation is particularly the case when coastal, inland valley, montane, and desert settings are contrasted. Indeed, one could argue that these varied locations are only considered together because they fall within a single modern political entity—the state of California.

Anthropologists have written extensively on the Native Americans of California, variously highlighting their linguistic diversity; high population densities; their political, social, and ideological traditions; and the distinctiveness of their hunting and gathering lifeways (e.g., Bean and Blackburn 1976; Heizer and Whipple 1971; Kroeber 1925; Lightfoot and Parrish 2009). In characterizing subsistence strategies and in particular the plant foods that were exploited, some scholars emphasize similarities across California by focusing upon primary resources, typically stressing the role of acorns (Baumhoff 1963; Heizer and Elsasser 1980; Kroeber 1925; Powers 1877). Others, particularly in recent years, have tended to emphasize the wide range of resources exploited, noting the importance of roots and small seeds, and the role of intentional burning in promoting resource richness and diversity (e.g., Anderson 2005; Bean and Lawton 1976; Jacknis 2004; Lightfoot and Parrish 2009).

These reconstructions of plant resource orientation provide important insights into Native California, but are drawn almost exclusively from a rich body of ethnographic and ethnohistoric information rather than being built from direct evidence of plant remains in the archaeological record. As a result, they are most applicable to understanding indigenous lifeways at the time of European contact, come with their own set of biases, and are invariably incomplete. Prehistoric hunter-gatherers in California likely would have had a broad range of plant resource strategies at the time of European contact, given strong differences in local settings, settlement patterns, population densities, and social complexity. To understand the origins of particular plant food procurement tactics, and how such strategies and resource reliance varied across time and space, one must focus on direct evidence of prehistoric plant use. Fortunately, the emerging prehistoric archaeobotanical record in California provides us with an opportunity to begin tracking these spatial and temporal trends in plant resource emphasis.

This article examines the paleoethnobotanical record from California and explicitly explores spatial and temporal variation in plant use west of the Sierra Nevada (the desert regions of California are not considered). In doing so, three main observations are made which have important implications for California paleoethnobotany. First, there is an immense diversity in both potential plant foods and actual adaptations documented across the western portion of the state. This diversity is particularly obvious in the earlier portions of the prehistoric record, and perhaps less so at the end of the sequence when small seeds dominate plant assemblages from most settings. Second, we need to carefully examine the relationship between plant use and settlement seasonality/annual duration to fully understand the socio-economic basis for localized plant resource adaptations. Finally, California archaeologists have had an acorn-centric perspective when reconstructing prehistoric plant use, and this perspective is not well-supported by the archaeobotanical record in much of western California.

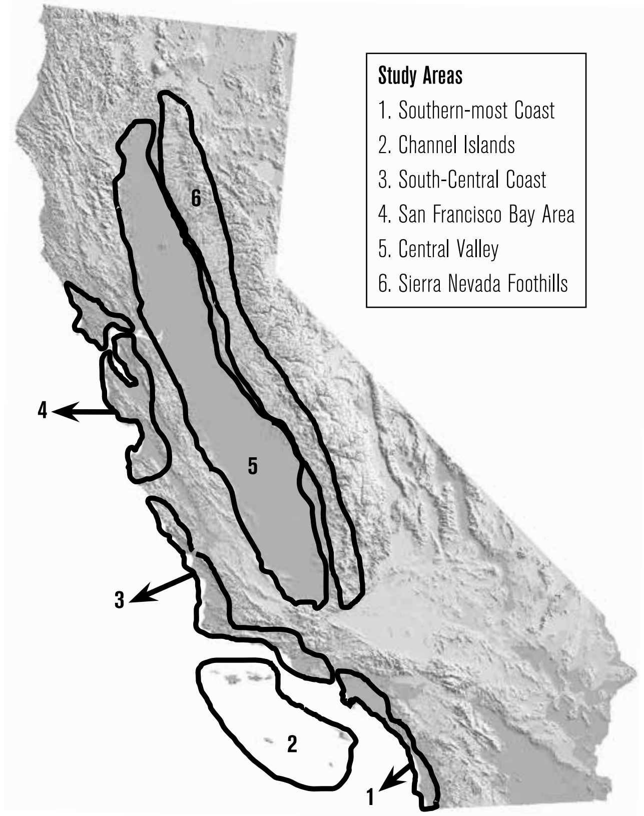

Figure 1. Western California study areas with prehistoric macrobotanical remains.

GEOTOPOGRAPHY AND DIVERSITY IN PLANT FOODS AND ADAPTATIONS

Lightfoot and Parrish (2009:50–94) have eloquently discussed the varied richness of topography, vegetation, climate, and landscape in California, highlighting its resource diversity and productivity. They also argue that this "uneven landscape" meant that native Californians "did not have to travel far to experience" or to capitalize on this heterogeneity (Lightfoot and Parrish 2009:52). Given the immense scale and variation in California landscapes, there is no simple way to examine spatial and temporal trends in prehistoric plant use. Scholars have subdivided California in various ways, depending on their goals. For example, Kroeber (1925) defined six different culture areas (central, Colorado River, Great Basin, northeast, northwest, and southern), while Lightfoot and Parrish (2009:60) defined eight very similar geomorphic regions—separating the central coast from other central California areas, and separating out the southern desert from the Great Basin (central coast, Great Basin, great central valley and Sierra Nevada, lower Colorado River, northeast, northwest coast, south coast, and the southern deserts). In contrast, Heizer and Elsasser (1980:Fig. 33), focusing on food resource orientation, mapped out eight different ecological culture types (coastal tidelands collectors, coastal sea hunters-fishers, desert hunter-gatherers, desert agriculturalists, foothill, lake, riverine, and valley), notably creating a series of narrower north-south oriented zones.

The spatial approach taken in this study is most similar to that of Heizer and Elsasser (1980:57) who were interested in how the "cultures of California can be classified in terms of their cultural response to these differing environments." The current study focuses on those settings in western California where sufficient samples of archaeobotanical data are currently available. Six areas are distinguished: Channel Islands, Central Valley, Sierra Nevada foothills, San Francisco Bay, South-Central Coast, and Southern-most Coast (Fig. 1).

Temporal trends in each area are summarized, and these observations form a basis for a subsequent discussion of variation and similarity between settings.

It is important to keep in mind that there is notable variation in vegetation communities both within and between the major areas with regard to the plant-food potential of habitats. Some areas (such as the Sierra Nevada foothills and inland portions of the greater San Francisco Bay area) have fairly abundant nut resources, including pine nuts and acorns, while others (such as the lower Sacramento Valley, various coastal settings, and the Channel Islands) have more limited nut resources but more abundant grasslands and other contexts where small seeds, legumes, and geophytes flourish (Kuchler 1976; Lightfoot and Parrish 2009). There is also variation in potential plant food distribution within each of these areas. For example, the eight Channel Islands are very different from one another and from the adjacent mainland (Junak et al. 2007). Similarly, the San Francisco Bay Area has considerable variation in rainfall and vegetation community distribution that impacts the potential for plant food resources, and these differences have been qualitatively ranked by Wohlgemuth (2010). It is also, of course, necessary to acknowledge that the following summary is based on the currently available macrobotanical record. The data are patchy at present both in terms of spatial and temporal coverage within each region, and based on highly varied macrobotanical field sampling strategies, sample sizes, laboratory methods, and analytical approaches. Regardless of these limitations, meaningful patterns can be discerned in the data which provide initial insights into broad trends in prehistoric adaptations.

San Francisco Bay Area

Using macrobotanical data from a diverse array of sites, Wohlgemuth (2010, 2016; see also Arpaia and Wohlgemuth in this issue) notes that the increased use of acorns, small seeds, and corms varied markedly over time and by locality within the general San Francisco Bay Area. Heavy reliance on acorns occurred earliest in the interior East Bay around 4,000–3,500 years ago. In contrast, higher use of acorns near the bay-shore appears to have occurred considerably later in time, varying anywhere from around 2,500 cal B.P. (in the South Bay) to around 1,000 cal B.P. (along the northwest bay margins). In addition, there is no indication of heavy acorn use at large shellmound sites near the East Bay shoreline. Finally, it should be noted that other nuts, such as bay nut, appeared to have been heavily exploited in a variety of San Francisco Bay area contexts.

An increase in the use of small seeds is well-documented after 1,000 cal B.P. Unlike the indications that increased use of acorns occurred first away from the bay-shore margins, the rise of small seed exploitation appears to have occurred around the same time in a variety of bay margin and interior settings. This trend is observed along the northwest margins of the bay, in the South Bay, and in inland settings such as the Livermore Valley (Popper 2002; Wohlgemuth 2002). In contrast, corms do not appear to have been a major part of the San Francisco Bay Area diet (Wohlgemuth 2013). Southwest of the San Francisco Bay in the Quiroste Valley, Cuthrell (2013) documented post-1,000 cal B.P. assemblages dominated by very high densities of small seeds (dominated by grasses), associated with low densities of nuts (dominated by hazel).

Central Valley

This region has a fairly limited macrobotanical record due mainly to the fact that much of the work at the largest and most substantial sites took place many decades prior to flotation and paleoethnobotanical studies in California. This lack of archaeobotanical rigor is unfortunate since this setting, particularly in the lower Sacramento Valley, had one of the highest densities of Native population at the time of European contact. Recent work by Wohlgemuth (this issue) in the lower Sacramento Valley reveals a heavy reliance on acorns circa 2,500 years ago (if not earlier), accompanied by increased exploitation of small seeds (especially Chenopodium) and Brodiaea corms by 2,500 years ago, and then very high densities of small seeds reflecting resource intensification after 1,000 years ago.

In the northern third of the Central Valley, investigations near Hamilton City by Hildebrandt and Kaijankoski (2011) document a low density but diverse range of nut and seed resources during the Middle Holocene (circa 7,400–6,400 cal B.P.). Acorn dominates the nut remains (along with wild grape, grey pine, juniper, and manzanita), and small seeds occur in higher densities in the Late/Middle Archaic occupations circa 2,800 cal B.P. However, in the Emergent Phase (circa 500 cal B.P.) small-seeded plant remains (most prominently represented by farewell to spring—*Clarkia* spp.) dominate the archaeobotanical record. In contrast, nuts (especially acorn but also pine nut) and manzanita (*Arctostaphylos* sp.) appear to have been considerably more important than small-seeded plants at one prominent historic-era Native village at the very northern end of the Central Valley (Hildebrandt and Darcangelo 2008).

Based on data from six Central Valley localities, Wohlgemuth (2013) argues that there are substantial differences in plant resource intensification even within areas within relatively close proximity. These differences appear to be related to the greater availability of particular plant resources over others. For example, Wohlgemuth (2013) suggests that people rarely used high-ranked plant foods like corms intensively when nut crops were locally abundant.

Sierra Nevada Foothills

Much of what we know currently about prehistoric plant use in the Sierra Nevada foothills is through the research conducted and synthesized by Rosenthal et al. (2011) as part of the East Sonora Bypass project situated in the gray pine-blue oak woodland in the north-central foothills. Intensive macrobotanical sampling and analysis during this project revealed distinct regional trends in plant use, and provide a strong baseline to investigate if these trends are represented at other locations within the greater foothill region (see also Meyer 2008; Whelan et al. 2013).

Plant use in the Sierra Nevada foothills is marked by high seasonality based on altitude, which affects seasonal ripening of plant foods such as nuts, seeds, greens, and corms (Rosenthal 2011). Gray pine nuts were important early in the sequence, followed by an increased use of acorns, and at the end of the sequence spring- and summer-ripening small seeds and fruits became important. Corms played a marginal role in the diet.

Overall, plant food intensification occurred later in the Sierra Nevada foothills compared to elsewhere in central California. East Sonora Bypass project archaeobotanical studies indicate change over the last 6,000 years from the Middle Archaic (7,000–3,000 cal B.P.) through the Recent Prehistoric II (610–100 cal B.P.), with a degree of continuity in the use of particular plants. The foothill Native Americans used gray pine extensively, with regular use of acorn and occasional use of small seeds and manzanita earlier in the sequence during the Middle Archaic (Rosenthal et al. 2011). This pattern of plant use continued into the Late Archaic, suggesting continuity in resource exploitation, resource availability, and dietary behavior. This pattern changed abruptly in the Recent Prehistoric II when acorn and manzanita use increased, along with the exploitation of a wider variety of small seeds. Gray pine use continued, but at a lower degree in terms of abundance and ubiquity, suggesting a change in procurement logistics and perhaps availability.

South-Central Coast

This region, running from south of Big Sur to the northern edge of the Los Angeles Basin, has very patchy archaeobotanical data. This data gap is particularly unfortunate for the Chumash around Santa Barbara, because plant foods played an important role in complex social and economic developments, at least at the end of the prehistoric sequence (e.g., Gamble 2008). Much of what is known about mainland Chumash plant use comes from ethnohistorical records, which provide ample evidence that historical period plant usage at Chumash sites included some acorn and bay nut use, but small seeds and fruits dominated the collections (Timbrook 1993, 2007).

Around Goleta Slough near Santa Barbara, limited macrobotanical sampling produced low frequencies and densities of nutshell in Early through Late Period contexts (Gerber 1993; Hammett 1991; Ruby 2015), and this pattern contrasts with inland sites in the Santa Ynez Valley where acorns are well-represented or abundant (Hildebrandt 2001; Jones and Mikkelsen 1998). Macrobotanical food resources from Goleta Slough sites are mainly represented by small-seeded plants (including grasses). It is also interesting to note that in the Late Period (after 700 years ago) in the Santa Ynez Valley, exceedingly high grass-seed densities suggest small seed intensification occurred further north in the region.

The macrobotanical record for the Central Coast indicates a focus on acorns and berries early in the cultural sequence, with an initial low use of small seeds and corms (Wohlgemuth 2004). At the Los Osos site at Morro Bay, Native Americans used acorn intensively during the Middle-Late Transition (950–700 years ago), followed by an increased use of small seeds and a modest increase in use of acorn after 700 years ago (Wohlgemuth 2015).

Southern-Most Coast

From the Los Angeles Basin southward in southern California, primary plant resources are spatially clustered within diverse geographic settings, and there is extreme elevational variation involving the coastal strip, inland valley floors, and highlands areas. The highlands are distinct from the coastal strip in terms of both the types of potential plant resources and their seasonal availability. Most notably, oaks are concentrated in the highlands, while the coastal areas are more ideally suited to grass and other small seed exploitation. Intensive study of plant remains in southern-most coastal California has provided robust samples from after 3,600 cal B.P., but extend back to 8,000 cal B.P. (e.g., Byrd and Reddy 2002:Table 4.4; Reddy 1999, 2001, 2003a, 2003b, 2003c, 2004, 2006).

Plant use along the southern California coast is notable in that small seeds, including legumes and cheno-ams,[1] dominate assemblages dating to the early part of the cultural sequence (starting 8,000 years ago), and that grasses were later incorporated into the plant food diet soon after (Reddy 2004). There is little evidence for acorn reliance throughout the coastal sequence, although there is a slight increase in acorn nutshell toward the end of the Late Prehistoric period (after 1,400 cal B.P. and primarily after 650 cal B.P.), suggesting an increase in their exploitation. This pattern stands in stark contrast to the importance of nuts (and acorns in particular) in central and northern California (e.g., Wohlgemuth 1996, 2004). Geophytes are also rare throughout the coastal southern California sequence. The relative density of small seeds increases over time, and in the latter portion of the Late Holocene grasses increase in importance compared to other small-seeded plants (Reddy 1999, 2004). Notably, intensive exploitation of select grasses is evident in the latter part of the sequence, particularly in the Protohistoric and Ethnohistoric periods (from 450–110 cal B.P.), when two grasses, maygrass (*Phalaris* sp.) and little barley (*Hordeum pusillum*), were intensively gathered by the Native Americans in the Los Angeles Basin (Reddy 2009, 2015, In Press).

Channel Islands

Our knowledge of the plants exploited by the Channel Islanders is based on data from select sites on five islands—San Clemente, San Nicolas, Santa Cruz, Santa Rosa, and San Miguel—with markedly different vegetation, climate, and cultural histories. Initial macrobotanical data indicate that there is broad consistency in plant use through time, with a diverse use of geophytes, small seeds, manzanita berries, and also acorns in low densities (Eisentraut 1990; Kristina Gill 2013, 2014, personal communication 2015; Martin 2010; Martin and Popper 1999; Reddy and Erlandson 2012; Reddy 2000a, 2000b, 2002, 2003a; Thakar 2014; Thomas 1995). The small seeds consist mostly of cheno-ams and grasses.

Daisy Cave on San Miguel Island reveals the importance of geophytes, especially Brodiaea-type corms, starting in the Early Holocene (or possibly the terminal Pleistocene) and continuing into the Late Holocene (Reddy and Erlandson 2012). This pattern is consistent with investigations by Gill (2014) at Diablo Valdez on Santa Cruz Island that documented a substantial carbonized Brodiaea corm assemblage indicative of multi-season collection from just after 6,000 cal B.P. to Spanish contact. In contrast, the southern-most island, San Clemente, has a robust sample of plant remains which extends back to circa 4,500 years ago. The assemblages are dominated by small-seeded plants, including legumes and grasses, along with trace amounts of acorns (e.g., Reddy 2002, 2003a). Upland/plateau sites also typically have higher densities of plant remains, often dominated by redmaids (*Calandrinia* sp.) or grasses (Reddy 2002:100–101, 2003a; Whitaker and Byrd 2015:246).

Based on data from San Clemente, Santa Cruz, and Santa Rosa, it is clear that acorns were utilized but in very low frequencies by Channel Islanders. Oaks are present on Santa Cruz today and likely have been there for several centuries, and in fact there is a great diversity of oaks on the island with 10 species present (Timbrook 1993). Interestingly, Timbrook (1993:57) proposed that accidental spillage of acorns brought in from the mainland led to the establishment of oaks on the island. In contrast, Santa Rosa Island has a lower diversity of oaks. If acorns were indeed brought to the islands by the Chumash during prehistoric and/or protohistoric times (Timbrook 1993; Kristina Gill, personal communication 2015), why did they not become an important food resource? Given the high labor investment required for this back-loaded food, its use was likely limited; perhaps it was only prepared and consumed during feasts and ritual events when traditions were reinforced. Instead, higher ranked foods such as corms and berries were much more important in the daily diet of the Native population on the islands than acorns. In particular, corms are easier to extract and prepare compared to acorns, which would make them attractive foods when available and abundant.

REGIONAL VARIATION—PLACING ACORNS IN CALIFORNIA PREHISTORY

Native Californians relied on wild plants for the bulk of their subsistence throughout prehistory. Given the great diversity in vegetation community composition, there was a wide range of foods available, dependent on setting. Despite this situation, there has been a tendency by anthropologists to emphasize the overwhelming importance of acorn as a dietary staple among Native Californians (e.g., Heizer and Elsasser 1980:91–101; Kroeber 1925; Powers 1877). Yet Kroeber (1925:523), in noting that acorn was a California staple, also stressed the geographic limits on its use: "To begin with, the oak is absent from many tracts. It does not grow in the higher mountains, in the desert, on most of the immediate coasts; and it is at best rare in districts like the baked plains inhabited by the southern Yokuts valley tribes, a fact that may help to explain the permanent association and commingling of the majority of these tribes with their foothill neighbors." In contrast, Gifford (1936:301) stated that "Balanophagy, or acorn eating, was probably the most characteristic feature of the domestic economy of Californian Indians." Since Gifford (1936), it has generally been assumed that acorns were the most important plant resource in prehistory. Subsequently, a pan-California model of food reliance has stressed the probable importance of acorns, with some level of acorn use starting in the Middle Holocene, and in some places the Early Holocene (e.g., Basgall 1987; Baumhoff 1963; Wohlgemuth 1996, 2004).

In assessing the earliest available evidence of acorns in the archaeological record, data from five early Holocene settings with archaeobotanical plant remains are considered (Table 1). Paleoethnobotanical studies reveal a relatively low use of acorns in all settings except in Northern California. Instead there appears to be great variance in what plant resources Native Californians relied upon in the Early Holocene—geophytes and small seeds were important on the Channel Islands, small seeds along the Southern-most Coast and in the greater San Francisco Bay Area, and other nuts (mainly pine nuts) in the Sierra Nevada foothills. As discussed in the previous section, acorns were used more extensively well after the Early Holocene in the Central Valley, Sierra Nevada foothills, and the San Francisco Bay area. For example, they do not appear to be important dietary contributors in the San Francisco Bay Area and Central Valley until around 3,500 years ago, about 600 years ago in the Sierra Nevada foothills, and not until around 500 years ago along the Southern-most Coast.

Does this variation mean that acorns were not as important in some places while there was heavy reliance on them in other areas? And how do we best assess the relative importance of acorns versus other plant

Table 1

PALEOETHNOBOTANICAL RESULTS FROM EARLY HOLOCENE SITES

Region	Reference	Small Seed Density n/L.	Grasses Density n/L.	Acorn Density mg./L.	Geophytes mg./L.	Other Nuts mg./L.
Channel Islands (Daisy Cave)	Reddy and Erlandson (2012)	0.100	0.000	0.000	0.030	0.000
Southern-most Coast (6 sites)	Reddy (2004)	0.020	0.000	0.000	0.000	0.000
Interior San Francisco Bay Area (CCO-696 Deep Locus)	Wohlgemuth (2004)	0.350	0.030	0.110	0.000	0.004
Sierra Nevada Foothills (CAL-629/630)	Rosenthal et al. 2011	0.043	0.024	0.174	0.000	0.620
North Coast Ranges (LAK-72)	Wohlgemuth (2004)	0.040	0.040	0.890	0.000	1.570

food resources? There are three issues that should be considered in addressing these questions: (1) whether acorns were indeed ideal/highly ranked foods that should have been exploited early on in the temporal sequence; (2) whether certain oak species were more highly ranked and more spatially restricted than other species; and (3) whether processing methods (including both the steps involved and where those steps took place) had a significant impact on the visibility of acorns in the archaeobotanical record.

It is possible that a low to minimal recovery of acorns in various archaeological contexts may reflect a greater emphasis on or availability of other nuts (e.g., gray pine or baynut) considered to be more highly ranked or requiring less processing, particularly in contexts of higher mobility and shorter stays at residential camps. It is also likely that regional and local variation in the density and types of oaks available had an impact on the abundance of acorns in the archaeobotanical record. Variation in local availability is particularly relevant for understanding the dearth of acorn remains at sites along the South-Central Coast, on the Southern-most Coast, on the Channel Islands, and in the southern portion of the Central Valley. Tan oak (*Notholithocarpus densiflorus*), black oak (*Quercus kelloggii*), and blue oak (*Q. douglasii)* are considered to have the highest rankings (Baumhoff 1963; McCarthy 1993). All three occur in varying densities from present to abundant in many interior central and northern California settings; however, in southern California only one of these three types (black oak) is available, and it is limited to localized upland settings (Baumhoff 1963:162–163). Instead, in the southern portion of California, lower ranked coast live oak (*Q. agrifolia*), engelman oak (*Q. engelmannii*), and canyon live oak (*Q. chrysolepis*) are common in the uplands, and the first two species are also present, albeit in low densities, near the coast. Therefore, it is perhaps not surprising that based on both ethnographic and archaeological data, acorns were never a staple food resource in southern California coastal contexts (including the Channel Islands). To date, acorn nutshell has been found in the densities approaching the frequencies characteristic of central California sites in only one interior ethnohistoric village in the Santa Ynez Valley (Wohlgemuth 2001). Similarly, there appear to be settings in central California (along the coast, and in the southern half of the Central Valley from the lower reaches of the Sacramento River southward) where the reliance on oaks was also more limited and varied.

Questions concerning the degree of reliance on and the desirability of acorns versus other plants foods at early occupation sites in California are also being raised in a comparable debate in the Near East. The plant diet of the Natufian (the terminal Pleistocene complex hunter-gatherer stage that preceded early agricultural villages) was traditionally interpreted as primarily focused on large-seeded wild cereals, supplemented by wild legumes, almonds, and pistachios. More recently, drawing on ethnographic analogies from California, it has been suggested that acorns may have also been an important part of the Natufian diet (see Barlow and Heck 2002; Mason 1995; McCorriston 1994). Although oaks occur within the catchment of many Natufian sites in the Near East (and within the same vegetation zone as pistachios and almonds), acorn macrobotanical remains are recovered very infrequently. A possible explanation is that the intensive processing necessary for acorns was a deterrent to their exploitation by Natufian populations. Interestingly, Near Eastern scholars have predicted that when acorns were included in the diet, their archaeological visibility was related to the types of acorns being exploited. Counter-intuitively, large acorns may be less visible than small acorns, as cost-benefit analysis indicates that large acorns were more likely to be processed at procurement locations and small acorns were more likely to be processed within residential bases (Barlow and Heck 2002:139–141).

Future studies in California that aim to more rigorously assess the relative dearth or abundance of acorns versus other plant foods in certain contexts invariably must explore and try to account for the processes by which acorns were incorporated into the archaeological record (Mason 1995; McCorriston 1994; Reddy 2004). Such studies have the potential to enhance and strengthen archaeobotanical interpretations, by avoiding the straightforward and potentially naïve assumption that greater abundance in the record always means a plant was consumed more frequently than other plants. Notably, plant processing pathways are valuable theoretical models that provide interpretive insight into the contexts in which plant material enters the archaeological record, and they can aid in identifying archaeological changes in procurement and preparation strategies. It should be noted that these cultural formation processes occur before and independently of taphonomic factors.

Dennell (1976) argued that food production, rather than food consumption, can be modeled from paleoethnobotanical data, mainly because plant resources are preserved in contexts of food gathering, production, and processing more commonly than in contexts of consumption. He constructed a generalized theoretical model of plant (crop) processing and deposition based on ethnographic grain processing in the Old World (Dennell 1974, 1976). This pioneering work was followed by the seminal studies conducted by Hillman (1984) and Jones (1984, 1987), who developed predictive models of specific processing activities through detailed ethnographic studies in the Old World. Hillman (1984) argued that there are relatively few efficient methods for processing a plant (or more specifically a crop) that are available to non-mechanized populations; i.e,. a plant can be processed in only a limited number of ways. Hillman (1984) and Jones (1984, 1987) defined specific stages and contexts in the processing sequence and concluded that specific ethnographic sample compositions result from particular processing stages. Thus, given a particular archaeological sample of plant remains resembling documented ethnographic samples, it is inferred that these archaeological remains were the product of essentially similar processing methods.

Following the research of Hillman (1984) and Jones (1984, 1987), several studies have developed predictive plant processing models for other plants (e.g., Bruno and Whitehead 2003; Engelmark 1989; Lu 2002; Palmer 1998; Reddy 2003c; Viklund 1998; among others). Such studies have been more common in the Old World and in specific parts of the New World where traditional and non-mechanized food gathering, production, and processing methods are still practiced; such practices have generally ceased to exist in the United States. Typically such models have been developed and applied to agricultural societies; however, they have equal applicability to hunter-gatherer contexts. For example, Asmussen (2010) replicated seed processing experiments on *Macrozamia moorei*, an Australian cyclad whose seeds were consumed by Pleistocene and Holocene hunter-gatherers in Australia, to develop criteria that distinguish human processing techniques from natural modification.

Although plant processing pathway studies are rare in North America, research in other contexts could be profitably adapted and applied to California settings to model how the archaeobotanical record could vary based on processing methods, and to better understand some of the cultural factors influencing the relative abundance or dearth of certain plant food remains. For example, the shift from brown (mature) pine-cone harvesting to green pine-cone harvesting in the Great Basin has significant implications for storage, land use, and seasonality (Eerkins et al. 2002:21–22; see also Hildebrand and Ruby 2006). It is also an ideal example of how modeling the processing pathways of brown-cone and green-cone procurement will undoubtedly generate very different archaeobotanical expectations in terms of the types and quantities of archaeobotanical remains produced at each stage and the types of sites and contexts within which these processing steps may have taken place.

Potential processing pathways used by Native Americans for acorns can be gleaned from ethnographic and ethnohistoric studies. Figure 2 presents a generalized processing-pathway model for all types of acorns, highlighting common processing stages, products, and the by-products likely to survive in the archaeological record. The model clearly demonstrates that the incorporation of acorns into the archaeological record is highly variable and is based on the method of preparation, the potential for the use of acorn shell as fuel, and (most importantly) accidental loss and spillage. Acorns were rarely roasted or parched directly over fire without clay casings because the clay reduced the tannic acid without a labor-intensive leaching process (White 2003). As a result, the likelihood of carbonization during acorn processing would occur only in the event of accidental spillage or discard into fires, severely limiting instances of carbonization. In contrast, grasses, other small seeds, and some nuts (such as gray pine) were typically parched during processing, a method that tends to create considerable accidental carbonization (e.g., Reddy 1997, 2003c). The use of acorn nutshell as fuel would have produced ample carbonized remains, but it is unclear how widespread this practice was in California. It is, however, documented among the Miwok in central California, where acorn by-product shell was stored for fuel because it made a hot and lasting fire (Barrett and Gifford 1933:143). Therefore, it is possible that the dietary importance of acorns versus

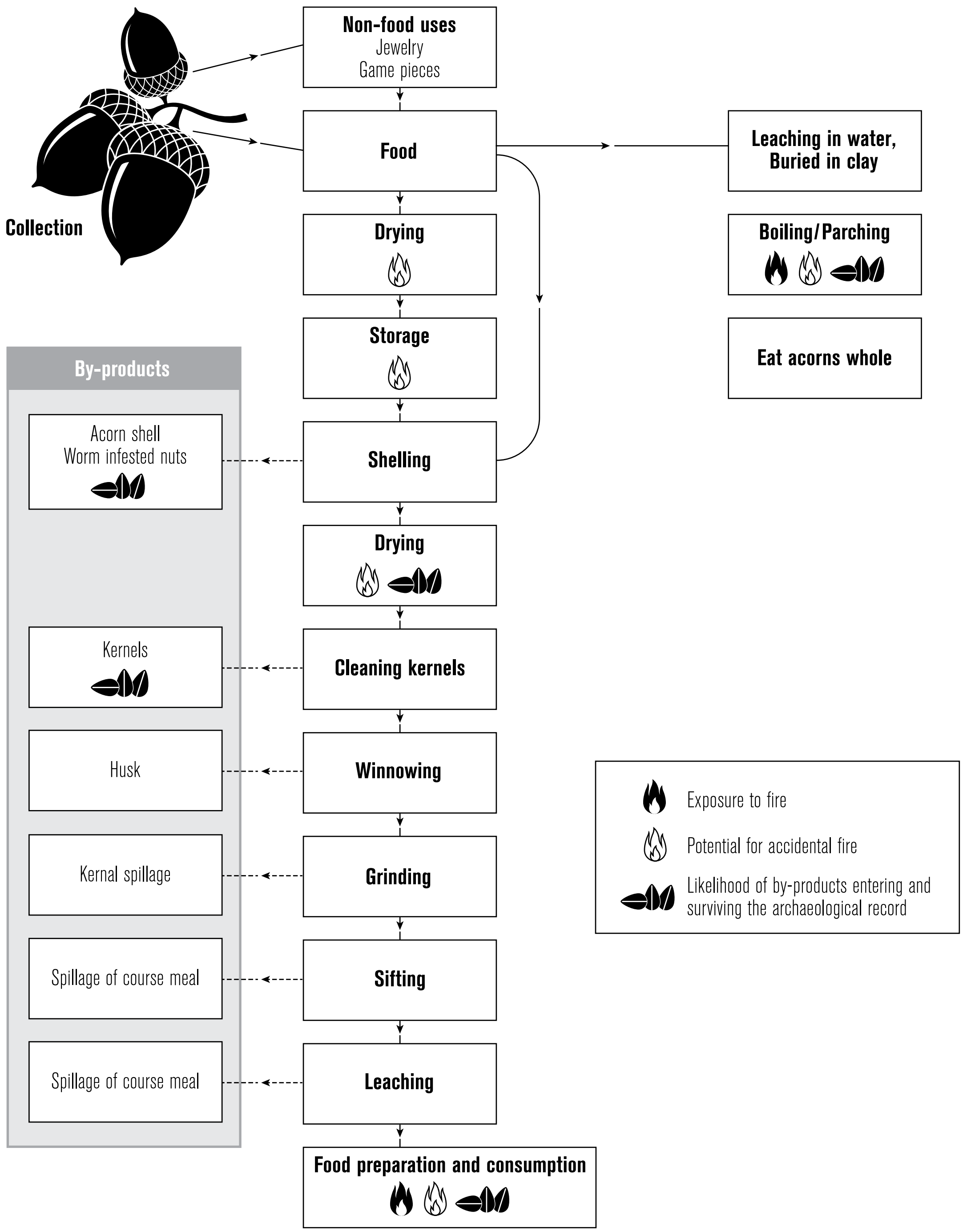

Figure 2. Generalized processing pathway for acorns.

other plant foods is underestimated in macrobotanical assemblages, depending on the processing pathways used and where each stage occurred. Such preliminary assessments highlight the utility of considering how, when, and where particular plants were processed, and providing tools for paleoethnobotanists to refine their interpretations of the archaeobotanical record. It also highlights contexts in which other kinds of microbotanical evidence (such as starches, phytoliths, and residues) could be applied to strengthen interpretations. Future research into acorn processing pathways also may want to consider alternate processing methods that were incorporated in the generalized model presented here. For example, White (2003) argues that acorns may not have always required multiple processing stages, and that the final product could have been something other than flour. He even suggests that alternative products and processing methods may have occurred during the Archaic period, although he does not specify what they were. Overall, incorporating insights gained from processing pathway studies will allow us to gain a greater appreciation for the implications of spatial variation and localized temporal changes to the relative frequency or density of macrobotanical acorn remains, particularly as to whether or not they reflect shifts in the relative dietary reliance on acorns.

LATE HOLOCENE CHANGES—SMALL SEEDS AND SETTLEMENT PERMANENCE

The fundamental trend in the trajectory of prehistoric plant use throughout California is the emergence of intensive small seed exploitation in later portions of almost all of the cultural sequences reviewed here. This pattern is true even in Southern-most Coastal California, where small seeds were the focus of the plant food economy early in time, and by the end of the sequence there was an increase in their frequency. It is apparent that ultimately small seeds become a mainstay of the plant diet in a variety of locations: the interior San Francisco Bay Area, Central Valley, South-Central Coast, and Southern-most Coast, and increased in importance in the Sierra Nevada Foothills and bayshore settings of the Bay Area. I propose that this focus and reliance on small seeds was related to changes in the nature of regional settlement, namely greater settlement permanence, as well as an increase in the size of village communities and an overall rise in regional population density. Milliken et al. (2007) suggest that Bay Area population growth and pressure would have been constant, and that the population would have regularly surpassed carrying capacity of the environment (see also Whitaker and Byrd 2014). Rosenthal et al. (2007) estimated that 100,000 Native Americans lived in the Central Valley between 180 and 130 cal B.P., and according to White (2003), the population in the lower Sacramento Valley went from circa 600 persons around 4,500 cal B.P. to more than 3,000 persons by 1,200 cal B.P., and finally to more than 12,000 persons around 130 cal B.P. Similar trends (increased population and/or population pressure) have been noted for the South-Central Coast and the Southern-most Coast (Byrd and Reddy 2002; Byrd and Raab 2007; Gamble 2008; Glassow et al. 2007 and references therein).

In each of the areas in California discussed, the rise of intensive small seed exploitation continued to be supplemented by the procurement and consumption of corms and nuts, as well as other secondary resources such as berries and greens. Small seeds, which notably included grasses, legumes, and cheno-ams, were available at varying time spans from early spring through late summer, and were then supplemented by nuts in the fall, berries in the spring and fall, and corms primarily in the winter. If indeed small seed exploitation was associated with increased settlement permanence and population density, what is it about small seed exploitation that would be optimal or expected in such contexts?

In sedentary settlements, food acquisition would have often necessitated logistical forays beyond the daily foraging range to ensure an adequate food supply. It also invariably might have involved the amplification of resource procurement within the daily catchment. Intensive exploitation of small seeds was ideally suited for such situations, and it would have entailed such things as (1) an overall increased focus upon variably-sized patches of small-seeded resources; (2) a greater labor investment in their procurement; (3) a more targeted collection of specific species during limited optimal collection windows within the spring-summer time span; and (4) a greater investment in obtaining, processing, and storing surpluses of small-seeded plants. Wohlgemuth (1996:98, 2002:29, 2004:145–149) has identified several characteristics of acorns and small seeds which further support the conclusion that small-seed exploitation during times of population pressure would have been a successful strategy. These include the following: (1) there is no scheduling conflict between acorns and small seeds; (2) there are limits to increasing the production of nut crops, while small seed production can be greatly increased, ultimately through cultivation and agriculture, to support increasing populations; (3) small seed intensification was a response to the inadequacy of acorns for maintaining expanding populations; (4) bulk gathering and processing as well as green-season gathering of small seeds could increase returns; (5) small seeds are gathered at lower return and reflect an increased diet breadth; and (6) an early intensification of acorns and a later intensification of small seeds appears to be related to regional population increases.

Such trends in the intensification and focus on small-seeded plants would have both facilitated and decreased the daily and annual mobility of more permanent village populations. This pattern is analogous to the rise in small-sized shellfish exploitation which also took place within the context of territorial social circumscription at the end of the Late Holocene sequence in portions of the San Francisco Bay Area and Southern-most Coastal California (Byrd and Reddy 2002; Whitaker and Byrd 2014). For Late Period villages in settings such as the Sacramento Valley, San Francisco Bay Area, and the South-Central Coast, traditional food acquisition patterns are often considered to have involved periodic seasonal forays for resources available outside the daily foraging catchments (particularly to upland locales containing greater densities and preferred types of nut resources). With increased settlement permanence and population pressure at the end of the prehistoric sequence in California, access to more distant food resources may have been subject to greater competition. Intensified procurement tactics within the daily foraging range could have offset such losses, further facilitating increased reliance on locally available small seeds (including grasses and legumes), as well as on greens, corms, and locally available nuts.

The adoption of controlled burning would have been a land management tool that further increased local plant food productivity (Lightfoot and Parrish 2009; Lightfoot et al. 2013a, 2013b). Such tactics, well-documented in a variety of California settings at the time of European contact, kept successional vegetation low, expanded grasslands, and increased wild resource productivity (Lightfoot and Cuthrell 2015). Anthropogenic burning was perhaps best suited to increasing the extent and density of various small-seeded plants as opposed to other plant and animal resources. Indeed it is logical to predict that the onset of intensive small seed exploitation may either be correlated with the persistent use of controlled burning to increase productivity, or that controlled burning represents a step to further increase the productivity of locally available resources—small seeds specifically. In other words, the increased use of small seeds could be a byproduct of the tradition of controlled burning, or alternatively, the controlled burning was practiced by Native Americans to improve small seed-stand productivity. It is uncertain which hypothesis is accurate since the onset of controlled burning as a Native Californian land management tool is unknown, but it may well extend back 1,000 or more years into the past (Lightfoot and Cuthrell 2015:5).

Optimal foraging theory modeling has indicated that small seed intensification is not cost effective because of the high labor investment per unit return (Rosenthal 2011). From such a perspective, small-seeded foods were most heavily exploited in a wide range of settings during the Late Holocene as part of a set of resource intensification strategies. Moreover, by the time of European contact and colonization, a wide range of land management practices were in use, most of which were tailored to encouraging the growth of plant food resources (e.g., Anderson 2005; Lightfoot and Parrish 2009). These Native Californian strategies are consistent with what Smith (2001) has referred to as low level food production.

Although there is no archaeobotanical evidence of an intentional prehistoric cultivation of small seeds, I have suggested that cultivation of small grasses (little barley and maygrass) took place during the historical period in at least one locality—along the lower Los Angeles River of Southern-most California (Reddy 2009, 2015, In Press). River valleys (such as this one or others such as the Sacramento and the Owens rivers) are ideal locales where rich plants resources provided an impetus for people to settle down. The long-term close association of humans and plants would have ultimately provided the optimal cultural environment for people to start cultivating plants. If intentional cultivation of small-seeded annuals was initiated at the end of the prehistoric sequence in coastal southern California, it could have involved a very low labor investment per unit return in riverine contexts. Villages along rivers were logistically located to exploit the riverine niche for corms and riparian plant foods, and also the valley floor for small seeds. Seasonal flooding would have presented an ideal opportunity to plant grass seeds in the water-logged sediments. If the planting was done in phases as the water receded, maturation would also be phased. In such a context, there would be minimal land preparation required, which would greatly reduce front-end labor investment. Furthermore, studies of such cultivation in seasonally flooded areas have demonstrated that the resulting products are largely weed-free (Reddy 1991, 2003c). Finally, the phased maturation would make collection manageable in that only sections of the population would need to participate in the harvest.

In summary, the rise of intensive small seed exploitation, coupled with increased manipulation of the local landscape to enhance productivity, would have enabled near-sedentary populations to reduce logistical forays, and to increase yields from locally available plant resources. The timing of these changes undoubtedly varied within California, but it appears to be restricted to the last 2,500 years, and to less than 1,000 years ago in most places.

CONCLUSIONS

This overview of emerging trends in prehistoric plant use in western California has emphasized major temporal and regional patterns, as well as pointed out substantive differences between geographic locales. Overall, prehistoric Native Californian plant use was dominated by the 'Sister Trilogy of California'—corms, nuts, and seeds. Moreover, the relative emphasis placed upon these major plant food categories varied spatially and temporally within western California, highlighting the great richness and diversity in plant resource utilization between and within regions. In other words, none of the regions relied equally on the food triad; instead, the focus (on corms, nuts, and seeds) was dependent on the region and time period involved. The results illustrate the immense potential of macrobotanical studies for furthering our understanding of prehistoric adaptations in California, while at the same time highlighting the limits of ethnographic and ethnohistoric observations and normative perspectives. Moreover, where organic preservation is good and subsurface deposits are present, paleoethnobotanical investigations should be an integral aspect of every archaeological excavation project in the region. Ideally, they should also be given the same importance in terms of designing research and budget allocations as artifact and faunal analysis, rather than often being a minor element, an afterthought, or not studied at all.

Overall, the types of plant foods that Native Americans used intensively, and the timing of plant intensification, varied based on differences in the food-resource potential of localities, the relative return rates of available foods, and the resource procurement practices that were employed. Notable trends that are readily discerned include the importance of corms in certain settings (such as the northern Channel Islands), the heavy reliance on small seeds early in the cultural sequence in other environs (such as the Southern-most Coast), the limited role of acorns in a variety of contexts, and the rise and predominance of small-seeded plants at the end of the prehistoric sequence.

Future studies can profit from giving more consideration to the underlying causal factors driving the pace and scale of change in plant usage, and the social contexts in which certain plants were added to the diet or became keystone resources. For example, under what conditions would a population weigh risk management or cultural preference over relative labor investment and shift focus to gathering a particular resource? And what role does social identity, cuisine, food palate, and indigenous food recipes play in structuring macrobotanical assemblages?

To gain insight into these questions, dependence solely on the local ethnographic record can be detrimental, and we need to look outside current political boundaries—not just in North America—and draw insight and inspiration from archaeological studies of food use in similar landscapes globally. Even a cursory look allows us to highlight several broader trends with implications for plant use in California. A reliance on small-seeded plants, for example, is a widespread phenomenon. In the Near East, inhabitants of the 23,000-year-old site of Ohalo II in the upper Jordan Valley intensively collected and consumed a wide range of wild small-seeded plants, including grasses, with much more limited focus on the larger wild grasses that would be later domesticated in the Early Holocene (Weiss et al. 2004a, 2004b). Similarly, during the Late Holocene in eastern North America, goosefoot (*Chenopodium berlandieri*), little barley, and maygrass were important plant resources, and at least some were cultivated (e.g., Scarry and Yarnell 2011). A focus and reliance on tubers and roots has similar widespread antiquity. For example, a series of Late Paleolithic sites in the Wadi Kubbaniya near Aswan Dam in Egypt are dominated by tubers of a nut-grass that thrived in riparian contexts (Hillman et al. 1989). Finally, several recent studies have highlighted the analytical power and nuanced nature of how household food acquisition, processing, and the consumption of daily meals and feasts can be structured and vary seasonally (Klarich 2010). Notably, work at the Early Neolithic site of Çatalhöyük in central Turkey has highlighted both the pragmatic and social aspects of daily meals and their provisioning within a sedentary village context (Atalay and Hastorf 2006; Bogaarda et al. 2009). Moreover, Jacknis (2004) has also shown how new perspectives on the existing ethnographic literature can provide insights into cultural variation in meals and taste palates in Native California.

Future investigation can profitably aim to unpack how people engage differently with plants based on social and cultural factors. The underlying causal factors related to variations in the timing of increased emphases on small seed exploitation need to be unraveled. This trend is certainly tied to local contextual factors and temporal trajectories, but logically should occur earlier in areas of higher population density or where settlement permanence first emerged (see also Wohlgemuth 2004, 2010). Another profitable line of inquiry entails identifying regional variation in which small-seeded plants were emphasized. Such research should consider whether the regional variability reflected variation in local availability/abundance, whether or not controlled burning allowed particular species to flourish over others, whether intentional planting occurred (particularly for grasses and *Chenopodium*), and what role cultural preferences and food palettes played. More research should be carried out on which small-seeded plants are ideal for storage and consumption in subsequent seasons, which plant species work well only if stored for short time periods, and which ones are not well-suited for storage at all. Overall, it is exciting to see that we have now reached a point in California paleoethnobotany where we can start exploring such questions in greater depth.

NOTE

1 Archaeobotanists use the common term 'cheno-ams' to refer to seeds that could be from plants in either the genus *Chenopodium* or the genus *Amaranthus*. During the carbonization process, seeds swell and distort, and it is often difficult to distinguish between the two genera.

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