

Evidence for an Island Chumash Geophyte-Based Subsistence Economy on the Northern Channel Islands

KRISTINA M. GILL

Department of Anthropology, University of California, Santa Barbara

KRISTIN M. HOPPA

Department of Anthropology, University of California, Santa Barbara

We synthesize northern Channel Islands archaeobotanical data to discuss broad, diachronic patterns in ancient plant use. Using quantitative and qualitative comparisons, we explore the relative importance of plant foods through time and consider how plant food rankings on the islands may have differed from those on the mainland. We argue that geophytes were the highest ranked plant food resource, valued for their contribution of easily procured carbohydrates in an island environment rich in marine protein and fat resources. Geophytes are phenomenally abundant on the islands, and were used consistently by the Island Chumash and their ancestors for at least 10,000 years with no significant change through time. We also explore the representation of various other plant foods through time and consider what archaeobotanical data indicate about the use of groundstone, division of labor, and island-mainland exchange networks.

CALIFORNIA'S NORTHERN CHANNEL ISLANDS have a long history of human occupation and excellent preservation of archaeological sites. Archaeological research on these islands has historically focused on the importance of marine resources to Island Chumash subsistence. We are just beginning to understand the role of island plant resources to subsistence practices, as archaeobotanical studies become more prevalent. There is a long-held perception among California archaeologists that island plant resources were not sufficiently diverse or abundant to support island populations, and therefore less important to the islanders than to mainland Chumash. Such characterizations started with early Spanish accounts and were perpetuated by field observations of biologists, botanists, and archaeologists over the past century. Prior to the last few decades, the island flora was subjected to more than a century of heavy grazing by introduced domestic animals (sheep, cattle, and pigs in particular), with devastating effects. With the livestock removed, island plant communities are recovering from overgrazing and recent field observations have noted a florescence of

native island flora, many of which were important food sources for the Island Chumash.

Here, we present archaeobotanical data from sites on Santa Cruz and San Miguel islands, using quantitative analyses to identify and discuss broad trends in ancient island plant use through time. We discuss plant resource rankings, Island Chumash foodways, and division of labor. We argue that on the Channel Islands, where fats and proteins are readily accessible from the rich marine environment, carbohydrate content (along with caloric value) is the most important nutritional component of plant foods. With this in mind, we reconsider island plant food rankings using carbohydrate content as the primary currency, along with seasonal availability and processing costs. Drawing from archaeobotanical and archaeological data, we argue that the Island Chumash had a geophyte-based subsistence economy, where brodiaea corms were the highest-ranked plant food, and one that provided an abundant and reliable carbohydrate staple for at least 10,000 years. We explore the use of other plant foods through time, as well as reasons for variation within the archipelago, including preservation issues, reporting

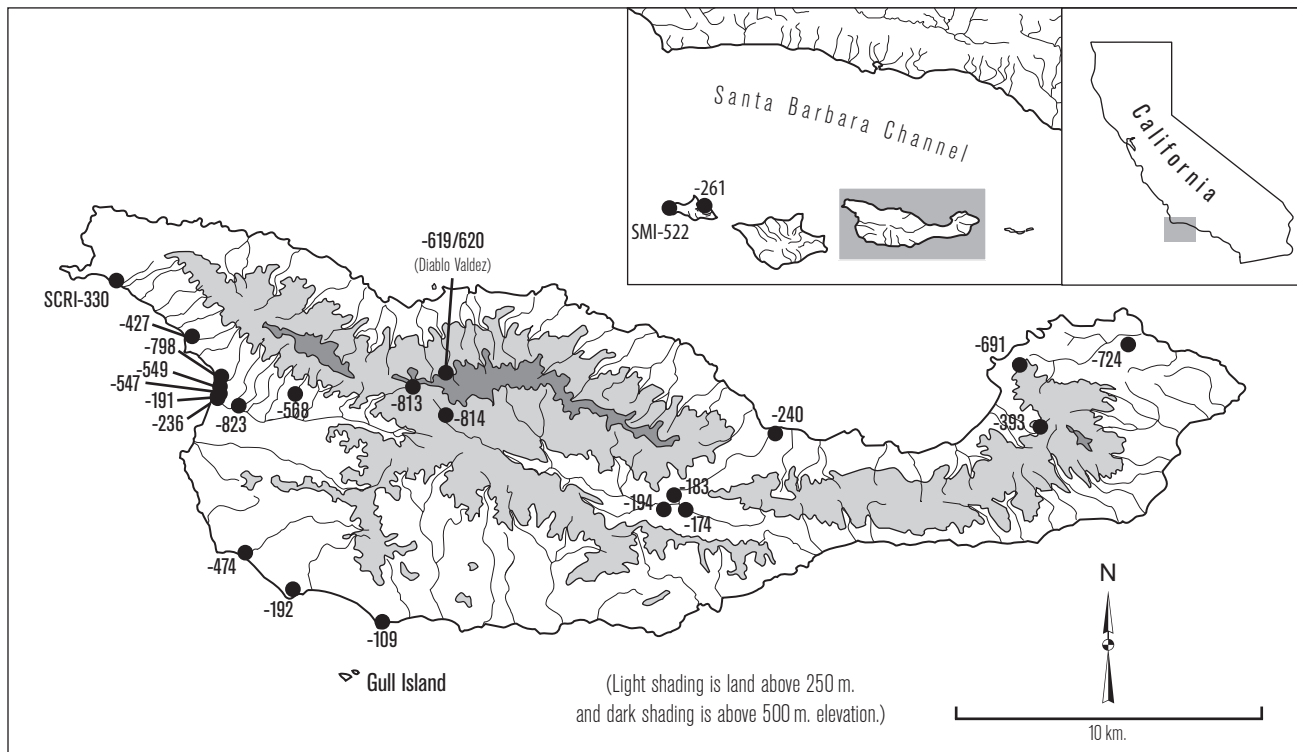


Figure 1. Map of the Northern Channel Islands and sites with paleoethnobotanical data.

methods for paleoethnobotanical data, and the disparate number of paleoethnobotanical studies on each island.

THE ISLAND ENVIRONMENT

Located between 19 and 44 km. from the mainland, the four northern islands (from east to west) of Anacapa, Santa Cruz, Santa Rosa, and San Miguel define the southern boundary of the Santa Barbara Channel (Fig. 1). Until approximately 9,000 years ago, these islands composed a single land mass known as Santarosae, located just nine km. from the mainland (Clark et al. 2014; Reeder-Myers et al. 2015). Due to mixing of the cold waters of the California current and the warmer waters of the Davidson current from Baja California, sea surface temperatures in the bight generally range from cool to warm, west to east. The variability in SST supports a high diversity of marine fauna that is also reflected in the archaeological record. The islands contain vast stretches of rocky shorelines and tide pools that support extensive seaweed and shellfish beds, as well as sandy beaches used as haul-outs and rookeries for a variety of pinnipeds. Kelp forests and

marine plant communities (i.e., surfgrass [*Phyllospadix* spp.], eelgrass [*Zostera* sp.]) around the islands support a variety and abundance of fish, shellfish, and marine mammals (Erlandson et al. 2015).

The terrestrial environment of each island varies considerably, depending on topography, precipitation, available freshwater, relative isolation, and historical impacts. Ranching operations that began in the mid-1800s significantly impacted the island flora, as upwards of 100,000 sheep roamed freely on Santa Rosa and Santa Cruz islands by the early 1900s. Erosion caused by overgrazing was often severe, a problem that persists on all the islands where extensive sheep operations occurred. On San Miguel Island, severe overgrazing by sheep destabilized dunes, which resulted in large-scale sand movement, soil erosion, and damaged the island's hydrology, as well as many archaeological sites (Erlandson et al. 2005). Elsewhere in the archipelago, the introduction of European grasses, mustard, fennel, eucalyptus, and other invasive taxa also dramatically altered island landscapes from prehistoric conditions. From the 1980s to the 2000s, a comprehensive program to eradicate non-native animals such as cattle, sheep, pigs,

rats, deer, and elk was implemented to begin restoration efforts on the islands (National Park Service 2015; The Nature Conservancy 2014). Ongoing efforts aim to restore the native flora and remove as many invasive plant taxa as possible.

Historical impacts limit our ability to interpret prehistoric vegetation communities based on modern observations, but some general trends can be noted. At least 12 plant communities occur on the Channel Islands, the most dominant of which include grassland, coastal dune/scrub, chaparral, and oak woodland (Junak et al. 1995; Philbrick and Haller 1977). The extent to which each community is represented varies, with the largest islands (Santa Cruz and Santa Rosa) supporting most communities, whereas only grassland and coastal dune/scrub occur on the smaller islands (Moody 2000; Philbrick and Haller 1977). Many of the most productive areas with the greatest botanical diversity occur in more interior settings, especially where higher precipitation (often in the form of water from fog) provides significant soil moisture during the driest months of the year (Baguskas et al. 2014; Fischer and Still 2007). As the island flora continues to recover from the ranching era, significant changes may take place in the plant communities represented on each island. Regardless, a variety of plant foods that are abundant in the grassland and coastal communities (e.g., geophytes, various small seeds) occur on all the northern islands.

THE ISLAND CHUMASH

The Island Chumash and their ancestors occupied the northern Channel Islands from at least 13,000 years ago (Erlandson et al. 2011; Johnson et al. 2002) until A.D. 1822 when the last of the islanders were removed to the missions under Spanish colonialism (Arnold 2001; Johnson 2001). During this long history of occupation, the Islanders adapted to rising seas, changing environmental conditions, and population growth. These adaptations are reflected in the material culture, with evidence for changes in technology (e.g., the *tomol* and shell fishhooks), subsistence practices (e.g., nearshore vs. pelagic fishing), regional exchange networks, and socio-political organization. Several cultural chronologies for the islands have been defined (see Glassow et al. 2007; King 1990), but we utilize Arnold (1992), with

some modification as noted, to discuss changes in plant procurement, groundstone technologies, and plant food processing through time.

Paleocoastal peoples, the earliest inhabitants of Santarosae, were adept at making fine chipped stone artifacts, including crescents, Channel Island Barbed points, and Amol points diagnostic of this time period, between ~12,000–8,000 cal B.P. (Erlandson et al. 2011; Gusick 2012; Rick et al. 2013). Paleocoastal sites found on the islands today represent the use of Santarosae's interior at the time, and plant food resources were at least one motivating factor in this early interior settlement (Erlandson et al. 2007; Reddy and Erlandson 2012). In the Middle Holocene, the Early (ca. 7,500–3,500 cal B.P.) and Late Early (ca. 3,500–2,500 cal B.P.) periods are characterized by high marine productivity, sea level stabilization, and an increase in the number of identified archaeological sites (Glassow 1993; Glassow et al. 2007; Kennett 2005). An increase in the number of interior sites and higher frequencies of dental caries rates during this time point to a possible increase in the importance of plant foods as population densities increased (Kennett 2005; Walker and Erlandson 1986). Mortar and pestle technology appears around 6,000 years ago on the islands (Glassow 2015:756) and mainland, suggesting to many researchers an important shift in subsistence towards acorn exploitation (e.g., Gamble and King 1997).

An apparent shift in settlement occurred during the Middle Period (ca. 2,500–1,350 cal B.P.), with an emphasis on coastal settlement and fewer interior settlements overall (Perry and Glassow 2015). Technological innovations, including the circular shell fishhook ca. 2,500 cal B.P., and the sewn plank canoe (or *tomol*) ca. 1,500 cal B.P., are associated with an intensification of fishing, including a notable increase in large pelagic fish such as swordfish and tuna in archaeological assemblages (Arnold and Bernard 2005; Gamble 2002; Glassow et al. 2007). The apparent escalation of a maritime orientation on the islands, including increased sedentism along the coast, pelagic fishing, and a growing regional exchange network, provide a foundation for Chumash socio-political complexity seen throughout the channel region (Arnold 1992, 2001; Gamble 2002, 2008; Glassow et al. 2007).

The socioeconomic complexity encountered by early European explorers in the Santa Barbara Channel emerged within the last 1,000 years. High marine

productivity combined with prolonged drought during the Medieval Climatic Anomaly (MCA) between 1,200 and 600 years ago has been suggested as a prime mover for the development of this complexity (Arnold 1992, 2001; Glassow et al. 2007; Jones et al. 1999; Kennett and Kennett 2000; Raab and Larson 1997). Arnold (1987) argued for the emergence of a ranked society, increased use of regional exchange networks, and increased craft specialization between A.D. 1150 and 1300, a period she defined as the Middle/Late Transition. Her work has shown that post-A.D. 1200, island populations manufactured millions of olivella shell money beads, which were exchanged with mainland populations for a variety of products such as obsidian, projectile points, bone tools, and other goods (King 1976; Munns and Arnold 2002; Timbrook 1993). King (1990) and Gamble (2005) argue that a ranked society and hereditary elites emerged prior to the MCA, during the Middle Period. The regional exchange network linking island and mainland populations became firmly entrenched after A.D. 1300, however, acting as a security net for coping with drought and declines in terrestrial or marine productivity through the Late Period (Arnold 1987, 2001).

Plant Foods in Regional Exchange Networks

Plant food resources, particularly acorns, wild cherry, and small seeds, were reportedly imported from the mainland in exchange for shell beads, a practice described in ethnohistoric accounts (King 1976; Timbrook 1993). Based largely on these ethnohistoric records and the prevailing assumption that island plant foods were not abundant enough to support growing island populations, Arnold (2001) and Arnold and Martin (2014) argued that mainland plant foods played an important role in regional exchange networks, especially during and after the MCA. Paleoethnobotanical data from several Middle/Late Transition and Late Period coastal sites on Santa Cruz Island showed that acorn nutshell is present in very low densities (Martin and Popper 2001), a pattern that holds true for earlier time periods as well. Given the high densities of acorn nutshell found in Late Period sites on the adjacent mainland (Hammett 1991; Hildebrandt 2004), Arnold (2001) proposed that shelled acorns may have been processed on the mainland and transported across the channel in exchange for shell beads. Fauvelle (2013) tested this hypothesis using experimental data on

tomol storage capacities and the transport efficiency of shelled versus whole acorns, concluding that acorns were probably not an important trade item. Gill and Erlandson (2014:570) agreed, but argued that the low density of acorn nutshell in island assemblages is more likely “due to the abundance of other island plant foods, not to mainland acorn processing decisions or *tomol* storage capacities.”

Various researchers have identified remains from plants not known on the Channel Islands today, including western sea purslane (Arnold and Martin 2014; Martin and Popper 2001), laurel sumac (Hoppa 2014), California black walnut (Martin and Popper 2001; Thakar 2014), and California wax myrtle (Gill 2015). Arnold (2001; Arnold and Martin 2014) argued that these mainland resources supplemented the local island diet during times of resource stress. These intriguing ideas are based on scant paleoethnobotanical data and the underlying assumptions that (1) island plant food resources were too marginal to support island populations, and (2) that island people needed to trade with the mainland to supplement local plant food resources. In light of recent archaeobotanical data summarized here, and Gill’s (2014, 2015) work on island geophytes, the role of plant foods in the regional exchange networks needs to be re-evaluated.

Island Groundstone Assemblages

Native people throughout California used manos and metates (millingstones), starting at least 9,000 years ago. Sites containing abundant millingstones, few projectile points, and few vertebrate remains are particularly abundant in southern California, occurring in both coastal and interior settings, a tradition known as the Millingstone Horizon (Erlandson 1994; Fitzgerald and Jones 1999; Wallace 1955). Despite the preponderance of Millingstone sites along the California mainland coast, the Millingstone Horizon is absent on the islands, pointing to an early subsistence regime different from the mainland. Archaeologists have long recognized this difference, suggesting first that the islands were settled later than the mainland (Olson 1930; Rogers 1929), or that plant exploitation and processing were less important on the islands, possibly due to higher marine productivity, lower plant resource availability, or a combination of factors (Erlandson 1994; Glassow et al. 2007; Orr 1968; Rozaire 1965). The assumption that island floras were ‘depauperate’ helped explain the lack of millingstones

at island sites, while the lack of millingsstones further strengthened the argument that island floras were depauperate (Arnold 2001; Erlandson 1994; Glassow et al. 2007; Kennett 2005; Rozaire 1965:49). The circularity of this reasoning perpetuated a long-standing dismissal of island plant resources, a notion directly challenged by the archaeobotanical data summarized here.

As noted earlier, mortar and pestle technology appears in the Santa Barbara Channel region around 6,000 years ago, with little change in form through time (Glassow 1996, 2015; Perry and Glassow 2015). The stone bowl is the most common type of mortar found in the region, and several bowl manufacturing sites have been identified on the islands (Conlee 2000; Schneider and Osborne 1996). Stone mortars made of non-local materials have been found at many sites on the islands and mainland, indicating the importance of stone bowl manufacture and trade within regional exchange networks (Conlee 2000; Wlodarski 1979).

Digging stick weights, also known as donut stones, are stones with a hole drilled through the middle. Found throughout the Early, Middle, and Late periods on the islands, the oldest known examples come from an early cemetery at CA-SRI-3 dated to ca. 7,500 cal B.P. (Glassow et al. 2010). Ethnohistoric records suggest that digging sticks weighted with perforated stones were used primarily for digging brodiaea-type corms, also known as *cacomites* (Gill 2014, 2015; Hudson and Blackburn 1979; Timbrook 2007). While donut stones are found throughout southern California, they are particularly prevalent in island assemblages. Sutton (2014) showed that of 525 specimens housed in California museum collections, 71% come from the northern islands, 16% from the southern islands, and only 13% from the mainland. The preponderance of digging stick weights on the islands suggests that geophytes were a more important food resource on the islands compared with the mainland, and possibly elsewhere in California (Gill 2015; Sutton 2014).

ISLAND PLANT FOODS

Food Underfoot: Geophytes of the Channel Islands

Geophytes, characterized by an edible underground storage organ (including tubers, bulbs, corms, and

rhizomes), have been recognized as an important traditional food source around the world (see Anderson 2005; Kelly 1995; Vincent 1985). Generally rich in carbohydrates and other nutrients, geophytes provide foragers with an energy source complementary to a diet rich in fats and proteins. The importance of geophytes as food has been well documented in western North America, from both ethnohistoric and archaeobotanical data (see Gill 2014). Brodiaea-type corms include several closely related genera in the Themidaceae family (with morphologically similar corms), and are commonly referred to as ‘Indian potato’ throughout much of California (Anderson and Rowney 1999; Gill 2014; Timbrook 2007; Todt 1997).

Among the Chumash, the term *cacomite* (or *shiq'o'n*) was most commonly applied to blue dicks (*Dichelostemma capitatum*) corms, while other geophytic plant foods like the mariposa lily (*Calochortus* spp.) were referred to as “another kind of *cacomite*” (Timbrook 2007:75). The corms were dug using a digging stick, often weighted with a perforated stone. They could then be eaten raw, but were more commonly taken back to a village or camp to be cooked in a roasting pit or earth oven. Fernando Librado, a consultant to ethnographer John P. Harrington, stated that *shiq'o'n* was particularly important on the islands, where several families were involved in harvesting and cooking large quantities at a time in roasting pits more than a meter across (Anderson 2005:295; Hudson and Blackburn 1983:213; Timbrook 2007:75).

Since the removal of livestock from the islands, it is increasingly apparent from spring blooms that blue dicks are phenomenally abundant on the islands today (see Gill 2015). Other brodiaea-type geophytes (i.e., *Bloomeria* spp.) are also abundant in places, but blue dicks are the most widespread and fecund today, even during a severe four-year drought. Edible geophytes are particularly vulnerable to predation on the mainland by gophers, which prefer brodiaea corms over other plant foods (Proctor and Whitten 1971). In the absence of gophers, geophytes on the islands appear to have been significantly more abundant and larger than they were on the mainland (Gill 2015), providing an easily procured source of carbohydrates and calories (Fig. 2). Gill (2014) has shown that brodiaea corms are available as a food source *year round*, and at least two different seasons of harvest (spring and fall) have been documented in



Figure 2. Island blue dicks corms, collected October 27, 2012 (photo by K. Gill).

archaeobotanical corms from the upland village site of Diablo Valdez (SCRI-619/620).

Island Plant Food Rankings

Ranking plant foods in terms of return rates is a useful tool for evaluating optimal foraging behavior and changes in diet breadth. However, these return rates are largely derived from experimental collecting and processing data from the Great Basin or Columbia Plateau (see Wohlgemuth 2010), which seem less applicable to island plant resources where herbivores were largely absent. Geophytes are extraordinarily abundant on the islands without gophers, oaks have higher regeneration rates without deer (Manuwal and Sweitzer 2010), and grasses, greens, and wildflowers are more abundant and diverse in the absence of rabbits

(Courchamp et al. 2003). Given the fats and complete proteins available to islanders from marine resources, we argue that the carbohydrate content of various plant foods is a more appropriate currency than caloric value alone (see Gill 2015). Foraging decisions may be different in other areas of California where fats are more difficult to obtain, and pine nuts, acorns, and other plant foods may have been targeted for their broader caloric (fat + carbohydrate) content.

Our revised ranking scheme for island plant foods, using a combined carbohydrate/calorie content as the primary currency, also considers the seasonal availability (and storability) of these plant foods, as well as their relative processing costs (see Gill 2015). Table 1 (adapted from Gill 2015) presents a revised ranking of island plant food categories, with a sample of genera within each

Table 1
ISLAND PLANT FOOD RANKINGS BASED ON CARBOHYDRATES, SEASONAL AVAILABILITY,
PROCESSING COSTS, AND ISLAND ARCHAEOBOTANICAL ASSEMBLAGES (GILL 2015:81, 256)

Rank	Plant Category and Type	Proximate Nutritional Composition per 100 g. (mean %)					Season of Harvest
		Protein	Fat	Carb	Water	KCal	
1	Geophytes brodiaea	1.09	0.91	31.78	63.10	139.70	all year
2	Kelps and Seaweeds bull kelp (dried) seaweed (dried)	3.00 18.60	5.70 4.00	57.40 40.90	5.20 12.50	292.90 274.40	all year
3	Small Seeds grass ^a cheno-arms ^{a,b} sage	10.90 11.80 13.60	0.40 3.80 13.30	73.50 71.60 59.50	9.20 9.80 8.50	334.00 290.00 411.80	summer
4	Fruits, Pts, and Berries manzanita pits cactus fruit ^c rose hips toyon berry	1.46 .50 2.67 2.92	5.20 0.10 3.14 2.64	82.36 10.90 33.25 27.48	8.40 88.00 59.90 65.30	382.10 42.00 172.00 147.90	summer
5	Leaves, Stems and Stalks cattail flowers (dried) yerba buena leaves willow dock stem	8.94 0.90 1.60	1.41 — 0.61	74.85 31.05 8.95	10.50 64.50 87.80	347.90 128.0 47.73	spring
6	Toxic Nuts/Pits wild cherry pit acorn (raw) black oak acorn, leached/cooked	5.25 4.02 2.25	3.65 9.98 17.80	70.82 39.15 25.15	18.20 46.00 54.70	337.20 262.20 269.80	late summer, fall
7	Non-toxic Nuts stone pine nut ^d gray pine nut ^d	31.10 25.00	47.40 49.40	11.60 17.50	5.60 3.60	552.00 574.00	fall
8	Aquatic Roots/Rhizomes cattail rhizome	0.45	0.28	3.25	93.78	17.40	spring, fall

Notes: data compiled from Gilliland 1985, except: ^aSimms 1985, 1987; ^bRepo-Carrasco-Valencia and Serna 2011; ^cWatt and Merrill 1975; ^dFarris 1993.

category that have been analyzed for proximal nutritional content (protein, fat, and carbohydrate). Erlandson (1988:103) noted that for the Chumash and other coastal peoples who consume large quantities of protein-rich but calorie-limited resources such as shellfish, the energy gleaned from carbohydrates are especially important in fueling metabolism and preventing protein poisoning. As with Wohlgemuth's (2010) ranking scheme based on caloric return rates, we suggest that geophytes are ranked highest when considering carbohydrate content as well. The values presented in Table 1 were based on analysis of raw brodiaea corms, which have a high moisture content (~63%). The actual carbohydrate value of cooked corms may be higher, an idea that warrants further testing. Combined with their phenomenal abundance on the

islands, low processing costs, and year-round availability, we argue that geophytes, and brodiaea-type corms in particular, were the highest ranked plant food.

Macrobotanical evidence for kelps and seaweeds has not yet been reported from the islands, but their nearshore abundance, nutritional composition, and availability year round suggest that they may have been an important food source (Gill 2015). Small seeds are ranked third, as they are rich in carbohydrates and fats, can be harvested in large quantities (Anderson 2005), have relatively minimal processing costs, and can be stored easily. While manzanita berry pits contain more carbohydrates per 100 g. than small seeds, they (and other fruits) are less well represented in the archaeobotanical record, which may be a product of preservation bias.

Fruits, berries, and manzanita pits would have been seasonally abundant, providing carbohydrates and important vitamins and minerals with minimal processing costs. Leaves, stems, flowers, and stalks (i.e., “greens”) do not preserve well, but were potentially important sources of carbohydrates, vitamins, and minerals.

We suggest that toxic nuts, including acorns and wild cherry pits, be ranked above non-toxic nuts (pine nuts and black walnut) because they contain much higher proportions of carbohydrates, in spite of the high processing costs (i.e., leaching) involved. Acorns and wild cherries are seasonally abundant on the larger islands, and their remains have been identified frequently in archaeobotanical assemblages, albeit in very low densities (see below). The locally available small-seeded Bishop pine nut appears not to have been used much (if at all) on the islands, likely due to the difficulties involved in extracting seeds from the seritinous cones (Gill 2015). Large-seeded pine nuts are occasionally identified in the island assemblages, and may have come from the Torrey pines on Santa Rosa Island or mainland pines (e.g., pinyon, gray), but were apparently not a significant part of the diet. As noted earlier, black walnut has also been occasionally identified in island assemblages (Martin and Popper 2001; Thakar 2014), but the costs associated with transporting them across the channel would have been significant. Aquatic roots/rhizomes are ranked last, and while they are not well represented in the macrobotanical assemblages, starch grain analysis may be an important avenue of future research to document the extent of their use.

Although ranking plant foods on broad scales is useful to archaeologists, important factors like plant community distributions and seasonal scheduling are also important. Many plant foods are available only during a certain time of year, and the seasonal round should be considered within the generalized ranking scheme. Greens are most abundant in the spring, but some (e.g., the young shoots of brodiaea and cattail) are also available in the fall. Small seeds, fruits, and berries generally ripen in the summer, except for the winter-ripening toyon. Wild cherry pits are available in the late summer/fall, and acorns and pine nuts are available only in the fall. Brodiaea corms and kelps/seaweeds are largely available for collection throughout the year. Rankings may have changed seasonally when certain important plant foods were available, but general

rankings are important to contextualize patterns seen in archaeobotanical data for various plant types.

ISLAND ARCHAEOBOTANICAL DATA

Island scholars have long suggested that interior sites may have been desirable because of their proximity to terrestrial plant resources (e.g., Glassow 1993; Kennett 2005; Perry and Delaney-Rivera 2011; Perry and Glassow 2015), but few have used paleoethnobotanical data to support these ideas until recently (see Gill 2014, 2015; Hoppa 2014; Martin 2010; Martin and Popper 2001; Thakar 2014). Paleoethnobotanical research on the Channel Islands began as early as the late 1960s (see Orr 1968), but the earliest researchers generally did not collect or present data in a form that can be used for comparative analysis with more recent studies (e.g., screened versus floated material). As we discuss in more detail below, there also continue to be differences in how paleoethnobotanists standardize and report data, making quantitative comparisons between extant datasets difficult at this time.

Our discussion includes currently available data recovered—using modern flotation methods and reported in a way comparable to other studies (see Fig. 1; Table 2)—from one site on San Miguel Island (Reddy and Erlandson 2012) and twenty-two sites on Santa Cruz Island (Gill 2015; Glassow et al. 2008; Gusick 2012; Hoppa 2014; Martin and Popper 1999, 2001; Thakar 2014). All these studies employed flotation to recover the majority of plant remains, but Gill (2015) and Reddy and Erlandson (2012) analyzed only the light fractions recovered using bucket flotation, which has a higher rate of recovery than the unmodified Flot-Tech machine used by others, who sorted both fractions. Additional qualitative paleoethnobotanical data are available from the northern Channel Islands except Anacapa, but they come from screened material and are not comparable to macrobotanical remains recovered from flotation samples.

In discussing archaeological data, the distinction between the Early and Late Early periods follows Gill (2015), and the Middle and Late Middle Period distinction follows Thakar (2014), as these two studies provide the most comprehensive archaeobotanical data available for these periods. We also include Transitional and Historic period samples with those dating to the

Table 2
SOIL VOLUMES AND NUMBER OF SAMPLES BY SITE ANALYZED FOR ARCHAEOBOTANICAL REMAINS

Site	Total Soil Volume (L)	# Samples	Cultural Periods with Years cal B.P.					
			PC >7,500	Early 7,500–3,500	Late Early 3,500–2,500	Middle 2,500–1,350	Late Middle 1,350–950	Late <950
			<i>Soil Volume and (# of samples) for each period</i>					
SCRI-109 ^a	38	3	38(3)					
SCRI-109 ^b	90	12		90(12)				
SCRI-174 ^c	16	4		16(4)				
SCRI-183 ^c	20	5		20(5)				
SCRI-191 ^d	13	7				13(7)		
SCRI-192 ^d	28	13						28(13)
SCRI-194 ^c	20	5		20(5)				
SCRI-236 ^e	354	8			81(2)	217(4)	56(2)	
SCRI-240 ^d	3	1						3(1)
SCRI-330 ^d	40	10						40(10)
SCRI-393 ^f	8	4		8(4)				
SCRI-427 ^b	6	1		6(1)				
SCRI-474 ^d	14	5				14(5)		
SCRI-547 ^a	22	1	22(1)					
SCRI-549 ^a	39	2	39(2)					
SCRI-568 ^g	225	6			76(2)	74(2)	75(2)	
SCRI-691 ^a	34	4	34(4)					
SCRI-724 ^c	20	5		20(5)				
SCRI-798 ^a	46	2	46(2)					
SCRI-813 ^g	15	4						15(4)
SCRI-823 ^g	200	5			40(1)	28(1)	132(3)	
SCRI-619/620 ^g	140	36		64(15)	40(13)	4(1)		32(7)
SMI-261 ^h	92	13	56(7)	19(3)	17(3)			
Total	1,483	156	235(19)	263(54)	254(21)	350(20)	263(5)	119(37)

^aGusick 2012; ^bMartin and Popper 1999; ^cHoppa 2014; ^dMartin and Popper 2001; ^eThakar 2014; ^fGraesch and Arnold 2003; ^gGill 2015; ^hReddy and Erlandson 2012.

Late Period, as the 2-sigma date ranges often overlap and there are fewer samples with available archaeobotanical data from these shorter periods (Martin and Popper 2001). During our data analysis, we found that plotting plant food densities from the Transitional and Historic Period samples separately from the Late Period did not significantly alter the general trends through time for each taxon. As additional data become available, we should be able to better define plant use during the Transitional and Historic periods.

Despite differences in site location, the total soil volumes for each time period are relatively

comparable, with the Late Period having the least amount of soil analyzed (see Table 2). Transportation is a serious limiting factor in soil sample volumes on the islands, as many areas are not accessible by vehicle, necessitating transportation of all samples by foot. This is particularly true for the mountainous interiors of Santa Cruz Island and on San Miguel, where there are no vehicles. In addition to sampling size, preservation issues are also important to consider when interpreting archaeobotanical data. Wohlgemuth (1996:85) suggested that the remains of robust taxa processed with fire (e.g., gray pine and bay nut) generally preserve well in central

California, while remains of smaller seeds accidentally lost during cleaning or parching may be less well preserved. However, many island sites show excellent preservation of carbonized macrobotanical remains, particularly because burrowing animals are absent. As a result, carbonized island plant remains are less subject to the mechanical breakage caused by gopher burrowing that is common in mainland soils. Other taphonomic issues, such as soil pH, soil type, argilliturbation, and exposure to the elements, can differentially affect preservation at sites, particularly those that were only ephemerally occupied (Braadbaart et al. 2009; Glassow et al. 1988; Hoppa 2014).

San Miguel Island

Reddy and Erlandson (2012) reported the recovery of numerous (and ubiquitous) brodiaea corm fragments (totaling 3.71 g.) from various strata that span the Paleocoastal to Late Early Period at Daisy Cave (CA-SMI-261). Small seeds, including bedstraw (*Galium* spp.) and goosefoot (*Chenopodium* spp.) were also recovered. A second site on the western end of San Miguel (CA-SMI-522), dated to approximately 10,000 cal B.P., also produced botanical remains, including brodiaea corms, wild cherry (*Prunus* sp.), gooseberry (*Ribes* spp.), and an unidentifiable seed fragment (Gill 2015). These remains were recovered from screened (1/8-inch) samples of charcoal, and are not comparable to flotation samples. Future analysis of flotation samples from this site would be valuable.

Santa Cruz Island

Ten of the 22 Santa Cruz Island sites from which paleoethnobotanical data are available are located adjacent to the modern coastline (CA-SCRI-109, -191, -192, -236, -240, -330, -474, -547, -549, -798), and three (CA-SCRI-427, -724, -823) are pericoastal sites located within 400 meters of the coast (Thakar 2014). Nine sites are in the island interior (CA-SCRI-174, -183, -194, -393, -568, -619/620 [Diablo Valdez], -691, -813, -814), over 400 meters from the coast (Perry and Glassow 2015) and without direct coastal access due to elevation or high sea cliffs. Sites dating to the Paleocoastal Period (SCRI-109, -547, -549, -798, -691) are considered interior even if they are located on the coast today, as sea levels were much lower when the sites were occupied (Erlandson 2015).

The 22 sites represent all cultural periods, but none were occupied during all time periods. The Paleocoastal samples from Daisy Cave (CA-SMI-261) have excellent preservation, but the five Paleocoastal sites on Santa Cruz Island have very low densities of plant remains, likely reflecting poor preservation rather than a lack of plant food exploitation. Occupation at these exposed sites may have been more seasonal in nature (Gusick 2012), resulting in more ephemeral deposits vulnerable to aeolian processes. As additional paleoethnobotanical work is conducted on sites of this age, plant use during the Paleocoastal Period will be better documented. For now, sites dating to later time periods have much higher plant densities (see Gill 2015; Thakar 2014).

ISLAND PLANT USE THROUGH TIME

In the analysis below, we include data from 143 flotation samples from 21 sites on Santa Cruz Island, representing a total of 1,391 liters of floated soil, as well as 13 samples from one site on San Miguel Island with a total of 92 liters of floated soil. One site (SCRI-814) was excluded from the analysis due to stratigraphic mixing that obscured the time period represented (see Gill 2015). Brodiaea corms are the most ubiquitous remains present, occurring in 67% of the samples from all time periods. Small seeds occur in 62% of the samples, and are generally dominated by grasses and cheno-ams. Greens (e.g., *Phacelia*, sea purslane) occur in 41% of the samples, manzanita in 36%, toxic nuts and pits (e.g., acorn and *islay*) occur in 26% of samples, and fruits such as toyon and prickly pear occur in 10% of samples. These ubiquity values are higher if we remove sites at which few to no plant food remains were recovered. At the sites with the largest samples (Gill 2015; Thakar 2014), brodiaea corms are the most frequently identified taxon, with ubiquity values ranging between 90% and 100%.

For comparisons between sites, we use soil volume to standardize the data by count (n)/liter or weight (g.)/liter. We used soil volume rather than standardized measures (ratios to total plant or wood charcoal weight), because soil volume was the only measure consistently reported by various researchers. Numeric counts are the most meaningful measurement for small seeds, but weights are more representative measures for items likely to fragment, including nutshells and geophytes.

Unfortunately, we were unable to directly compare all samples using the same measure (n/L vs. g/L) for nutshell and geophyte densities through time. Martin and Popper (2001) only reported weight densities for geophytes and nutshell, for instance, while Thakar (2014) only reported count densities for these remains. Ideally, paleoethnobotanists working on the islands and elsewhere in California should report counts and weights alongside soil volumes for each sample.

We present box plots for various taxa, illustrating the median value of a distribution for each set of data (represented by the center horizontal mark), as well as the 25th and 75th percentiles of the distribution (represented by the lower and upper edges of the box). Differences are statistically significant at the 0.05 level when there is no overlap between the notched portions (95% confidence interval) of the boxes (McGill et al. 1978; Wilkinson et al. 1992). When comparing counts by category (e.g., small seeds, geophytes), we use the total count density per sample for each plant food category. For geophytes, we compare count densities (n/L) of data reported by all studies except Martin and Popper (2001), then compare weight densities (g/L) of data reported by all studies except Thakar (2014).

We explored patterns in the data, including and excluding features, to determine whether feature data significantly skewed the overall pattern. Except where noted, features are included as they did not skew the patterns but contain important subsistence data. Non-toxic nuts were not included in this independent assessment of various taxa, as they have not yet been recovered with high enough frequency on the islands to compare in a statistically meaningful way (see also Gill 2015). Generally, the most comprehensive data sets include plant remains from the Early (Gill 2015), Late Early (Gill 2015; Thakar 2014), Middle (Martin and Popper 2001; Thakar 2014), Late Middle (Thakar 2014), and Late Periods (Gill 2015; Martin and Popper 2001). At this time, a comprehensive comparison of differences in plant use based on site location on an island-wide scale is not very meaningful, as the majority of available paleoethnobotanical data come from two studies with sites dating primarily to different time periods (Gill 2015; Thakar 2014).

Geophytes

As previously mentioned, count densities are not the best measure for remains that fragment easily, such as

geophytes and nuts/nutshell. The degree of fragmentation cannot accurately be estimated, as it could be affected by a variety of taphonomic factors and/or processing techniques. Nevertheless, both count and weight densities are shown for geophytes (Fig. 3), using as many datasets as possible. Data from Gill (2015) are included in both measures, as both counts and weights were reported and can be compared with the other data separately. While there are several different edible geophytes that occur on the islands, brodiaea-type corms are the only geophyte remains identified archaeologically on the islands, sometimes occurring in great abundance (Gill 2014, 2015; Martin and Popper 2001; Reddy and Erlandson 2012; Thakar 2014). While count densities for geophytes should be interpreted with caution, there is no significant difference in brodiaea corm count densities for any time period, from the Paleocoastal through the Late periods. A comparison of weight densities for geophytes also shows no significant change through 10,000 years, suggesting that geophytes were a staple food source for the Island Chumash, and one that appears to have been stable throughout the Holocene (see also Gill 2015).

Small Seeds and Greens

Count densities are most meaningful for small seeds and greens, as the whole or nearly whole seed is recovered. The “greens” category includes plant foods where the leaves, stems, or stalks were primarily eaten, even though the seed was the only plant part recovered archaeologically. The “small seeds” category includes those taxa with an edible small seed, even if the greens were also eaten.

Like geophytes, small seeds are found throughout the 10,000-year island sequence. Small seed densities are significantly lower in Paleocoastal sites compared with later time periods, but this pattern may be partly explained by preservation and/or seasonality issues (Fig. 4). Some Paleocoastal sites exhibit excellent preservation, but many of the Santa Cruz Island sites of this time period appear to have been more briefly occupied (Gusick 2012), with few small seeds recovered. The seeds of cheno-ams and grasses dominate the Early and Late Early periods, with remaining taxa composing generally less than 35% of the assemblage. During the Middle Period small seeds appear more diverse, with red maids composing the majority of the small

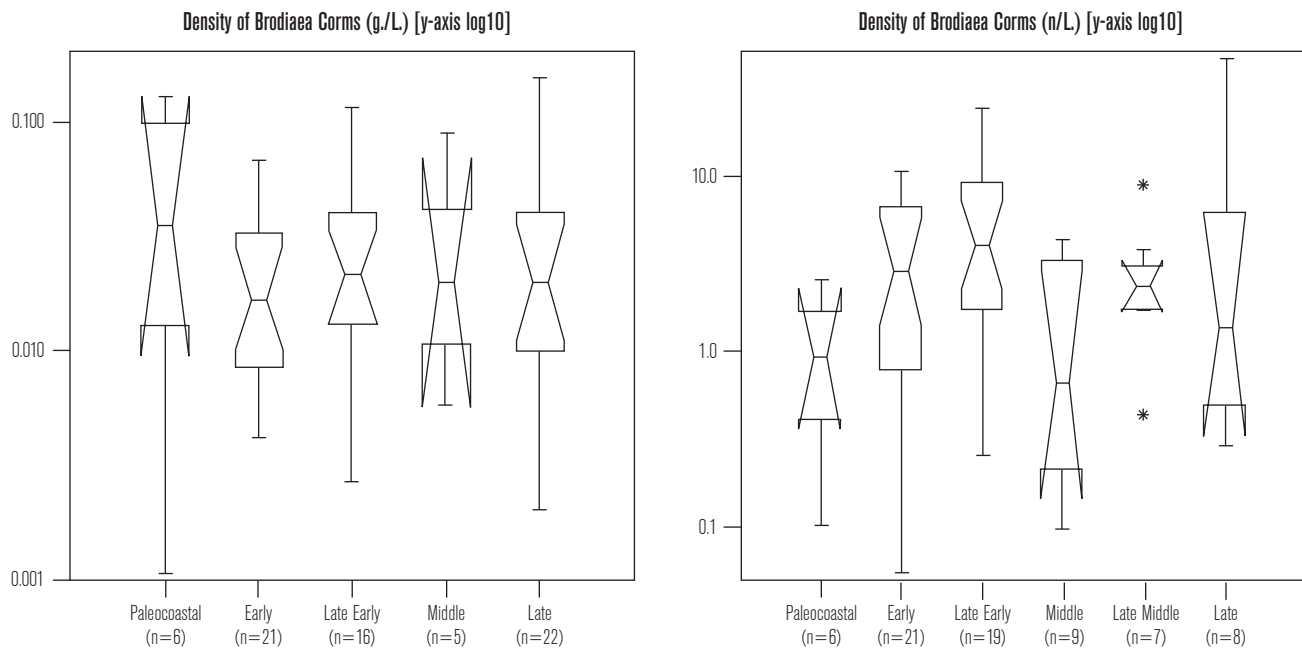


Figure 3. Brodiaea corm densities in Northern Channel Island assemblages through time.

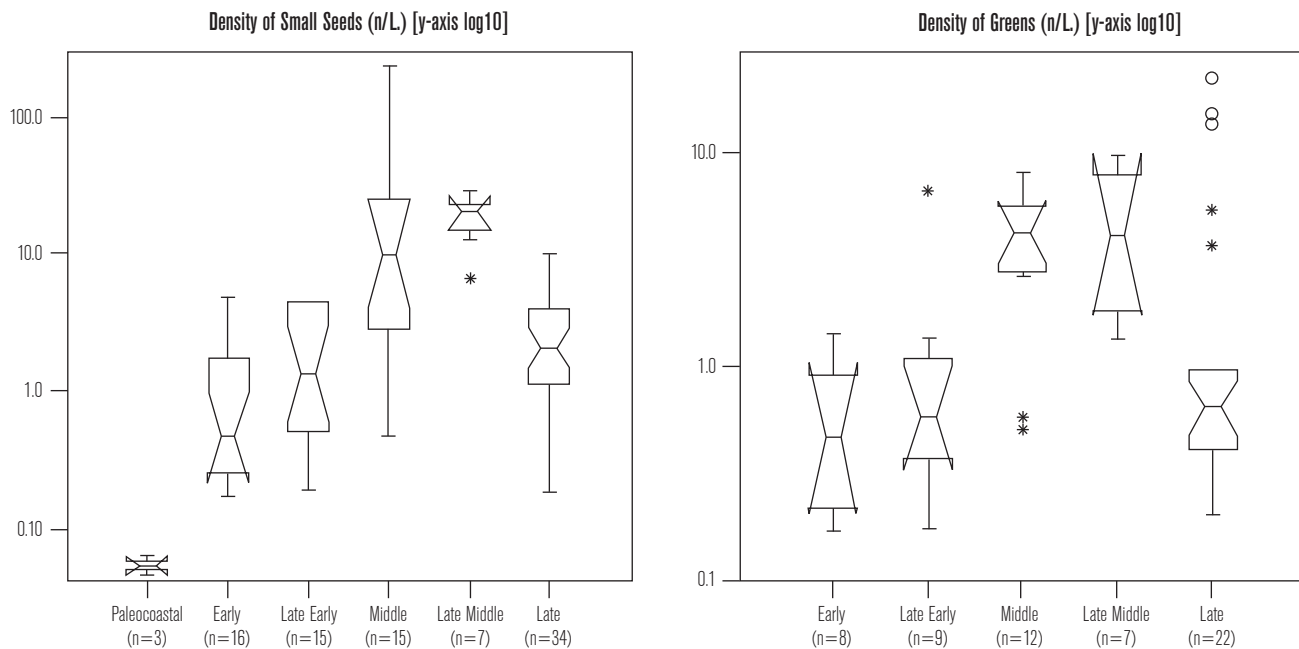


Figure 4. Small seeds and greens densities in Northern Channel Islands assemblages through time.

seeds, followed by cheno-ams, grasses, and tarweed. Grasses dominate the Late Middle Period seed samples, followed by red maids and seeds of the bean family. A significant increase in the densities of small seeds

and greens is apparent in the Middle and Late Middle periods compared with earlier or later time periods. In the Late Period, grasses continue to dominate the small seed category, but there is an increase in the relative

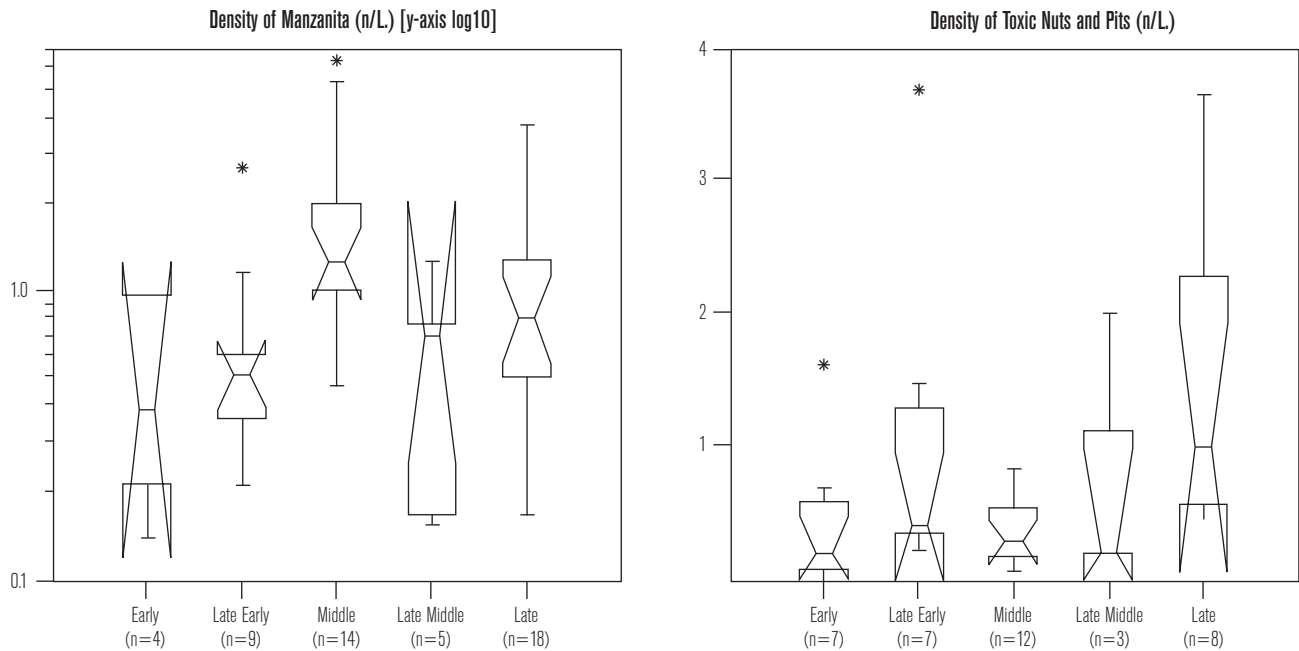


Figure 5. Manzanita berry pits and toxic nuts/pits densities in Northern Channel Island assemblages through time.

proportion of *Phacelia* (23%) and western sea purslane (13%) seeds, both of which were eaten primarily as greens. The densities of small seeds and greens in Late Period deposits are statistically similar to those seen in the Early and Late Early periods.

As the majority of Middle and Late Middle Period paleoethnobotanical data are reported by Thakar (2014) from coastal sites, with earlier and later time periods better represented at the upland village site of Diablo Valdez (SCRI-619/620, see Gill 2015), it is unclear at this time whether the increase in small seed densities and diversity seen here during the Middle Period is temporal or spatial in nature. These changes are interesting, but more data from sites located in coastal vs. interior settings, and dating to various time periods, are needed to evaluate how meaningful these patterns are.

Fruits, Berries, and Non-Toxic Pits

The remains of fruits are found less frequently on the islands than some other plant food remains, probably due to preservation bias. Nevertheless, manzanita berry pits dominate this category, whereas other non-toxic pits and fruits (i.e., lemonade berry, cactus, and elderberry) were recovered less frequently. The much higher carbohydrate

content of manzanita pits (~82%) compared with those of other taxa in this category may explain the focus on manzanita berry pits on the islands (Fig. 5). Although none have been reported from Paleocoastal deposits, manzanita is well represented in all later time periods. There is a significant increase in manzanita from the Late Early to the Middle periods, but no significant difference between any other periods. As with the small seeds category, it is unclear whether the increase in manzanita from the Late Early to the Middle Period is temporal or spatial in nature. Manzanita berry pits are the only remains where feature data made a significant difference in the range of data. A Late Period hearth-clearing pit feature at the Diablo Valdez site had a density of 25 pits per liter, compared with the other 50 samples containing manzanita where the highest density was 6.3 pits per liter.

Toxic Nuts and Pits

Toxic nuts and pits involve those taxa that require processing to remove toxins (tannic or hydrocyanic acids) prior to consumption. On the islands, this category includes acorns and wild cherry (*islay*) pits. Acorn nutshell occurs relatively frequently in island assemblages, but only in very low densities (Gill 2015;

Gill and Erlandson 2014; Thakar 2014). Wild cherry pits are typically found less frequently than acorn, but have been identified at several sites from various time periods. While count densities for easily fragmented nutshell are not the best unit of measure, toxic nuts/pits were not recovered in enough samples that reported weights to compare weight densities. Wild cherry and acorn have been recovered from the 10,000-year-old Paleocoastal site CA-SMI-522, but these screen-recovered specimens are not directly comparable to others derived from flotation samples. There is no significant change in toxic nuts/pits densities during the past 7,500 years (Fig. 5).

DISCUSSION

Island Plant Foods Through Time

Brodiaea corms represent the single most ubiquitous plant food taxon identified archaeologically on the northern Channel Islands, with corms sometimes occurring in very high densities (Gill 2013, 2015). The aggregated plant data presented here show no statistically significant change in brodiaea corm densities on the islands for nearly 10,000 years, from the Paleocoastal Period through the Late/Historic periods. This long-term pattern of consistent brodiaea corm use points to a stable geophyte resource base that persisted on the islands throughout the Holocene. Although their densities are much lower than brodiaea corms, toxic nuts (acorn and *islay*) also show a pattern of no significant change from the Early to the Late periods, suggesting that this food source was also relatively stable through time.

On the other hand, statistically significant increases are evident in the densities of small seeds, greens, and manzanita berry pits during the Middle or Late Middle periods. These apparent increases are countered by a significant decrease in the Late Period, largely statistically similar to earlier time periods for each category. Taxa from each of these categories are generally well represented in island plant assemblages, and it is possible that these changes indicate a real shift in the way plant foods were used, processed, and deposited in island sites. However, the majority of data from the Middle and Late Middle periods come from coastal or pericoastal sites (Thakar 2014), while the majority of data from earlier and later time periods come from interior/upland

sites (Gill 2015), with some Late Period coastal data as well (Martin and Popper 2001). Therefore, caution is warranted when interpreting these apparent changes through time, especially in relation to changes in diet breadth. The disparities in the location of sites occupied during various time periods may be a more significant factor affecting densities through time. Alternatively, if there was a real shift in plant use during the Middle and Late Middle periods, it is clear that not all plant food categories were included (i.e., geophytes and toxic nuts/pits). Additional archaeobotanical data are needed from a wider range of sites that represent various time periods and coastal vs. interior settings.

While density measures were the only quantifiable measure that could be compared in our aggregated plant data (due to differential data reporting issues), other standardized measures (e.g., ratios) are important and should be considered in future analyses. Gill (2015) documented no statistically significant change in the use of various plant foods (i.e., brodiaea, small seeds, manzanita, acorn) for nearly 6,000 years at Diablo Valdez, when the data were analyzed using quantitative measures of diversity and density, and were standardized by total plant weight.

As archaeobotanical data continue to accumulate from various island contexts, we will also be better able to evaluate and test the island plant food ranking scheme presented here, using carbohydrate content as the primary currency. For now, the ubiquity, abundance, and long-term stability of brodiaea geophyte remains for the last 10,000 years on the northern Channel Islands attests to their high rank among island plant foods. The focus on other plant foods rich in carbohydrates, such as the seeds of grasses and cheno-ams, manzanita berry pits, *islay*, and acorns is also evident in the archaeobotanical data summarized here. Although direct macrobotanical evidence for the use of marine algae (kelps and seaweeds) as food has not yet been reported from the islands, they may also have been an important source of carbohydrates and other key nutrients. Because the presence of seaweeds in island sites has been inferred from shellfish data (see Ainis et al. 2014), and they were widely eaten by Pacific Coast peoples, we tentatively suggest that marine algae were highly ranked among “plant” foods.

Notably, plant foods high in calories (fats) but low in carbohydrates (i.e., pine nuts) are largely absent from

the island assemblages, despite their local availability to island foragers and their documented importance elsewhere in California (Farris 1993; Wohlgemuth 2004). In the current aggregated assemblage, we have no direct evidence for the use of the small-seeded Bishop pine that is abundant on Santa Cruz Island today. Large-seeded and/or thick-shelled pine nuts have been reported in very low frequencies from three sites on Santa Cruz Island: SCRI-191 (Martin and Popper 2001), Diablo Valdez (Gill 2015), and SCRI-333 on the western end (Gamble 2013). These larger pine nuts could have come from the Torrey pines on Santa Rosa Island or various pines on the adjacent mainland. Future archaeobotanical research on Santa Rosa Island may clarify this pattern further, but it currently appears that pine nuts were not a significant part of the Islander diet.

Island Diet, Groundstone, and Sexual Division of Labor

In addition to documenting prehistoric diet and plant resource ranking, paleoethnobotanical remains are also the material evidence of subsistence labor. The focus of the Island Chumash and their ancestors on brodiaea geophytes as a staple food source beginning at least 10,000 years ago has been documented here. The island artifact assemblage also supports a focus on geophyte resources. Since milling technology is not required to process geophytes, a geophyte-based subsistence regime explains the lack of the Millingstone Horizon on the islands. We also find no discernable association between a change in plant use and the appearance of mortar and pestle technology in the region around 6,000 years ago. Rather, mortar and pestle technology may indicate a broader increase in processing various other resources (see Jones 1996).

As previously discussed, digging stick weights are especially prevalent on the northern islands (Sutton 2014). Olson (1930) found that digging stick weights accompanied up to 28% of the burials he excavated on Santa Cruz Island (Gill 2015; Sutton 2014; Walker and Erlandson 1986:380). In an analysis of dental caries on human teeth from burials on Santa Rosa Island, Walker and Erlandson (1986) found that caries are more prevalent during the Early Period, likely due to a heavy dependence on plant foods rich in carbohydrates. They argued that higher caries rates among females may indicate a sexual division of labor in which women, who

primarily gathered plants, consumed more of these foods than men who specialized in hunting and fishing.

Archaeologists often associate plant procurement, processing, and archaeobotanical remains with women and a sexual division of labor, but we hesitate to correlate evidence of plant use solely with women's work. Such associations may be valid in certain areas and/or time periods, but they are based largely on ethnographic patterns that may not apply to earlier time periods. Ethnohistoric accounts for the Santa Barbara Channel indicate that men and women used digging sticks to harvest brodiaea corms (Gill 2015; Hudson and Blackburn 1979). Hollimon's analysis of mortuary goods from Santa Cruz Island burials found "no strong pattern of differentiation between the artifacts associated with males and females during any prehistoric period. Males were just as often buried with groundstone tools and basketry impressions as were females" (Holliman 1990:120–121). Digging stick weights were associated with both male (60.9%) and female (39.1%) burials. Sutton (2014:37–38) also noted that digging stick weights were buried with children, who may have played a significant role in procuring plant foods on the islands. The evidence suggests that on the islands, men, women, and children were involved in gathering geophytes and likely other plant resources as well (see Gill 2015).

Mainland Plants in Island Sites:

Dietary Necessity or Luxury Goods?

Distinguishing between mainland versus island-derived archaeobotanical remains is inherently difficult as the effects of overgrazing resulted in the extirpation of an unknown number of island taxa (see Gill 2015). Some taxa that may have come from the mainland have been encountered in a few island assemblages, despite the high transportation costs associated with crossing the channel (see Fauvelle 2013). For instance, black walnut nutshell has been identified at two sites on Santa Cruz Island (SCRI-191, -823; Martin and Popper 2001; Thakar 2014), and California wax myrtle (used as a cooking spice) was identified in Late Period deposits at Diablo Valdez (Gill 2015). These taxa are found only on the mainland today, and because they are long-lived trees, would not easily have been extirpated from the islands in the historic era. Given the abundance of geophytes, other edible plants, and marine algae on the Channel Islands,

it seems increasingly unlikely that mainland plant foods were imported to the islands out of dietary or subsistence necessity, even during periods of environmental stress. Island archaeobotanical assemblages show that these mainland plants do not appear to have been particularly important, nor do they appear to significantly increase in frequency later in time. Rather, they occasionally may have been imported as luxury goods that added to the diversity of the plant-food base available locally to the Islanders (see Gill 2015).

CONCLUSIONS

Our analysis demonstrates that there is a long history of terrestrial plant use on the northern Channel Islands. The importance of geophytes to island subsistence is now well documented, with no significant changes in use for at least 10,000 years. Acorns and other toxic nuts/pits occur in very low densities throughout the sequence, showing little or no significant change over the past 7,500 years. An increase in the densities of small seeds, greens, and manzanita berry pits has been identified during the Middle and Late Middle periods compared with earlier or later in time, but this pattern is limited to a few coastal or pericoastal villages on western Santa Cruz and requires additional testing.

The geophyte-based island subsistence regime discussed here (see also Gill 2015) appears to be different than the subsistence regime on the adjacent mainland, where acorns and other nut resources appear to have been more important (see Hammett 1991; Hildebrandt 2004; Wohlgemuth 2004, 2010). In light of the archaeobotanical evidence for a focus on geophytes over the last 10,000 years, it should no longer be surprising that the Millingstone Horizon is not represented in island assemblages. Why this tradition was so widespread on the mainland remains to be seen, and the hypothesis that Millingstone assemblages indicate a focus on small-seed processing needs to be tested using archaeobotanical data. The argument that the appearance of mortar and pestle technology around 6,000 years ago in the Channel region signaled a shift in subsistence towards acorn intensification is not supported by island archaeobotanical data. Instead, mortar and pestles were probably used for a wide range of plant and animal resources, and may signal an increase in general food processing (Jones 1996).

Our analysis of island archaeobotanical data points to a terrestrial resource base that was far more productive and stable than previously considered. Supplementary plant data from multicomponent sites dating to later time periods and situated in various locales (interior/coastal, upland/lowland) on all the islands will be crucial to answering more nuanced questions about spatial and temporal variations in island plant use. Microbotanical (phytoliths, starch, etc.) research will also be key for identifying plant remains not well represented in the macrobotanical record and for determining the function of groundstone tools on the islands. While these broad patterns will continue to become better refined through additional research, they offer an intriguing baseline for plant use on California's northern Channel Islands. A geophyte-based subsistence regime provided the Island Chumash and their ancestors with an easily procured and abundant supply of carbohydrates that complemented a diet rich in marine fats and proteins.

ACKNOWLEDGEMENTS

We thank the guest editors, Seetha Reddy and Eric Wohlgemuth, for organizing this special issue, as well as senior editor Bill Hildebrandt. We also thank Jon Erlandson for various thoughtful discussions that helped solidify and clarify many of the ideas presented in this paper. Gary Brown, Jon Erlandson, Amber VanDerwarker, and an anonymous reviewer also provided feedback that strengthened the paper significantly. Finally, we thank the Nature Conservancy, the UC Natural Reserve System, and the National Park Service for supporting ongoing research.

REFERENCES

- Ainis, Amira F., René L. Vellanoweth, Queeny G. Lapeña, and Carol S. Thornber
2014 Using non-dietary gastropods in coastal shell middens to infer kelp and seagrass harvesting and paleoenvironmental conditions. *Journal of Archaeological Science* 49:343–360.
- Anderson, M. Kat
2005 *Tending the Wild: Native American Knowledge and Management of California's Natural Resources*. Berkeley: University of California Press.
- Anderson, M. Kat, and David L. Rowney
1999 The Edible Plant *Dichelostemma capitatum*: Its Vegetative Reproduction Response to Different Indigenous Harvesting Regimes in California. *Restoration Ecology* 7(3):231–240.

- Arnold, Jeanne E.
1987 *Craft Specialization on the Prehistoric Channel Islands, California*. Berkeley: University of California Press.
- 1992 Complex Hunter-Gatherer-Fishers of Prehistoric California: Chiefs, Specialists, and Maritime Adaptations of the Channel Islands. *American Antiquity* 57(1):60–84.
- 2001 Social Evolution and the Political Economy in the Northern Channel Islands. In *The Origins of a Pacific Coast Chiefdom: The Chumash of the Channel Islands*, Jeanne E. Arnold, ed., pp. 287–296. Salt Lake City: University of Utah Press.
- Arnold, Jeanne E., and Julianne Bernard
2005 Negotiating the Coasts: Status and the Evolution of Boat Technology in California. *World Archaeology* 37:109–131.
- Arnold, Jeanne E., and Lana S. Martin
2014 Botanical Evidence of Paleodietary and Environmental Change: Drought on the Channel Islands, California. *American Antiquity* 79(2):227–248.
- Baguskas, Sara A., Seth H. Peterson, Bodo Bookhagen, and Christopher J. Still
2014 Evaluating spatial patterns of drought-induced tree mortality in a coastal California pine forest. *Forest Ecology and Management* 315:43–53.
- Braadbaart, F., I. Poole, and A. A. van Brussel
2009 Preservation Potential of Charcoal in Alkaline Environments: An Experimental Approach and Implications for the Archaeological Record. *Journal of Archaeological Science* 36:1672–1679.
- Clark, Jorie, Jerry X. Mitrovica, and Jay Alder
2014 Coastal Paleogeography of the California-Oregon-Washington and Bering Sea Continental Shelves during the latest Pleistocene and Holocene: Implications for the Archaeological Record. *Journal of Archaeological Science* 52:12–23.
- Conlee, Cristina A.
2000 Intensified Middle Period Ground Stone Production on San Miguel Island. *Journal of California and Great Basin Anthropology* 22(2):374–391.
- Courchamp, Franck, Jean-Louis Chapuis, and Michel Pascal
2003 Mammal Invaders on Islands: Impact, Control and Control Impact. *Biological Review* 78(3):347–383.
- Erlandson, Jon
1988 *Of Millingstones and Molluscs: The Cultural Ecology of Early Holocene Hunter Gatherers on the California Coast*. Ph.D. dissertation, University of California, Santa Barbara.
- 1994 *Early Hunter Gatherers of the California Coast*. New York: Plenum Press.
- 2015 Coastal versus Interior: Some Thoughts on the Archaeology of California's Channel Islands. *Journal of Island and Coastal Archaeology* 10(3)
- Erlandson, Jon M., Michael H. Graham, Bruce J. Bourque, Debra Corbett, James A. Estes, and Robert S. Steneck
2007 The Kelp Highway Hypothesis: Marine Ecology, The Coastal Migration Theory, and the Peopling of the Americas. *Journal of Island and Coastal Archaeology* 2(2):161–174.
- Erlandson, Jon M., Torben C. Rick, and Curt Peterson
2005 A Geoarchaeological Chronology of Holocene Dune Building on San Miguel Island, California. *The Holocene* 15(8):1227–1235.
- Erlandson, Jon M., Torben C. Rick, Todd J. Braje, Molly Casperson, Brendan Culleton, Brian Fulfroost, Tracy Garcia, Daniel A. Guthrie, Nicholas Jew, Douglas J. Kennett, Madonna L. Moss, Leslie Reeder, Craig Skinner, Jack Watts, and Lauren Willis
2011 Paleoindian Seafaring, Maritime Technologies, and Coastal Foraging on California's Channel Islands. *Science* 331(6021):1181–1185.
- Erlandson, Jon M., Todd J. Braje, Kristina M. Gill, and Michael H. Graham
2015 Ecology of the Kelp Highway: Did Marine Resources Facilitate Human Dispersal from Northeast Asia to the Americas? *Journal of Island and Coastal Archaeology* 10(3):392–411.
- Farris, Glenn
1993 Quality Food: The Quest for Pine Nuts in Northern California. In *Before the Wilderness: Environmental Management by Native Californians*, Thomas C. Blackburn and Kat Anderson, eds., pp. 229–240. Menlo Park, California: Ballena Press.
- Fauvelle, Mikael
2013 Evaluating Cross-Channel Exchange in the Santa Barbara Region: Experimental Data on Acorn Processing and Transport. *American Antiquity* 78(4):790–798.
- Fischer, Douglas T., and Christopher J. Still
2007 Evaluating patterns of fog water deposition and isotopic composition on the California Channel Islands. *Water Resources Research* 43:1–13.
- Fitzgerald, Richard T., and Terry L. Jones
1999 The Milling Stone Horizon Revisited: New Perspectives from Northern and Central California. *Journal of California and Great Basin Anthropology* 21(1):67–93.
- Gamble, Lynn H.
2002 Archaeological Evidence for the Origin of the Plank Canoe in North America. *American Antiquity* 67(2):310–315.
- 2005 Culture and climate: reconsidering the effect of paleoclimatic variability among Southern California hunter-gatherer societies. *World Archaeology* 37(1):92–108.
- 2008 *The Chumash World at European Contact: Power, Trade, and Feasting Among Complex Hunter-Gatherers*. Berkeley: University of California Press.

- 2013 New Perspectives on Social Structure of the Middle Holocene in the Santa Barbara Channel Region: A View from El Montón on Western Santa Cruz Island. Paper read at the SAA 78th annual meeting in Honolulu.
- Gamble, Lynn H., and Chester King
 1997 Middle Holocene Adaptations in the Santa Monica Mountains. In *Archaeology of the California Coast During the Middle Holocene*, Jon M. Erlandson and Michael A. Glassow, eds., pp. 61–72. [*Perspectives in California Archaeology, Volume 4.*] Los Angeles: Cotsen Institute of Archaeology, University of California, Los Angeles.
- Gill, Kristina M.
 2013 Paleoethnobotanical Investigations on the Channel Islands: Current Directions and Theoretical Considerations. In *California's Channel Islands: The Archaeology of Human-Environment Interactions*, Jennifer E. Perry and Christopher W. Jazwa, eds., pp. 113–136. Salt Lake City: University of Utah Press.
- 2014 Seasons of Change: Using Seasonal Morphological Changes in Brodiaea Corms to Determine Season of Harvest from Archaeobotanical Remains. *American Antiquity* 79(4):638–654.
- 2015 *Ancient Plant Use and the Importance of Geophytes among the Island Chumash of Santa Cruz Island, California*. Ph.D. dissertation, University of California, Santa Barbara.
- Gill, Kristina M., and Jon M. Erlandson
 2014 The Island Chumash and Exchange in the Santa Barbara Channel Region. *American Antiquity* 79(3):570–572.
- Gilliland, Linda E.
 1985 *Proximate Analysis and Mineral Composition of Traditional California Native American Foods*. Master's thesis, Department of Nutrition Science, University of California, Davis.
- Glassow, Michael A.
 1993 Changes in Subsistence on Marine Resources through 7000 Years of Prehistory on Santa Cruz Island. In *Archaeology on the Northern Channel Islands of California*, Michael A. Glassow, ed., pp. 75–94. Salinas, Cal.: Coyote Press.
- 1996 The Significance to California Prehistory of the Earliest Mortars and Pestles. *Pacific Coast Archaeological Society* 32(4):14–26.
- 2015 Chronology of Red Abalone Middens on Santa Cruz Island, California, and Evidence for Subsistence and Settlement Change. *American Antiquity* 80(4):745–759.
- Glassow, Michael A., Larry R. Wilcoxon, and Jon M. Erlandson
 1988 Cultural and Environmental Change During the Early Period of Santa Barbara Channel Prehistory. In *The Archaeology of Prehistoric Coastlines*, Geoff Bailey and John Parkinson, eds., pp. 64–77. Cambridge: Cambridge University Press.
- Glassow, Michael A., Lynn H. Gamble, Jennifer E. Perry, and Glenn S. Russell
 2007 Prehistory of the Northern California Bight and the Adjacent Transverse Ranges. In *California Prehistory: Colonization, Culture, and Complexity*, Terry L. Jones and Kathryn A. Klar, eds., pp. 191–213. Lanham, Maryland: AltaMira Press.
- Glassow, Michael A., Jennifer E. Perry, and Peter Paige
 2008 *The Punta Arena Site: Early and Middle Holocene Development on Santa Cruz Island*. [*Santa Barbara Museum of Natural History Contributions in Archaeology.*] Santa Barbara, California: Santa Barbara Museum of Natural History.
- Glassow, Michael A., Todd J. Braje, Julia G. Costello, Jon M. Erlandson, John R. Johnson, Don P. Morris, Jennifer E. Perry, and Torben C. Rick
 2010 *Channel Islands National Park Archaeological Overview and Assessment*. Channel Islands National Park, Department of Interior.
- Graesch, Anthony P., and Jeanne E. Arnold
 2003 *Small Scale Testing at SCRI-393: An Early Period Ridgetop Site*. Report on file at Channel Islands National Park, Ventura, California.
- Gusick, Amy G.
 2012 *Behavioral Adaptations and Mobility of Early Holocene Hunter-Gatherers, Santa Cruz Island, California*. Ph.D. dissertation, University of California, Santa Barbara.
- Hammett, Julia E.
 1991 *Ecology of Sedentary Societies Without Agriculture: Paleoethnobotanical Indicators from Native California*. Ph.D. dissertation, University of North Carolina, Chapel Hill. Ann Arbor: University Microfilms.
- Hildebrandt, William R.
 2004 *Xonxon'ata, in the Tall Oaks: Archaeology and Ethnohistory of a Chumash Village in the Santa Ynez Valley*. [*Santa Barbara Museum of Natural History Contributions in Anthropology* 2.] Santa Barbara, California.
- Hollimon, Sandra E.
 1990 *Division of Labor and Gender Roles in Santa Barbara Channel Area Prehistory*. Ph.D. dissertation, University of California, Santa Barbara.
- Hoppa, Kristin M.
 2014 Island Interiors and Terrestrial Resources: Floral Data from Middle Holocene Sites on Santa Cruz Island. In *Papers from the 8th California Islands Symposium, 23–26 October 2012, Ventura, California*. Provo, Utah: Monte L. Bean Live Sciences Museum, Brigham Young University Press.
- Hudson, Travis, and Thomas Blackburn
 1979 *The Material Culture of the Chumash Interaction Sphere. Volume I: Food Procurement and Transportation*. Santa Barbara, California: Ballena Press and Santa Barbara Museum of Natural History.

- 1983 *The Material Culture of the Chumash Interaction Sphere. Volume II: Food Preparation and Shelter*. Santa Barbara, California: Ballena Press and Santa Barbara Museum of Natural History.
- Johnson, John R.
2001 Ethnohistoric Reflections of Cruzeño Chumash Society. In *Origins of a Pacific Coast Chieftdom: The Chumash of the Channel Islands*, Jeanne E. Arnold, ed., pp. 53–70. Salt Lake City: University of Utah Press.
- Johnson, John R., Thomas W. Stafford, Henry O. Ajie, and Don P. Morris
2002 Arlington Springs Revisited. In *Proceedings of the 5th California Islands Symposium*, D. Browne, K. Mitchell, and H. Chaney, eds., pp. 541–545. Santa Barbara: Santa Barbara Museum of Natural History.
- Jones, Terry L.
1996 Mortars, Pestles, and Division of Labor in Prehistoric California: A View from Big Sur. *American Antiquity* 6:243–264.
- Jones, Terry L., Gary M. Brown, L. Mark Raab, Janet L. McVickar, W. Geoffrey Spaulding, Douglas J. Kennett, Andrew York, and Phillip L. Walker
1999 Environmental Imperatives Reconsidered: Demographic Crises in Western North America During the Medieval Climatic Anomaly. *Current Anthropology* 40(2):137–170.
- Junak, Steve, Tina Ayers, Randy Scott, Dieter Wilken, and David Young
1995 *A Flora of Santa Cruz Island*. Santa Barbara, California: Santa Barbara Museum of Natural History.
- Kelly, Robert L.
1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Washington D.C.: Smithsonian Institution Press.
- Kennett, Douglas J.
2005 *The Island Chumash: Behavioral Ecology of a Maritime Society*. Berkeley: University of California Press.
- Kennett, Douglas J., and James P. Kennett
2000 Competitive and Cooperative Responses to Climate Instability in Coastal Southern California. *American Antiquity* 65(2):379–395.
- King, Chester
1976 Chumash Intervillage Economic Exchange. In *Native Californians: A Theoretical Retrospective*, Lowell J. Bean and Thomas C. Blackburn, eds., pp. 289–318. Ramona: Ballena Press.
- 1990 *Evolution of Chumash Society: A Comparative Study of Artifacts Used for Social System Maintenance in the Santa Barbara Channel Region Before A.D. 1804*. New York: Garland Publishing.
- Manuwal, Thad, and Rick Sweitzer
2010 Browse Impacts of Introduced Mule Deer to Island Scrub Oak Habitats on Santa Catalina Island, California. In *Oak Ecosystem Restoration on Santa Catalina Island, California: Proceedings of an On-Island Workshop, February 2–4, 2007*, Denise A. Knapp, ed. Avalon, California: Catalina Island Conservancy.
- Martin, Lana S.
2010 *Reconstructing Paleoenvironmental Instability and Plant Resource Availability on Santa Cruz Island using Macrobotanical Analysis*. Master's thesis, Department of Anthropology, University of California, Los Angeles.
- Martin, S., and Virginia Popper
1999 *Macrobotanical Analysis of Flotation Light Fractions from CA-SCRI-109 and -427, Santa Cruz Island, Santa Barbara County, California*. Report on file at the Department of Anthropology, University of California, Santa Barbara.
- 2001 Paleoethnobotanical Investigations of Archaeological Sites on Santa Cruz Island. In *The Origins of a Pacific Coast Chieftdom: The Chumash of the Channel Islands*, Jeanne E. Arnold, ed., pp. 245–259. Salt Lake City: University of Utah Press.
- McGill, Robert, John W. Tukey, and Wayne A. Larsen
1978 Variations of Box Plots. *The American Statistician* 32(1):12–16.
- Moody, Aaron
2000 Analysis of Plant Species Diversity with Respect to Island Characteristics on the Channel Islands, California. *Journal of Biogeography* 27(3):711–723.
- Munns, Ann M., and Jeanne E. Arnold
2002 Late Holocene Santa Cruz Island: Patterns of Continuity and Change. In *Catalysts to Complexity: Late Holocene Societies of the California Coast*, Jon M. Erlandson and Terry L. Jones, eds. [*Perspectives in California Archaeology* 4.] Los Angeles: Cotsen Institute of Archaeology, University of California, Los Angeles.
- National Park Service
2015 *Channel Islands Timeline*. Electronic document, <http://www.nps.gov/chis/learn/historyculture/upload/Park-Timeline-2012v.pdf>
- Olson, Ronald L.
1930 Chumash Prehistory. *University of California Publications in American Archaeology and Ethnology* 28(1). Berkeley.
- Orr, Phil C.
1968 *Prehistory of Santa Rosa Island*, Santa Barbara, California: Santa Barbara Museum of Natural History.
- Perry, Jennifer E., and Colleen Delaney-Rivera
2011 Interactions and Interiors of the Coastal Chumash. Perspectives from Santa Cruz Island and the Oxnard Plain. *California Archaeology* 3(1):103–125.

- Perry, Jennifer E., and Michael A. Glassow
2015 Prehistoric Settlement in Island Interiors: Evidence From California's Santa Cruz Island. *Journal of Island and Coastal Archaeology* 10(2):184–206.
- Philbrick, Ralph N., and J. Robert Haller
1977 The Southern California Islands. In *Terrestrial Vegetation of California*, Jack Major and Michael G. Barbour, eds., pp. 893–906. New York: Wiley.
- Proctor, John, and Kenneth Whitten
1971 A Population of the Valley Pocket Gopher (*Thomomys bottae*) on a Serpentine Soil. *American Midland Naturalist* 85(2):517–521.
- Raab, L. Mark, and Daniel O. Larson
1997 Medieval Climatic Anomaly and Punctuated Cultural Evolution in Coastal Southern California. *American Antiquity* 62:319–336.
- Reddy, Seetha N., and Jon M. Erlandson
2012 Macrobotanical Food Remains from a Trans-Holocene Sequence at Daisy Cave (CA-SMI-261), San Miguel Island, California. *Journal of Archaeological Science* 39(1):33–40.
- Reeder-Myers, Leslie, Jon M. Erlandson, Daniel R. Muhs, and Torben C. Rick
2015 Sea level, paleogeography, and archaeology on California's Northern Channel Islands. *Quaternary Research* 83(2):263–272.
- Repo-Carrasco-Valencia, Ritva A. M., and Leslie A. Serna
2011 Quinoa (*Chenopodium quinoa*, Willd.) as a source of dietary fiber and other functional components. *Ciência e Tecnologia de Alimentos, Campinas* 31(1):225–230.
- Rick, Torben C., Jon M. Erlandson, and René L. Vellanoweth
2001 Paleocoastal Marine Fishing on the Pacific Coast of the Americas: Perspectives from Daisy Cave, California. *American Antiquity* 66(4):595–613.
- Rick, Torben C., Jon M. Erlandson, Nicholas P. Jew, and Leslie A. Reeder-Myers
2013 Archaeological Survey, Paleogeography, and the Search for Late Pleistocene Paleocoastal Peoples of Santa Rosa Island, California. *Journal of Field Archaeology* 38(4):324–331.
- Rogers, David Banks
1929 *Prehistoric Man of the Santa Barbara Coast*. Santa Barbara: Santa Barbara Museum of Natural History.
- Rozaire, Charles
1965 *Archaeological Investigations on San Miguel Island*. Report on file at National Park Service, Western Region, San Francisco.
- Schneider, Joan S., and Richard H. Osborne
1996 A Model for the Production of Portable Stone Mortars and Bowls. *Pacific Coast Archaeological Society Quarterly* 32(4):27–40.
- Simms, Steven R.
1985 Acquisition Cost and Nutritional Data on Great Basin Resources. *Journal of California and Great Basin Anthropology* 7(1):117–126.
1987 Behavioral Ecology and Hunter-Gatherer Foraging: An example from the Great Basin. *BAR International Series* 381. Oxford.
- Sutton, Elizabeth A.
2014 Digging Stick Weights and Doughnut Stones: An Analysis of Perforated Stones from the Santa Barbara Channel Region. *Journal of California and Great Basin Anthropology* 34(1):17–42.
- Thakar, Heather B.
2014 *Risk Reducing Subsistence Strategies and Population Growth, A Case Study from Santa Cruz Island*. Ph.D. dissertation, University of California, Santa Barbara.
- The Nature Conservancy
2014 *Santa Cruz Island, California*. Electronic document, <http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/placesweprotect/santa-cruz-island-california.xml>, accessed November 26, 2014.
- Timbrook, Janice
1993 Island Chumash Ethnobotany. In *Archaeology on the Northern Channel Islands*, M. A. Glassow, ed., pp. 47–62. Salinas, California: Coyote Press.
2007 *Chumash Ethnobotany: Plant Knowledge Among the Chumash People of Southern California*. Santa Barbara and Berkeley: Santa Barbara Museum of Natural History and Heyday Books.
- Todt, Donn L.
1997 Cross-Cultural Folk Classifications of Ethnobotanically Important Geophytes in Southern Oregon and Northern California. *Journal of California and Great Basin Anthropology* 19(2):250–259.
- Vincent, Anne S.
2011 Plant Foods in Savanna Environments: A Preliminary Report of Tubers Eaten by the Hadza of Northern Tanzania. *World Archaeology* 17(2):131–148.
- Walker, Phillip L., and Jon Erlandson
1986 Dental Evidence for Prehistoric Dietary Change on the Northern Channel Islands. *American Antiquity* 51(2):375–83.
- Wallace, William
1955 A Suggested Chronology for Southern California Coast Archaeology. *Southwestern Journal of Anthropology* 11:214–230.
- Watt, Bernice K., and Annabel L. Merrill
1975 *Composition of Foods: Raw, Processed, Prepared*. Agriculture Handbook No. 8, Consumer and Food Economics Institute, Agricultural Research Service. United States Department of Agriculture, Washington D.C.

Wilkinson, Leland, M. A. Hill, J. P. Welna, and
G. K. Birkenbeuel

1992 *SYSTAT for Windows: Statistics, version 5*. Evanston,
IL.: SYSTAT, Inc.

Wlodarski, Robert J.

1979 Catalina Island Soapstone Manufacture. *Journal of
California and Great Basin Anthropology* 1(2):331–355.

Wohlgemuth, Eric

1996 Resource Intensification in Prehistoric Central
California: Evidence from Archaeobotanical Data.
Journal of California and Great Basin Anthropology
18(1):81–103.

2004 *The Course of Plant Food Intensification in Native
Central California*. Ph.D. dissertation, University of
California, Davis.

2010 Plant Resource Structure and the Prehistory of Plant
Use in Central Alta California. *California Archaeology*
2(1):57–76.



