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Foraging Ancient Landscapes: Seasonal and Spatial Variation in Prehistoric Exploitation of Plant and Animal Food Resources on Santa Cruz Island, California

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In recent years, paleoethnobotanical research on the Northern Channel Islands of California has challenged long-held assumptions regarding the nature of aboriginal patterns of plant exploitation and helped refine our understanding of prehistoric Chumash subsistence economies. Yet little effort has been made to systematically integrate paleoethnobotanical analyses and datasets with normative subsistence studies, which tend to focus on the abundant (and highly visible) shellfish remains that dominate archaeological assemblages on the Northern Channel Islands. I contend that understanding how the Island Chumash moved about and exploited prehistoric landscapes requires analysis of all subsistence remains—marine and terrestrial, faunal and floral—from multiple sites, site types, and stratigraphic contexts. In this article, I integrate chronological control on century and seasonal timescales with the analysis of well-preserved macrobotanical and faunal assemblages from multiple locations on Santa Cruz Island. These data reveal that variation over relatively short temporal and spatial scales structured foraging decisions and produced persistent and identifiable patterns in the archaeological record. In this analysis, reconstruction of seasonal and spatial variation in quantity and array of primary plant and animal food resources exploited contributes to effective assessment of land use and mobility.

In recent years, burgeoning paleoethnobotanical research on the Northern Channel Islands of California has challenged long-held assumptions regarding the nature of aboriginal patterns of plant exploitation and helped refine our understanding of prehistoric Chumash subsistence economies. Notable efforts from Santa Cruz Island contribute greatly to our understanding of paleodietary shifts in response to climatic fluctuations (Arnold and Martin 2014), intensification in the exploitation of plant foods (Thakar 2015), optimal foraging resource rankings (Gill 2013), seasonality (Gill and Erlandson 2014), and the use of interior site locations (Hoppa 2014). These studies (among others) indicate that how the prehistoric Chumash moved about and exploited the island landscape was intimately, and inextricably, tied to the distribution and availability of key plant-food resources. Indeed, such assertions have long been made in the complete absence of supporting paleoethnobotanical data (e.g., Kennett 2005:153; Kennett et al. 2007:362). Yet little effort has been made to systematically integrate paleoethnobotanical analyses and datasets with normative subsistence studies, which tend to focus on the abundant (and highly visible) shellfish remains that dominate archaeological assemblages on the Northern Channel Islands. I contend that systematic study of macrobotanical remains and an integration of all subsistence datasets can contribute significantly to our understanding of prehistoric patterns of land use.

Variations in the abundance and distribution of both terrestrial and marine resources on Santa Cruz Island shaped prehistoric Chumash foraging behaviors (Kennett 2005:58). Santa Cruz Island boasts over 480 native plant taxa, with the richest flora of all the Channel Islands (Junak et al. 1997:2; Schoenherr et al. 1999:295). The distribution and abundance of these species is equally varied; differences in elevation, slope exposure, soil, rainfall patterns, temperature, wind exposure, sun exposure, and proximity to the coast structure unique vegetation communities (Schoenherr et al. 1999:293;

Smith 1998:17). Roughly ten principal plant communities occur on Santa Cruz Island: coastal strand, coastal bluff scrub, coastal marsh, grassland, coastal sage scrub, island chaparral, riparian, island woodland, southern oak woodland, and closed-pine forest, each offering a distinctive combination of useful plants within relatively short distances of one another (Junak et al. 1995; Smith 1998). Although Santa Cruz Island is the largest and most ecologically diverse of the four Northern Channel Islands, animal food resources available to the prehistoric inhabitants were distributed unevenly across the land and were temporally variable in abundance. High primary productivity, due to nutrient-rich upwelling along the coastline, allows for rich and diverse marine resources. Shellfish occur in highly productive beds, sea mammals haul out individually and in groups, and many fish are abundant within discrete nearshore marine habitats (Kennett 2005:29). These coastal habitats provide an assortment of protein-dense resources, often located away from plant communities that provide seasonally high carbohydrate rewards. The relative contributions of these different food resources depended on their relative abundance, distribution, and accessibility throughout the year (Kennett 2005:38). Understanding how the Island Chumash moved about and exploited prehistoric landscapes requires analysis of all subsistence remains—marine and terrestrial, faunal and floral—from multiple sites, site types, and stratigraphic contexts.

In this article, I integrate previously published chronological data (see Thakar 2014a) with a novel exploration of seasonal and spatial variation in well-preserved macrobotanical and faunal assemblages from three locations on Santa Cruz Island. I argue that variation over relatively short temporal and spatial scales structured foraging decisions and produced persistent and identifiable patterns in the archaeological record. In this analysis, reconstruction of seasonal and spatial variations in the quantity and array of primary plant and animal food resources exploited contributes to an effective assessment of land use and mobility. A nuanced understanding of how the Island Chumash moved about and exploited the ancient landscape is integral to contextualizing wider social and political developments that occurred in coastal California during the Late Holocene.

The Late Holocene represents a period of demographic, cultural, and economic development for the Chumash of the Santa Barbara Channel region of California. A significant population increase (Glassow 1999:56; Kennett et al. 2009:310) parallels the development of new maritime technologies (Arnold 2007; Gamble 2002; Rick et al. 2002, 2004), craft specialization (Arnold 1992, 2001, 2004), and the emergence of social hierarchies (Winterhalder et al. 2010). Most of these changes occurred between the terminal Early Period, Phase Ez (3,000–2,440 cal. years B.P.), and the Middle Period (2,440–800 cal. years B.P.), in the regional chronology (Kennett 2005:8, 83). Throughout these three temporal phases, clear diachronic trends towards decreased mobility and economic intensification in the exploitation of small oily seeds and small fatty fish are well documented in the archaeological assemblages considered in this study (see Thakar 2014a, 2014b, 2015). However, the array, quantity, and characteristics of plant and animal taxa exploited also demonstrate short-term seasonal and small-scale spatial trends that persisted throughout multiple temporal periods and may obscure diachronic trends if not fully considered in reconstructions of foraging behavior. This paper contributes an assessment of persistent land-use patterns in the western sector of Santa Cruz Island during this time of significant demographic, cultural, and economic development.

ARCHAEOLOGICAL AND ENVIRONMENTAL SETTING

The data considered here are derived from three substantial habitation sites (CA-SCRI-236, CA-SCRI-823, and CA-SCRI-568) within the Cañada Christy watershed in the western sector of Santa Cruz Island, the largest and most ecologically diverse of the four Northern Channel Islands. I refer to these three sites as the Coastal, Pericoastal, and Interior sites, referencing their relative locations—on the coast, one kilometer up the watershed, and three kilometers up the watershed (Fig. 1). The Cañada Christy watershed is the second largest watershed on the island, dropping from an elevation of 1,250 feet westward to the ocean, over a distance of 4.6 miles (7.4 km.), crosscutting all of the major vegetation communities (Junak et al. 1995:3; Schoenherr et al. 1999:288) and facilitating access to the entire spectrum of marine and terrestrial resources (Fig. 2). Within the geographic confines of this watershed,

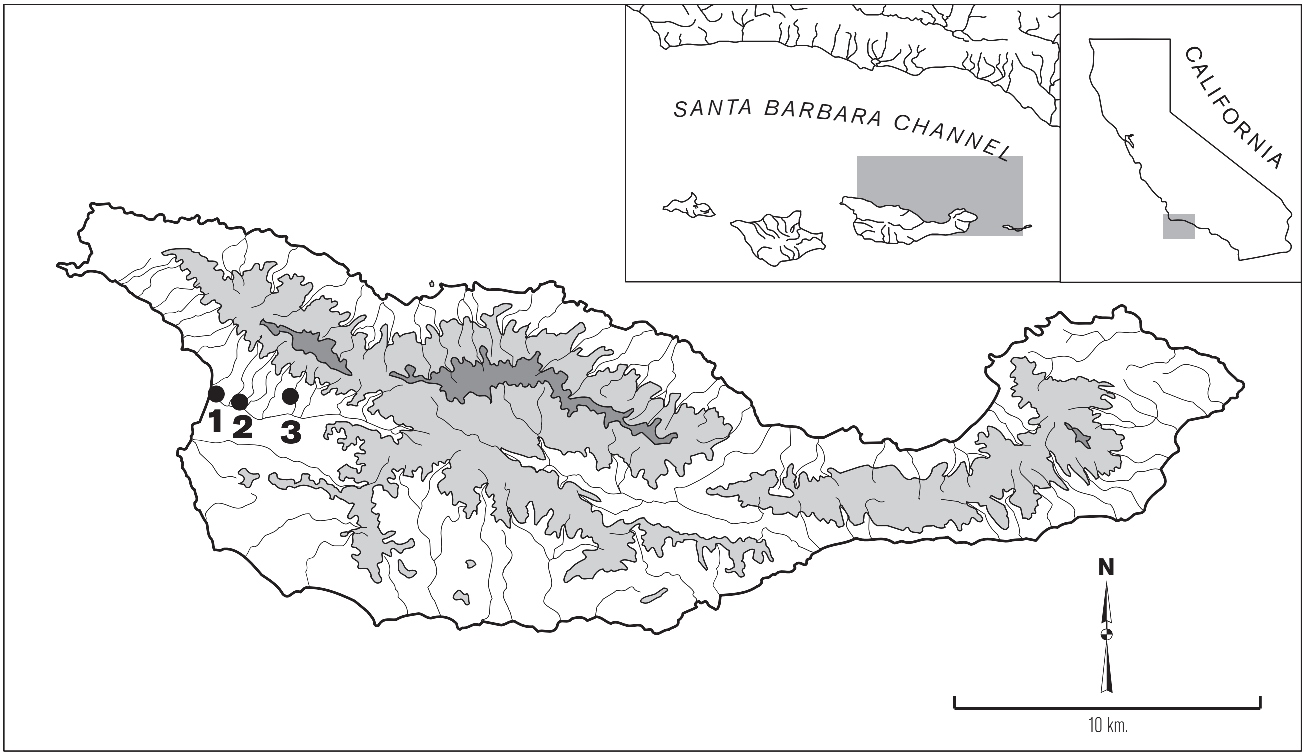

Figure 1. Location of the three archaeological sites considered on Santa Cruz Island, California. Light shading is land above 250 m. and dark shading is above 500 m. elevation. The three archaeological sites considered in this article are: (1) CA-SCRI-236 "Coastal," (2) CA-SCRI-823 "Pericoastal," and (3) CA-SCRI "Interior."

Figure 2. Photograph of Canada Christy watershed looking west from the head of the watershed out towards the ocean. (Photo provided courtesy of Michael Glassow.)

the prehistoric inhabitants of Santa Cruz Island had access to one of the most reliable freshwater sources on the island, plant communities as diverse as pine forest, riparian woodland, and coastal strand, and productive stretches of sandy beach, rocky intertidal reefs, and kelp forest. A recent publication documents three broad periods of contemporaneous site occupation (terminal Early Period, Middle Period, and Late Middle Period) at all three of these site locations between 3,000 cal. B.P. and 1,000 cal. B.P. (Thakar 2014a). Radiocarbon data supporting this interpretation are summarized in Table 1. Analysis of the assemblages presented in this study is limited to the temporal periods represented at all three locations. Sampling from different sites, site types, and environmental contexts makes it possible to link the use of different places on the landscape to one another within an annual context.

CA-SCRI-236 is a large archaeological shell midden long associated with the historic Chumash village of Ch'oloshush (Arnold 2004). Archaeological deposits, including evidence of at least 15 large house depressions and laterally extensive surface deposits, are dispersed over a minimum of 5,400 square meters (Thakar 2014a). Perched along the edge of a large marine terrace, just 50 feet above sea level, this coastal site overlooks an expansive sandy beach with easy access to a diversity of marine resources. The adjacent canyon provides one of the most permanent and reliable water sources on the island, and well-established patches of coastal strand, coastal marsh, coastal bluff scrub, riparian, and grassland vegetation communities that cover the surrounding land provide many useful terrestrial resources (Table 2). This site is ideally situated for the exploitation of a diversity of marine and terrestrial food resources and had secure access to fresh water.

CA-SCRI-823 is another dense shell midden located at the tip of a low-lying ridge (~250 feet above sea level), approximately one kilometer from Christy beach, overlooking the flat marine terraces. This is the smallest of the three sites included in this study; nonetheless, it

Table 1

CONVENTIONAL AMS ^{14}C AND OXCAL CALIBRATED/MODELED DATE RANGES BASED ON SITE-BASED STRATIGRAPHIC SEQUENCE BAYESIAN MODELS FOR CA-SCRI-236, CA-SCRI-823, AND CA-SCRI-568

Site	Excavation Level	NOSAMS Sample ID	Conventional Age (^{14}C B.P.)	ΔR	Modeled 68% range cal B.P.	Modeled 95% range cal B.P.
CA-SCRI-236	Level 15	88165	1,790 ± 25	155 ± 44	1,260 – 1,175	1,289 – 1,114
CA-SCRI-236	Level 16	106998	1,850 ± 25	143 ± 44	1,294 – 1,219	1,330 – 1,171
CA-SCRI-236	Level 17	88166	2,020 ± 35	101 ± 44	1,535 – 1,434	1,580 – 1,375
CA-SCRI-236	Level 19	88167	2,070 ± 25	95 ± 44	1,574 – 1,486	1,618 – 1,431
CA-SCRI-236	Level 20	106999	2,100 ± 25	92 ± 44	1,618 – 1,516	1,689 – 1,479
CA-SCRI-236	Level 21	88168	3,350 ± 30	261 ± 21	2,865 – 2,776	2,911 – 2,751
CA-SCRI-236	Level 22	101029	3,340 ± 25	261 ± 21	2,900 – 2,805	2,943 – 2,773
CA-SCRI-823	Level 3	88155	1,720 ± 25	185 ± 44	1,158 – 1,062	1,194 – 1,003
CA-SCRI-823	Feature 1	88160	1,750 ± 30	170 ± 44	1,180 – 1,096	1,217 – 1,056
CA-SCRI-823	Level 4	88156	1,780 ± 25	164 ± 44	1,219 – 1,129	1,256 – 1,081
CA-SCRI-823	Level 5	88157	1,990 ± 25	115 ± 44	1,500 – 1,375	1,545 – 1,314
CA-SCRI-823	Level 6	88158	3,530 ± 30	261 ± 21	3,155 – 3,025	3,206 – 2,962
CA-SCRI-568	Level 9	88151	1,650 ± 45	210 ± 43	1,060 – 921	1,162 – 876
CA-SCRI-568	Level 10	106996	2,130 ± 25	88 ± 44	1,639 -1,535	1,695 – 1,494
CA-SCRI-568	Level 11	88152	2,130 ± 25	88 ± 44	1,691 – 1,586	1,749 – 1,533
CA-SCRI-568	Level 12	106995	3,640 ± 30	261 ± 21	3,324 – 3,220	3,358 – 3,156
CA-SCRI-568	Level 13	106996	3,770 ± 30	261 ± 21	3,424 – 3,336	3,473 – 3,282

Note: Data summarized from Thakar (2014a: Tables 1–4). AMS dates based on marine shell submitted to National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) at the Woods Hole Oceanographic Institution. Variable ΔR values based on paired organic and planktonic marine foraminiferal carbonate from laminated varves reported by Hendy et al. (2012).

Table 2

SUMMARY OF PREFERRED HABITAT(S) OF ALL PLANT TAXA IDENTIFIED IN THE STUDY ASSEMBLAGE

Taxonomic Name	Common Name	Coastal Strand	Coastal Marsh	Coastal Bluff Scrub	Grassland	Riparian	Coastal Sage Scrub	Island Chaparral	Island Woodland	Southern Oak Woodland	Pine Forest
		Greater Proximity to Coastal site						Greater Proximity to Interior site			
Anacardiaceae *Rhus* spp.	Lemonade/Sugar Berry					X	X	X	X		
Asteraceae	Sunflower Family			X	X		X	X			
Asteraceae *Ambrosia chamissonis*	Beach ragweed	X									
Asteraceae *Artemisia* spp.	Sagebrush						X	X			
Asteraceae *cf. Achillea millefolium*	White Yarrow			X	X			X			
Asteraceae *cf. Helianthus annuus*	Sunflower				X			X			
Asteraceae *cf. Madia* spp.	Coast Tarweed			X	X	X	X				
Asteraceae *Hemizonia* spp.	Common Tarweed				X		X				
cf. Boraginaceae	Borage Family				X						
Boraginaceae *Amsinckia menziesii*	Fiddleneck				X		X				
Boraginaceae *Phaceli*a spp.	Phacelia						X	X	X		
cf. Brassicaceae	Mustard Family	X			X						
Brassicaceae *Lepidium cf. nitidum*	Peppergrass				X						
Cactaceae *Opunti*a spp.	Prickly Pear			X	X		X	X			
Caryophyllaceae *Silene antirrhina*	Sleepy catchfly					X	X	X			
Chenopodiaceae *Atriplex* spp.	Saltbush	X	X	X	X		X				
Chenopodiaceae *Chenopodium berlandieri*	Goosefoot					X	X				
Chenopodiaceae *Chenopodium californicum*	Soaproat				X		X				
Convolvulvaceae *Calystegia* spp.	Morning glory			X	X	X			X		
Curcubitaceae *Marah macrocarpus*	Wild cucumber			X	X		X	X	X		
Cyperaceae *cf. Carex* spp.	Sedge		X					X			X
Cyperaceae *Scirpus* spp.	Bulrush		X			X					
Ericaceae *Arctostaphylo*s spp.	Manzanita							X	X	X	X
cf. Euphorbiaceae	Spurge Family				X		X				
Fabaceae	Legume	X		x	X	X	X	X	X		X
Fabaceae *Astragalus* spp.	Locoweed	X			X		X	X			
Fabaceae *Lathyrus vestitus*	Pacific Pea							X	X		X
Fabaceae *Lotus* spp.	Lotus			x		X	X	X			X
Fabaceae *Lupinu*s spp.	Lupine			x	X	X	X	X	X		
Fabaceae *Pickeringia montana*	Chaparral Pea							X			X
Fabaceae *Trifolium* spp.	Clover				X	X	X				
Fagaceae *Quercus* spp.	Acorn					X		X	X	X	X
Geraniaceae *Geranium carolinianum*	Carolina cranesbill				X						
Iridaceae *Sisyrinchium bellum*	Blue eyed grass				X		X				
Laminaceae *Salvia* spp.	Sage						X				
Laminaceae *Salvia columbariae*	Chia						X				
Lilliaceae *Dichelostemma capitatum*	Blue Dicks				X		X				
Malvaceae *Sidalcea malviflora*	Checker mallow	X			X		X				
Nyctaginaceae *Abronia* spp.	Verbena	X									
Onagraceae *Clarkia* spp.	Farewell to Spring				X	X		X	X		X
cf. Papaveraceae	Poppy Family				X		X	X	X		X
Plantaginaceae *Plantago erecta*	California Plantain				X		X	X			
Poaceae	Grass Family	X			X	X	X	X	X		

Table 2 *(Continued)*

SUMMARY OF PREFERRED HABITAT(S) OF ALL PLANT TAXA IDENTIFIED IN THE STUDY ASSEMBLAGE

Taxonomic Name	Common Name	Coastal Strand	Coastal Marsh	Coastal Bluff Scrub	Grassland	Riparian	Coastal Sage Scrub	Island Chaparral	Island Woodland	Southern Oak Woodland	Pine Forest
		Greater Proximity to Coastal site						Greater Proximity to Interior site			
Poaceae *Bromus carinatus*	Brome grass				X		X				
Poaceae *Hordeum* spp.	Meadow Barley				X		X				
Poaceae *Phalaris caroliana*	Canary grass				X						
Polemoniaceae *Gilia* spp.	Gilia				X	X	X				
Polygonaceae	Buckwheat Family					X	X				
Portulacaceae *Calandrinia ciliata*	Red maids				X		X	X			
Portulacaceae *Claytonia perfoliata*	Miners lettuce						X	X	X	X	
Rhamnaceae *cf. Ceanothus megacarpus*	Ceanothus							X			X
cf. Rosaceae	Rose Family										
Rosaceae *Heteromeles arbutifolia*	Toyon					X	X	X	X	X	X
Rosaceae *Prunus ilicifolia*	Island Cherry					X		X	X		
Rosaceae *Rosa californica*	California Wild Rose					X	X			X	X
Rubiaceae *Galium* spp.	Bedstraw						X	X		X	X
Scrophulariaceae	Figwort Family						X	X			
Salicaceae *Salix* spp.	Willow Family					X					
Solanaceae *Solanum* spp.	Nightshade				X	X	X	X		X	
Solanaceae *Nicotiana clevelandii*	Tobacco	X					X				
Violaceae *Viola pedunculata*	Johnny jump up				X		X				

Note: Table is based on data from Junak et al. 1995, and Schoenherr 1999 (Thakar 2014b: Table 5.2)

contains evidence of significant and recurring occupation over several millennia, with over 2,500 square meters of visible surface deposits. Set back less than 150 meters from the reliable fresh water of Cañada Christy, the prehistoric occupants of this site would have enjoyed secure, easy access to water throughout the year, as well as to abundant annual seeds, greens, and fruits from the surrounding grassland, riparian, coastal sage scrub, and island chaparral vegetation communities (Table 2).

CA-SCRI-568 is a substantial shell midden with a minimum of 10 large discernible house depressions that is located on a prominent knoll approximately three kilometers inland from the coast. Surface deposits are laterally extensive and cover the entire landform (approximately 5,000 square meters), with increased density toward the leeward side. At an elevation of 450 feet above sea level, the prehistoric occupants of this substantial habitation site enjoyed an unobstructed view of the entire watershed, including all primary access points by land or by sea. Set back over 500 meters from the canyon bottom, the closest sources of water were likely small streams in adjacent ravines to the east and to the west. These same ravines support a rich mixture of island chaparral and coastal bluff scrub species, including scattered scrub oak and manzanita (Table 2). The canyon bottom below supports a productive grassland habitat where blue dicks grow in much greater abundance than elsewhere in the watershed. This site appears favorably situated for exploitation of a diversity of terrestrial food resources.

MATERIALS AND METHODS

The paleoethnobotanical, zooarchaeological, and isotopic analyses considered provide a novel assessment of seasonal and spatial patterns in raw datasets reported by Thakar (2014b: Appendices A, B, C). I restrict the present analysis to common food resources for both paleoethnobotanical and zooarchaeological studies. Although an exhaustive discussion of the primary materials and methods is provided in my dissertation (Thakar 2014b:44–90), I summarize briefly basic details relevant to this study of seasonal and spatial variation.

At least one volumetrically-controlled unit was excavated to the full depth of archaeological deposits at CA-SCRI-236 (1 m. × 50 cm.), CA-SCRI-823 (1 m. × 1 m.), and CA-SCRI-568 (1 m. × 1 m.). Excavation levels of variable depths were defined based on visible stratigraphic variation in the composition and density of natural or cultural constituents. We systematically collected 50 cm. × 50 cm. bulk soil samples from each level of excavation in their entirety, without sifting or sorting, for flotation recovery (using a Flote-Tech machine-assisted flotation device) of fragile macrobotanical and small faunal remains in the Collections Processing Laboratory at the University of California, Santa Barbara. Although sample size varied greatly due to variable stratigraphic depths, most flotation samples measured between 30 and 50 liters, with an average of 42 liters. Botanical and faunal remains were pulled from all sizes of both the light and heavy fractions for analysis. The remaining deposits from each excavation level were screened through 1/8-inch mesh on site before they were transported to the Collections Processing Laboratory for analysis.

Paleoethnobotanical Analysis

To ensure maximum efficiency and collection of useful data, we passed the light-fraction sample to be analyzed through a set of geological sieves (2.0 mm., 1.4 mm., 1.0 mm., and 0.5 mm.) to size-fractionate the sample and increase ease of identification. This resulted in five distinct size fractions, including the materials smaller than 0.5 mm. in size, all of which we analyzed separately with the aid of a stereoscopic microscope (10–40X). We removed all charred macrobotanicals from the 2.0 mm. fraction for identification. From the 1.4 mm. fraction, we removed all carbonized non-wood plant material, including nutshell, seeds, and other identifiable plant parts. The remaining 1.4 mm. materials (including wood charcoal) were collected as residue and excluded from further analysis. We pulled all acorn nutshell and seeds (whole and broken fragments) from the 1.0 mm. fraction, with the remaining material left as residue. We scanned 0.5 mm. and the less than 0.5 mm.-sized fractions for identifiable seeds (i.e., whole seeds or large seed fragments with the complete shape more or less intact), which were removed and counted. Once pulled from the heavy fractions, charred macrobotanical remains from these samples were also passed through a set of geological sieves (2.0 mm., 1.4 mm., and 1.0 mm.), sorted, and identified according to the same procedures used to sort plant remains recovered in the light fraction.

Identification of Macrobotanical Remains. I used modern botanical guides to develop a list of native and endemic taxa likely to occur in the recovered macrobotanical assemblages (Munz 1974; Smith 1998); *A Checklist of Vascular Plants of Channel Islands National Park* (Junak et al. 1997) proved particularly useful in this pursuit. I relied on *Chumash Ethnobotany* (Timbrook 2007), *Tending the Wild* (Anderson 2005), and *Ethnobotany of the California Indians* (Mead 2003), among others (Goodrich et al. 1996; Largo et al. 2009; Strike and Roeder 1994; Timbrook 1990; Timbrook et al. 1982) to identify plants of known economic importance to native California peoples. I identified archaeological specimens by reference to modern specimens housed in the Integrative Subsistence Laboratory and the Cheadle Center for Biodiversity and Ecological Restoration, both at the University of California, Santa Barbara. I also relied on published and digital seed identification guides (CalFlora) to identify seeds for which I did not have comparative samples. I examined all plant specimens using a stereoscopic light microscope and identified each specimen to the lowest possible taxonomic level based on morphological comparison to modern reference materials. Most seeds were identified to genus, with some taxa identified to species, based on phytogeography/monospecificity on the Northern Channel Islands.

Methods of Quantification and Analysis. I recorded count, weight (in grams), portion of plants (shell versus seed), and provenience information, with the exception of wood charcoal, which I weighed but did not count. I found most of the seeds identified in the samples too small to yield appreciable weights; consequently, I only recorded counts for many taxa. I counted fragments of seeds and other materials as individual specimens unless I was certain that two fragments fit together (i.e., I had broken the seed myself). These raw data of counts and weights, reported in Thakar (2014b:388–393, Appendix B), provided the basis for all quantitative analyses of the macrobotanical assemblages included in this study. Tables 3 and 4 present summaries of the

Table 3

SUMMARY OF PALEOETHNOBOTANICAL DATA BY SITE, TEMPORAL PERIOD, AND SAMPLE PROVINIENCE

Site	Temporal Period	Excavation Level	Total Soil Volume (liters)	Total Wood WT (grams)	Total Plant WT (grams)	Total Plant Count
Coastal Site (CA-SCRI-236)	TEP	Level 22	34	98.23	98.43	534
		Level 21	47	189.31	190.90	578
	MP	Level 20	49	101.66	104.34	1,714
		Level 19	35	101.67	104.15	10,804
		Level 18	50	181.12	190.85	9,694
		Level 17	83	54.01	58.63	3,317
	LMP	Level 16	26	40.96	41.43	577
		Level 15	30	62.10	62.24	351
Pericoastal Site (CA-SCRI-823)	TEP	Level 6	40	46.00	48.64	2,137
	MP	Level 5	28	58.39	60.58	1,771
	LMP	Level 4	42	40.71	42.71	3,015
		Feature 1	60	66.38	70.58	3,621
		Level 3	30	25.91	30.30	2,779
Interior Site (CA-SCRI-568)	TEP	Level 13	40	24.88	26.30	396
		Level 12	36	32.24	33.14	469
	MP	Level 11	39	17.03	21.28	2,475
		Level 10	35	24.94	26.43	4,627
	LMP	Level 9	38	17.37	18.76	2,056
		Level 8	37	41.68	52.09	3,027

Note: Based on raw datasets available in Thakar 2014b: Appendix B. "TEP", "MP", and "LMP" are used to designate occupation during the Terminal Early Period, Middle Period, and Late Middle Period respectively.

paleoethnobotanical data used here for the quantitative analysis of persistent spatial variation.

In order to standardize the raw data and facilitate comparisons between samples and sites, I considered three primary quantitative measures: plant density, standardized counts (ratios), and ubiquity. Plant density, calculated as the total charred plant weight recovered from each sample divided by the original soil volume of the sample, provides a measure of plant abundance while correcting for comparisons between large and small samples. Standardized plant counts, calculated as the total plant count recovered from each sample divided by the total plant weight recovered from the sample, reveals variation in plant abundance relative to plant-related activities (Miller 1988:75; Pearsall 2000:203). Comparison of these ratios from varied depositional contexts reveals the relative importance of plant resources, thus more accurately reflecting spatial differences in plant use (VanDerwarker 2006:74, 75). Ubiquity values, and ranks thereof, evaluate the frequency of occurrence of individual taxa and provide a rough measure of which taxa routinely find their way into specific spatial contexts. Although ubiquity is not a direct measure of the importance of a plant taxon in a site assemblage or in the diet of the site's inhabitants, it can provide some idea of the relative importance of the taxon (Wright 2010:50).

Zooarchaeological Analysis

Abundant faunal remains recovered (primarily) in the heavy fractions of the flotation samples comprise the principal source of the shellfish, bird, and fish data considered in this analysis. Once separated from all other cultural and non-cultural remains, I sorted and weighed all vertebrate remains recovered by category (e.g., mammal, bird, fish, and unidentified). The animal bone assemblages considered here include all bone specimens larger than 1/8 inch (3.2 mm.) and all identifiable bone elements (e.g., fish vertebrae) larger than 1/16 inch (1.6 mm.) from the flotation samples, as well as mammal bone specimens larger than 1/4 inch (6.4 mm.) from the

Table 4

FREQUENCY (COUNT) OF PRIMARY PLANT TAXA MENTIONED IN TEXT BY SITE, TEMPORAL PERIOD, AND SAMPLE PROVINIENCE

Site	Temporal Period	Excavation Level	Total Soil Volume (liters)	Common Tarweed	Saltbush	Goosefoot	Meadow Barley	Canary grass	Red maids	Phacelia	Bean Family	Pacific Pea	Clover	Checker mallow	Bedstraw	Manzanita	Acorn Nutmeat/shell	Blue Dicks	Wild cucumber
Coastal Site (CA-SCRI-236)	TEP	Level 22	34	–	4	73	–	4	–	–	–	–	24	4	4	–	–	–	36
		Level 21	47	–	–	21	–	7	7	7	30	–	7	–	–	24	18	–	94
	MP	Level 20	49	–	113	31	–	166	129	35	22	–	78	31	–	97	37	50	218
		Level 19	35	1,012	411	3,071	–	214	1,732	24	64	–	72	–	–	43	25	97	534
		Level 18	50	2,807	56	991	–	167	3,198	8	–	–	195	–	37	44	24	8	583
		Level 17	83	11	28	198	–	81	362	151	196	–	77	70	–	112	33	8	182
	LMP	Level 16	26	16	21	2	–	15		23	24	–	–	16	–	4	–	33	20
		Level 15	30	2	85	15	–	4	9	15	12	–	15	4	–	5	–	13	–
Pericoastal Site (CA-SCRI-823)	TEP	Level 6	40	17	40	44	–	92	89	127	38	2	124	–	14	46	12	40	312
	MP	Level 5	28	77	-	123	–	48	127	37	–	4	37	–	34	35	4	12	342
	LMP	Level 4	42	8	-	158	–	226	307	–	8	–	320	37	138	53	–	75	863
		Feature 1	60	28	-	41	10	130	85	21	56	–	–	5	123	39	–	148	310
		Level 3	30	17	2	84	–	137	137	1	18	3	223	38	36	21	–	50	746
Interior Site (CA-SCRI-568)	TEP	Level 13	40	–	–	–	–	–	8	–	–	–	–	–	–	24	44	76	85
		Level 12	36	8	1	–	15	40	53	–	–	1	15	–	8	13	8	23	146
	MP	Level 11	39	33	–	97	14	326	643	–	12	8	54	159	4	247	7	167	213
		Level 10	35	13	–	40	–	280	131	–	59	34	74	114	–	86	–	135	535
	LMP	Level 9	38	15	–	81	15	112	154	–	7	7	47	81	51	29	7	143	147
		Level 8	37	26	45	–	8	93	386	–	41	56	168	–	45	–	74	326	–

Note: Based on raw datasets available in Thakar 2014b, Appendix B. "TEP", "MP", and "LMP" are used to designate occupation during the Terminal Early Period, Middle Period, and Late Middle Period respectively.

screened samples. Although I processed and analyzed flotation and screened samples separately, I aggregate values by excavation level for marine mammals in order to augment representation of this animal class. Table 5 presents a summary of the zooarchaeological vertebrate data used in this study for quantitative analysis of persistent spatial variation. Analysis of the invertebrate assemblage focuses on the abundance and size of California mussel (*Mytilus californianus*) larger than 1/8 inch (3.2 mm.) retained in the heavy fraction of the flotation samples (Table 6).

In the present analysis, I consider two fundamental quantitative units used to describe taxonomic abundances of bony fish, cartilaginous fish, marine mammals, and marine birds: the number of individual specimens (NISP) and bone weight. Raw data reported by Thakar (2014b:394–420, Appendix C), provide the basis for density values used to standardize the data, facilitate comparison between samples, and assess spatial variation between sites. I also consider a series of independent ratios (often referred to as indices in the zooarchaeological literature; see Broughton 1999) to avoid the problem of dependency inherent in relative percentages and to measure changes in the relative abundance of different faunal classes.

Beyond abundance or relative importance of distinct vertebrate categories, I also consider variation in the size of primary animal food resources. Vertebral centra height provides a well-established proxy for size among bony fish taxa (Bertrando and McKenzie 2011; Casteel 1976; Granadeiro and Silva 2000; Pletka 2011; Reitz and Wing 2008). I consider measurements from all complete bony fish vertebral centra (N=2,606) recovered from all size screens >1/16 inch of both the light and heavy fractions.

Table 5

SUMMARY OF ZOOARCHAEOLOGICAL VERTEBRATE CLASS DATA BY SITE, TEMPORAL PERIOD, AND SAMPLE PROVINIENCE

Site	Temporal Period	Excavation Level	Total Soil Volume (liters)	Bird NISP	Bird WT	Marine Mammal NISP	Marine Mammal WT	Cartilaginous Fish NISP	Cartilaginous Fish WT	Bony Fish NISP	Bony Fish WT
Coastal Site (CA-SCRI-236)	TEP	Level 22	34	45	1.92	34	20.30	3	0.47	3,623	106.18
		Level 21	47	23	1.54	48	10.03	8	0.39	1,731	116.03
	MP	Level 20	49	21	12.37	238	92.05	71	4.83	2,728	58.79
		Level 19	35	18	3.81	273	164.41	47	4.14	3,393	74.87
		Level 18	50	16	4.36	301	276.37	52	2.05	4,919	79.14
		Level 17	83	15	2.13	290	140.09	65	10.71	5,030	86.09
	LMP	Level 16	26	7	4.62	130	33.47	30	2.68	2,527	46.74
		Level 15	30	6	1.05	56	96.58	13	5.20	2,551	40.56
Pericoastal Site (CA-SCRI-823)	TEP	Level 6	40	1	0.32	41	50.71	11	3.33	604	24.65
	MP	Level 5	28	5	1.51	13	24.68	19	2.11	1,715	49.34
	LMP	Level 4	42	7	3.66	51	29.16	6	0.90	411	21.09
		Feature 1	60	5	0.75	39	51.74	10	1.28	540	24.44
		Level 3	30	5	3.71	36	21.47	19	10.94	1,069	23.02
Interior Site (CA-SCRI-568)	TEP	Level 13	40	11	9.89	14	10.91	1	2.39	337	9.34
		Level 12	36	2	0.25	25	12.41	2	0.73	151	7.10
	MP	Level 11	39	5	0.32	40	22.49	14	2.73	2,586	17.48
		Level 10	35	3	0.24	27	5.77	13	3.27	1,136	25.59
	LMP	Level 9	38	2	0.40	31	59.65	1	0.01	338	7.86
		Level 8	37	0	0	42	37.23	1	0.30	33	6.30

Note: Based on raw datasets available in Thakar 2014b: Appendix C. NISP and weight (grams) of all birds (>1/8th"), marine mammals (>1/8th"), and fish (>1/16") identified in floated samples. Marine mammal NISP and weight also include specimens (>1/4") recovered from screened samples. "TEP", "MP", and "LMP" are used to designate occupation during the Terminal Early Period, Middle Period, and Late Middle Period respectively.

The anterior adductor scar length in California mussel provides a reliable proxy of mussel valve length (Glassow et al. 2016; Thakar 2014b:87). In this study I consider measurements from mussel umbos (*N*=9,371) greater than 1/8 inch in size for which anterior adductor scars were visible and complete. For all samples, I restricted measurement to either right- or left-sided mussel valves (based on whichever side was used for MNI) in order to reduce the likelihood of duplication.

Oxygen Isotope Analysis

I selected a minimum of 15 whole, or nearly whole, California mussel shells from the floated assemblage from each excavation level included in the paleoethnobotanical and zooarchaeological analyses. To prevent duplication, I chose exclusively left or right valves from a single level assemblage. All the shells selected were well preserved, with intact outer prismatic (calcite) layers and an intact terminal growth margin. Of the shells that met these two basic criteria, I gave preference to those in the middle of their size range in order to minimize the possible effect of slower growth common with senescence in larger and older California mussels (following Glassow et al. 2012).

I prepared the shells selected for analysis following the procedures established by Glassow et al. (1994, 2012). I collected eight calcite samples from the exterior surface of each shell, beginning with the edge of the shell (sample A) and continuing at 2 mm. increments along the growth axis (sample B, C, D, and so on). The first sample (sample A) from the terminal growth margin provides a record of the sea surface temperature (SST) at the time of

Table 6

SUMMARY OF ABUNDANCE (MNI AND WEIGHT IN GRAMS) OF CALIFORNIA MUSSEL (*MYTILUS CALIFORNIAUS*) DATA BY SITE, TEMPORAL PERIOD, AND SAMPLE PROVINIENCE

Site	Temporal Period	Excavation Level	Soil Volume (liters)	Measure	Quantity	Total	Density (Total/Soil Volume)
Coastal Site (CA-SCRI-236)	TEP	Level 22	34	WT	4,491.94	7,659.49	225.28
				MNI	650	878	26
		Level 21	47	WT	8159.66	11420.99	243.00
				MNI	1,597	2,044	43
	MP	Level 20	49	WT	4226.52	4756.18	97.06
				MNI	738	779	16
		Level 19	35	WT	5436.80	5974.18	170.69
				MNI	1,206	1,260	36
		Level 18	50	WT	7,679.49	8,846.59	176.93
				MNI	1,204	1,300	26
		Level 17	83	WT	6,253.36	7,447.69	89.73
				MNI	1216	1216	15
	LMP	Level 16	26	WT	2,807.50	3,067.87	118.00
				MNI	512	568	22
		Level 15	30	WT	2,004.60	2,579.37	85.98
				MNI	353	395	13
Pericoastal Site (CA-SCRI-823)	TEP	Level 6	40	WT	3,303.60	3,701.67	92.54
				MNI	628	659	16
	MP	Level 5	28	WT	4,469.18	5,112.47	182.59
				MNI	887	941	34
	LMP	Level 4	42	WT	4,685.31	5,197.74	123.76
				MNI	925	968	23
		Feature 1	60	WT	9,181.23	16,154.58	269.24
				MNI	1,914	2,098	35
		Level 3	30	WT	4,057.04	4,924.20	164.14
				MNI	807	850	28
Interior Site (CA-SCRI-568)	TEP	Level 13	34	WT	8,124.92	8,745.99	257.24
				MNI	1,581	1,618	48
		Level 12	47	WT	6,074.22	6,402.22	136.21
				MNI	1,184	1,304	28
	MP	Level 11	49	WT	9,740.27	9,939.77	202.85
				MNI	1,373	1,386	28
		Level 10	35	WT	7,449.19	7,723.10	220.66
				MNI	1,280	1,298	37
	LMP	Level 9	50	WT	3,201.45	3,499.89	70.00
				MNI	520	550	11
		Level 8	83	WT	1,348.36	1,519.34	18.31
				MNI	243	397	5

Note: Based on raw datasets available in Thakar 2014a: Appendix C. "TEP", "MP", and "LMP" are used to designate occupation during the Terminal Early Period, Middle Period, and Late Middle Period respectively.

harvest, and the remaining seven samples contextualize this value, providing an extended view of SST variation prior to the time of harvest. Due to budget constraints, six to eight seasonality estimates for each excavation level rely on these 8-sample extended profiles (Fig. 3). An additional seven to nine estimates for each excavation level are based on the value of the terminal growth margin (sample A) in the context of one additional sample (sample B) and in reference to the extended profiles of other shells from the same excavation level. This sampling program provides 15 seasonality estimates for each excavation level (Fig. 3).

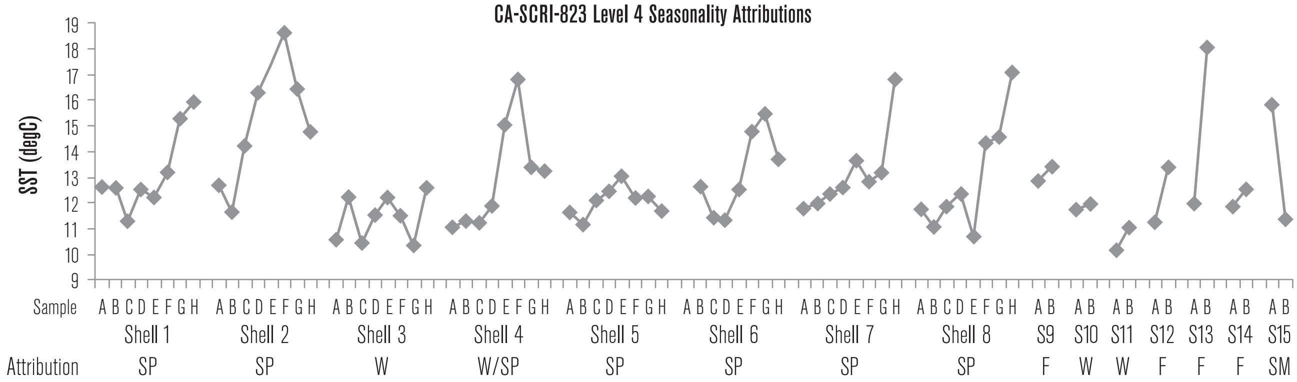

Figure 3. Seasonal profiles of California shells from CA-SCRI-823 (Pericoastal site) level 4. An example of a stratigraphic level with a highly seasonal occupation signature. SP, W, F, and SM used to denote, respectively, spring, winter, fall, and summer attributions. Sample A represents the value of the terminal growth band, Sample B, C, D, and so on represents the value of samples 2 mm., 4 mm., 6 mm., and so on from the terminal growth margin providing context for the interpretation of Sample A.

Laboratory Procedures of Oxygen Isotope Analysis. Altogether, this analysis included 1,275 carbonate samples from 250 mussel shells. I analyzed the first 715 carbonate samples on a Thermo-Finnegan MAT 253 Isotope Ratio Mass Spectrometer (IRMS) coupled online to a Kiel IV Carbonate device for automated CO_2 preparation in the Weldeab Stable Isotope Laboratory in the Earth Science Department at the University of California, Santa Barbara. Based on the reproducibility of the NBS-19 standards, instrument precision (1σ) is estimated as ±0.05‰ for $\delta^{18}O$. The remaining 560 samples were analyzed on a GVI Micromass Optima Stable Isotope Ratio Mass Spectrometer (SIRMS) equipped with an ISOCARB automated common acid bath system under the direction of Dr. Howard Spero at the Stable Isotope Laboratory in the Department of Geology at the University of California, Davis. Based on the reproducibility of the international standard NBS-19 and house standard SM-92 run alongside the archaeological samples, instrument precision (1σ) is estimated to be ± 0.07‰ for $\delta^{18}O$.

Evaluation and Interpretation of Oxygen Isotope Data. For comparison to expected seasonal SST fluctuations, I used the measured $\delta^{18}O$ ratios to mathematically estimate SSTs using the Horibe and Oba (1972) calcite equation:

$$T=17.04-4.34\left((\delta^{18}O_{c(VPDB)})-(\delta^{18}O_{(\mathrm{water(SMOW)})})\right)$$
$$+0.16\left((\delta^{18}O_{c(VPDB)})-(\delta^{18}O_{(\mathrm{water(SMOW)})})\right)^2$$

where T is in degrees Celsius, $\delta^{18}O_{c(VPDB)}$ is the isotopic value of the calcite sample relative to Pee Dee Belemnite, and $\delta^{18}O_{water(SMOW)}$ is the assumed isotopic value of the ocean on the standard mean ocean water (SMOW) scale. Following Rick et al. (2006), in the present study this equation was modified by replacing $\delta^{18}O_{water(SMOW)}$ with a local measurement of seawater obtained off the eastern end of Santa Rosa Island (–0.32‰).

Modern monthly SST averages inferred from two decades of NOAA Advanced Very High-Resolution Radiometer (AVHRR) satellite data facilitate reconstruction of expected inter-annual variation. These data are significantly correlated positively with SSTs from offshore moorings (mounted at a depth of three meters) around Santa Cruz Island and high tide temperatures from intertidally mounted temperature data loggers at ecological monitoring sites around Santa Cruz Island (see Blanchette et al. 2006:692), but provide the distinct advantage of a much longer time series, and presumably a more reliable representation of broad seasonal patterning. Given high instrument precision (±0.05‰ for $\delta^{18}O$ on the Thermo-Finnegan MAT 253 IRMS and ±0.07‰ for $\delta^{18}O$ on the GVI Micromass Optima SIRMS) and strongly patterned seasonal variability in SST, most shells in this study can confidently be attributed to 2–3 month intervals. Using the raw data reported by Thakar (2014b:369–387, Appendix A) I estimate the season of harvest based on the following schema. *Winter/Early Spring* (December–April): the SST calculated for the terminal edge value is cool and stable, near the estimated annual minima, and preceded by rapid cooling. *Late Spring/Early Summer* (April–July): the SST calculated for the terminal edge value is intermediate

Table 7

RESULTS OF ANOVA AMONG SITES ON ABUNDANCE OF MACROBOTANICAL REMAINS

						Tukey post-hoc comparisons *p*		
Source of variation	df	SS	MS	*F*	*p*	CST:PER	PER:INT	INT:CST
By Plant Weight Density								
Site	2	4.377	2.188	9.692	0.002	0.001	0.094	0.001
Error	16	3.613	0.226					
By Standardized Plant Counts								
Site	2	6.619	3.309	2.807	0.090	0.169	0.999	0.130
Error	16	18.862	1.179					

between the estimated annual minima and maxima, and indicates rapid warming relative to the time of harvest. *Summer* (August–October): the SST calculated for the terminal edge value is warm and stable compared to the estimated annual maxima, preceded by rapid warming. *Fall* (October–December): the SST calculated for the terminal edge value is intermediate between the estimated annual maxima and minima, preceded by rapid cooling relative to the time prior to harvest.

Statistical Analysis

In the present study, I aggregate assemblages by site in order to evaluate broad spatial trends that supersede temporal variation and reflect persistent spatial patterns in land use. All quantitative analyses of the paleoethnobotanical and zooarchaeological datasets were performed using SYSTAT statistical software (v. 9). I examined probability plots of residuals for the assumption of normality, and plots of residuals vs. estimated values for independence of error terms. Data not meeting these assumptions were appropriately transformed. I analyzed variation in the abundance of macrobotanical remains using a one-way ANOVA and performed post-hoc Tukey HSD tests to evaluate the statistical significance of differences between sites.

RESULTS AND INTERPRETATION

Rather than being a comprehensive evaluation of all aspects of the paleoethnobotanical and zooarchaeological assemblages, the results of this analysis illuminate significant variation in specific attributes of the macrobotanical and faunal remains, such as abundance, ubiquity of primary taxa, relative importance of broad resource categories, and size of key resources.

Significant Spatial Trends in Exploitation of Plant Food Resources

Plant Abundance. The density of charred macrobotanical remains (including wood charcoal) indicates that the overall abundance of plant remains at the Coastal site consistently and significantly exceeded the abundance of plant remains from the Pericoastal and Interior sites (Table 7). These results suggest that people produced much greater quantities of charred macrobotanical remains while living near the coast than while living further up the watershed towards the island interior. It is important to note that the abundance of wood charcoal, which dominates the macrobotanical assemblages, drives this pattern and may reflect more frequent or more intense use of wood for fuel or other purposes (such as fish processing) at the Coastal site.

Counts standardized by the total plant weight focus the analysis on variation in non-wood plant taxa (counts do not include wood charcoal). Comparisons between sites indicate that the abundance of non-wood plant taxa relative to all plant-related activities was significantly lower at the Coastal site than at the Pericoastal and Interior sites (Table 7). In contrast, comparisons between the assemblages recovered from the Pericoastal and Interior sites demonstrate no significant difference. These results suggest that people generally collected, processed, or consumed much greater quantities of non-wood plant taxa while living away from the coast.

Plant Ubiquity as a Measure of Primary Plant Taxa. High ubiquity values calculated for canary grass, blue dicks, manzanita, red maids, clover, goosefoot, common tarweed, acorn, and legumes relative to other plant food resources suggest that the prehistoric Island Chumash consistently relied on these primary plant foods throughout the temporal periods considered. However, the relative importance of these resources, and the others considered in this analysis, varies substantially by site. Rank-order comparisons of ubiquity values by site (Table 8) suggest that red maids and blue dicks are among the most highly-ranked plant food resources at the Pericoastal and Interior sites. Tarweed, acorn, and pacific pea are also more ubiquitous relative to other taxa at the Interior site than at the Coastal site. This comparison suggests that these five taxa were of greater relative importance away from the coast. In contrast, goosefoot and canary grass are among the highest ranked resources at the Coastal and Pericoastal sites. Phacelia and saltbush are also higher ranked at the Coastal site than at the Interior site. This pattern suggests that these four taxa were of greater importance relative to other taxa near the coast.

Ratios of Primary Plant Taxa Assessing Importance. The standardized count of macrobotanical remains from blue dicks, acorn, canary grass, and manzanita reveals a consistent pattern of greater collection, processing, or consumption of these taxa away from the coast, with the relative importance increasing with distance (Table 9). Comparisons between sites indicate that the mean standardized count of blue dicks and acorn shell/nut meat recovered from the Interior site was significantly higher than from the Pericoastal site or the Coastal site. Similarly, the mean standardized count of canary grass recovered from the Interior site was significantly higher than from the Coastal site, and the mean standardized count of manzanita recovered from the Interior site was marginally significantly higher than from the Coastal site. In contrast, the distribution of values for all four of these primary plant taxa fell in between the values from the Interior and the Coastal sites with no statistically significant difference between the Pericoastal and Coastal sites. Although this pattern contrasts with the high ubiquity values for canary grass in Coastal assemblages, it is not contradictory. Canary grass was an important plant food resource that consistently appeared in all assemblages from the Coastal site; however, it is evident that canary grass was much more abundant in assemblages from the Interior site.

Table 8

RANKING BY UBIQUITY VALUE OF PRIMARY PLANT FOOD RESOURCES FOR EACH SITE

Rank	Coastal site	Pericoastal site	Interior site
1	Goosefoot Canary grass	Goosefoot Canary grass Red maids Blue Dicks Common Tarweed Bedstraw Manzanita	Red maids Blue Dicks
2	Phacelia Clover Saltbush Manzanita	Phacelia Clover	Canary grass Common Tarweed Manzanita Clover Pacific Pea Acorn
3	Sunflower Family Red maids Blue Dicks	Legume Pacific Pea Checker mallow	Legume Wild Barley Bedstraw

The mean standardized count of macroremains of clover and wild cucumber (aka manroot, which is not always considered a food resource; cf. Arnold and Martin 2014) indicates significantly greater collection, processing, or consumption of these taxa occurred at the smaller Pericoastal site (Table 9) than at the Coastal site, but not at the Interior site. Nonetheless, the distribution of values from the Interior site was generally lower than at the Pericoastal site and not statistically different from the distribution of values from the Coastal site. These two resources, particularly clover (among other greens), are most abundant during the early spring. Consistently greater exploitation of this resource at the Pericoastal site strongly suggests that a highly seasonal occupation of this location persisted throughout the terminal Early Period until the late Middle Period.

Notably, the remaining primary plant taxa (red maids, goosefoot, common tarweed, and legumes) did not demonstrate statistically significant variation between site assemblages (Table 9). Quantitative analysis of diachronic trends reflects significant temporal variation in exploitation (and intensification) of these four taxa that supersedes and obscures evidence of broad spatial patterns in their use (Thakar 2014b, 2015).

Table 9

RESULTS OF ANOVA AMONG SITES ON RATIOS OF PRIMARY PLANT TAXA

						Tukey post-hoc comparisons p		
Source of variation	df	SS	MS	F	p	CST:PER	PER:INT	INT:CST
Blue Dicks by Standardized Counts								
Site	2	42.381	21.191	6.460	0.009	0.617	0.089	0.007
Error	16	52.484	3.280					
Canary Grass by Standardized Counts								
Site	2	86.255	43.127	3.385	0.059	0.578	0.382	0.048
Error	16	203.839	12.740					
Acorn by Standardized Counts								
Site	2	1.137	0.568	3.350	0.061	0.929	0.085	0.103
Error	16	2.714	0.170					
Manzanita by Standardized Counts								
Site	2	23.076	11.538	1.850	0.189	0.970	0.354	0.189
Error	16	99.791	6.237					
Clover by Standardized Counts								
Site	2	27.687	13.844	3.517	0.054	0.044	0.366	0.366
Error	16	62.972	3.936					
Marah by Standardized Counts								
Site	2	347.705	173.852	2.200	0.030	0.026	0.461	0.233
Error	16	632.148	39.509					
Red Maids by Standardized Counts								
Site	2	86.655	43.328	0.685	0.518	0.921	0.513	0.677
Error	16	1,011.803	63.238					
Goosefoot by Standardized Counts								
Site	2	87.751	43.875	0.967	0.401	0.606	0.966	0.413
Error	16	725.606	45.350					
Tarweed by Standardized Counts								
Site	2	30.135	15.067	1.026	0.381	0.921	0.513	0.677
Error	16	234.889	14.681					

Significant Spatial Trends in Exploitation of Animal Food Resources

Abundance (Density) of Vertebrate Remains. The abundance of vertebrate remains reflects a persistent emphasis on the capture, processing, or consumption of vertebrate animal food resources near the coast, with the relative abundance of vertebrate remains decreasing with distance from the coast (Table 10). Comparisons between the three sites indicate that mean animal bone density in assemblages from the Coastal site was significantly higher than in assemblages from the Pericoastal site or the Interior site. Similarly, the mean animal bone density recovered in assemblages from the Pericoastal site was significantly higher than from the Interior site. These results in the overall abundance of vertebrate remains were largely driven by variation in the density of fish bone, which dominates the faunal assemblages recovered from all three sites. Indeed, the highly statistically significant differences between sites persist even when only the fish bone NISP and weight are considered (Table 10).

Faunal Class. The ratio of bird remains to bony fish remains suggests that birds were increasingly important,

Table 10

RESULTS OF ANOVA AMONG SITES ON DENSITY OF VERTEBRATE REMAINS

						Tukey post-hoc comparisons *p*		
Source of variation	df	SS	MS	*F*	*p*	CST:PER	PER:INT	INT:CST
Bone NISP: Soil Volume								
Site	2	16,238.400	8,119.200	13.005	0.000	0.004	0.029	0.001
Error	16	9,989.333	624.333					
Bone Weight: Soil Volume								
Site	2	18.045	9.022	28.396	0.000	0.003	0.029	0.000
Error	16	5.084	0.318					
Fish Bone NISP: Soil Volume								
Site	2	13,582.574	6,791.287	12.217	0.001	0.004	0.909	0.001
Error	16	8,894.487	555.905					
Fish Bone Weight: Soil Volume								
Site	2	7.370	3.685	16.243	0.000	0.008	0.249	0.000
Error	16	3.630	0.227					

relative to bony fish, moving away from the coast and up the watershed toward the island interior. Comparisons between the three sites indicate that the ratio of bird bone to bony fish bone (by weight) in assemblages recovered from the Coastal site was significantly lower than from the Interior site. Moreover, the distribution of values from the Pericoastal site fall between the values from the other two sites, with no statistically significant difference between the Pericoastal and Coastal sites or between the Pericoastal and Interior sites (Table 11).

In contrast, the ratio of marine mammal (primarily California sea lion) remains relative to bony fish remains suggests that people consistently hunted, processed, or consumed much greater quantities of marine mammals relative to bony fish while living near the coast. Comparisons between the three sites indicate that the ratio of marine mammal bone to bony fish bone in assemblages recovered from the Coastal site was significantly much higher than from the Pericoastal or Interior sites. Further comparisons between the assemblages demonstrate no significant difference between the Pericoastal and Interior sites (Table 11).

Bony Fish Size. The size of bony fish vertebrae recovered from the Coastal, Pericoastal, and Interior sites documents a consistent and highly significant increase in the size of bony fish being transported, moving from the coast to the interior of the watershed (Table 12). Comparisons between the three sites indicate that the mean size of fish vertebrae in assemblages from the Coastal site was significantly lower than in assemblages from the Pericoastal site or the Interior site. Additional comparison between assemblages indicates that the mean size of fish vertebrae recovered from Pericoastal assemblages is also significantly smaller than from Interior assemblages. These results suggest that people preferentially transported larger fish one kilometer up the watershed to the Pericoastal site, and even larger fish three kilometers up the watershed to the Interior site. Thus, fish decreased in importance, abundance, or both, but increased in size with distance from the coast.

Mussel Size. Great quantities of California mussel shell recovered from the three sites indicate a heavy reliance on this staple resource across all three sites and throughout the temporal periods considered. However, the mean size of California mussel shells recovered from the Coastal, Pericoastal, and Interior sites document a highly significant increase in the size of California mussel transported away from the coast (Table 12). Comparisons between the three sites indicate that the mean size of California mussel shells in assemblages from the Coastal site ($\mu = 39.71$ mm., $\sigma = 15.02$ mm.) was quite significantly lower than in assemblages from the Pericoastal site ($\mu = 43.42$ mm., $\sigma = 22.73$ mm.) and the Interior site ($\mu = 42.65$ mm., $\sigma = 16.19$ mm.). However,

Table 11

RESULTS OF ANOVA AMONG SITES ON FAUNAL CLASS RATIOS

						Tukey post-hoc comparisons *p*		
Source of variation	**df**	**SS**	**MS**	***F***	***p***	**CST:PER**	**PER:INT**	**INT:CST**
Bird: Bony Fish by NISP								
Site	2	24.792	12.396	1.608	0.231	0.936	0.452	0.218
Error	16	123.364	7.710					
Bird: Bony Fish by Weight in grams								
Site	2	2,937.083	1,468.541	4.990	0.021	0.318	0.304	0.016
Error	16	4,708.611	294.288					
Marine Mammal: Bony Fish by NISP								
Site	2	0.791	0.395	9.967	0.002	0.005	0.980	0.005
Error	16	0.635	0.040					
Marine Mammal: Bony Fish by Weight in grams								
Site	2	896.088	448.044	6.835	0.007	0.016	0.971	0.020
Error	16	1,048.847	65.553					
Cartilaginous Fish: Bony Fish by NISP								
Site	2	0.010	0.005	0.794	0.469	0.481	0.562	0.997
Error	16	0.100	0.006					
Cartilaginous Fish: Bony Fish by Weight in grams								
Site	2	2.640	1.320	1.085	0.361	0.353	0.865	0.633
Error	16	19.466	1.217					

Table 12

RESULTS OF ANOVA AMONG SITES ON BONY FISH VERTEBRAE SIZE AND MUSSEL SHELL SIZE

						Tukey post-hoc comparisons *p*		
Source of variation	**df**	**SS**	**MS**	***F***	***p***	**CST:PER**	**PER:INT**	**INT:CST**
Bony Fish Vertebrae Size								
Site	2	311.039	155.519	24.691	0.000	0.000	0.025	0.001
Error	2603							
California Mussel Shell Size								
Site	2	33.078	16.539	16.401	0.000	0.000	0.227	0.000
Error	9368	9447.042	1.008					

comparisons between assemblages from the Pericoastal site and assemblages from the Interior site indicate no significant difference in the mean size of California mussel shells transported to these two sites. These results suggest that throughout all temporal periods people preferentially transported larger mussels away from the coast to the Pericoastal and Interior sites.

Seasonal Variation in Site Occupation

Graphing the serial samples from each shell and comparing the profiles with modern monthly SST averages inferred from two decades of NOAA Advanced Very High-Resolution Radiometer (AVHRR) satellite data (Thakar 2014b:Figure 4.8), I estimated the month and season of death for each individual shell. Figure 3 illustrates seasonal profiles and attributions based on an oxygen isotope analysis of 15 shells from a single stratum at the Pericoastal site. In this example, it is evident that the Island Chumash primarily harvested shellfish during the spring, with some additional contributions during the fall and winter. Notably, only one attribution indicates summertime harvesting. Altogether, the distribution of seasonal attributions suggests targeted seasonal harvesting and transportation of California mussel to the Pericoastal site. This pattern resonates well with the overall bimodal distribution of 60 seasonal attributions based on California mussel shells recovered from the Pericoastal site.

Table 13 and Figure 4 summarize the seasonal attributions of all 250 shells considered in this study, by site. The relative proportion of shells harvested during the late spring/early summer is much greater at the Pericoastal site than at the Coastal or Interior site. This pattern suggests that the Pericoastal site was preferably occupied by the Island Chumash during the spring as fresh greens sprouted and abundant seeds began to appear in the adjacent grassland and coastal sage scrub plant communities. In contrast, the relative proportion of shells harvested during the peak summer months was much greater at the Coastal site than at either the Pericoastal or Interior site. Thus, occupation at the coast is strongly associated with the productive fishing months of the summer and early fall. However, the relative proportion of shells harvested during the fall months is greatest at the Pericoastal and Interior sites. This suggests that the Island Chumash moved towards the interior of the island as fleshy fruits ripened and nuts matured in

Table 13

SEASONAL ATTRIBUTIONS BASED ON OXYGEN ISOTOPE ANALYSIS OF MUSSEL SHELL

	Late Spring/ Early Summer (Apr–Jun)		Summer (Jul–Sep)		Fall Oct–Dec)		Winter/ Early Spring (Jan–Mar)		
Site	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**Total**
Coastal	12	10.40%	61	**53.01%**	38	33.04%	4	3.48%	115
Pericoastal	27	**45.00%**	7	11.67%	23	**38.33%**	3	5.00%	60
Interior	13	17.33%	22	29.33%	28	**37.33%**	12	**16.00%**	75

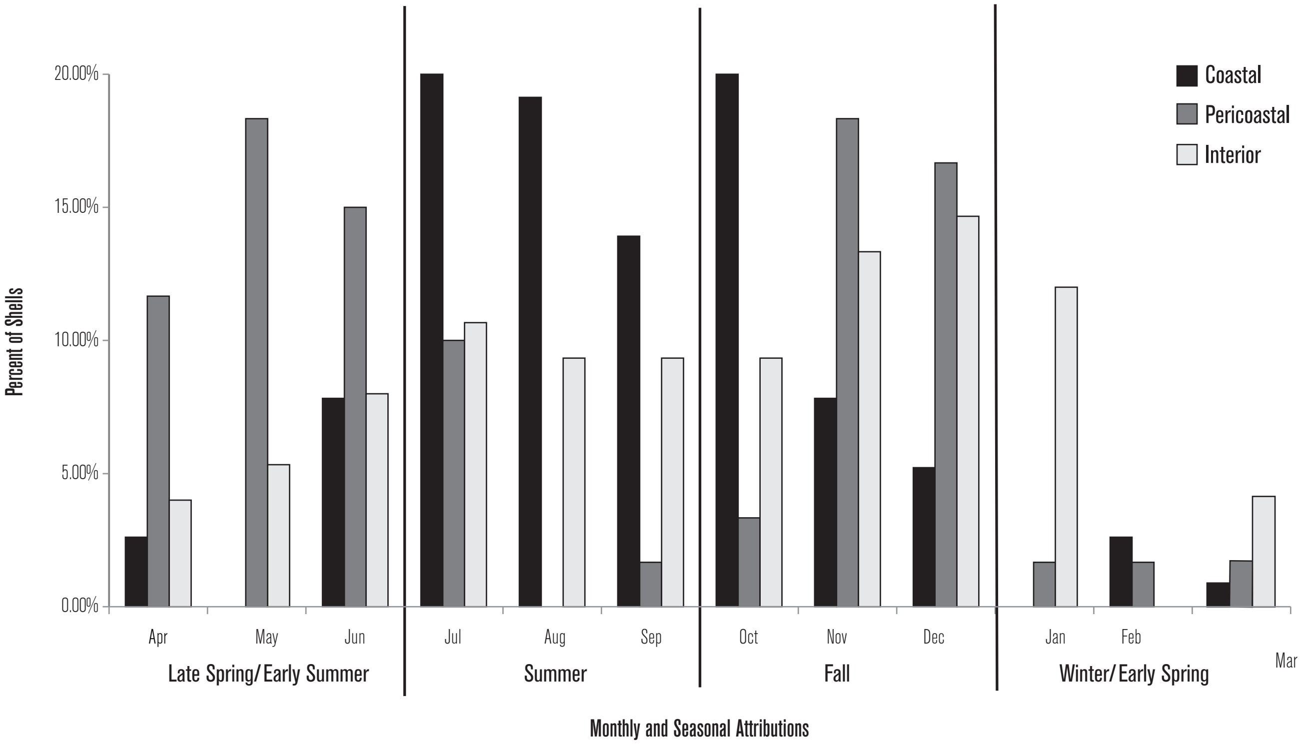

Figure 4. Monthly and seasonal harvest attributions based on oxygen isotope analysis.

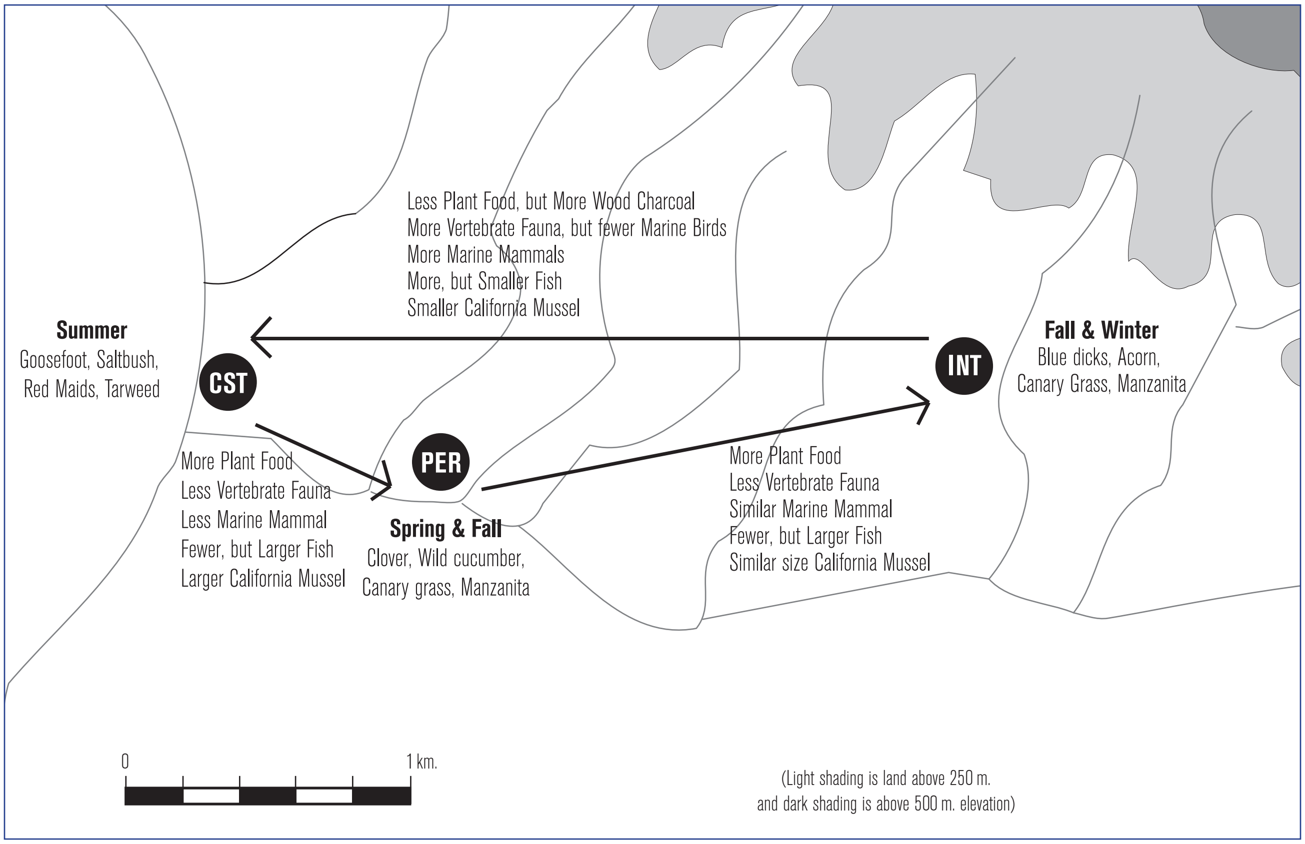

Figure 5. Summary of statistically significant seasonal and spatial trends in land-use. "CST", "PER", and "INT" are used to designate the Coastal, Pericoastal, and Interior site locations, respectively.

chaparral and woodland plant communities. Although evidence for winter/early spring occupation at any of the three sites is minimal, the relative proportion of shells harvested during this season is greatest at the Interior site. Perhaps drawn by abundant corms still available, waiting in the winter soil around the Interior site, people appear to have moved away from the coast during the coldest, and leanest, season.

DISCUSSION

In a recent GIS model Reeder-Myers (2014:212, 213) found that access to carbohydrates (i.e., plant foods) was a secondary predictor of site location on Santa Cruz Island (following primary access to protein and freshwater). Yet at the scale of individual watersheds (which controls for access to freshwater and marine protein sources), it is evident that the seasonal and spatial distribution of carbohydrate resources significantly influenced the location of central places. These patterns are only revealed through the integration of multiple lines of data—isotopic, faunal, and botanical. Assessment of season of occupation places groups of foragers at particular points on the landscape during particular seasonal windows, linking the use of different places on the landscape to one another within an annual context. Quantitative evaluations of macrobotanical and faunal remains demonstrate significant shifts in the abundance, array, and specific qualities of food resources used and transported by the Island Chumash over relatively short distances, as people moved from the Coastal site one kilometer up the watershed to the Pericoastal site, and three kilometers up the watershed to the Interior site. Altogether, these rich datasets, integrated with the expectations of Central Place Foraging (CPF), facilitate a holistic understanding of how the Island Chumash inhabiting Cañada Christy during the Late Holocene organized their exploitation of food resources across the landscape (see Fig. 5).

Understanding the Persistence of Seasonal and Spatial Foraging Patterns

The central tenet of CPF asserts that human foragers select settlement locations that maximize foraging efficiency, based on factors such as travel time and transportation costs (Kelly 2013:68–69). However, foraging behavior is also sensitive to short-term spatial and temporal variation in food resources (e.g., Cashdan 1992). Thus, the location and function of residential bases and logistical camps are expected to vary in response to the distribution and abundance of resources across the landscape (Kennett 2005:225). Reconstruction of foraging behavior within the Cañada Christy watershed ca. 3,000–1,000 cal B.P. suggests that each of the three sites considered here served as residential bases as well as logistical camps during distinct seasons. Low-level intermittent occupation at the Coastal, Pericoastal, and Interior sites occurred throughout the year, making it impossible to identify whether plant and animal food remains were present due to possible storage or due to temporary site occupation during the expected season of abundance. A lack of clear seasonal discrepancies within or between the array of plant or animal food resources exploited provides little support for the interpretation that food resources were stored from one season to the next.

During the productive fishing months of the summer and early fall, people consistently established residential bases at the Coastal site. While living at this location, great quantities of marine fauna, particularly shellfish, fish, and marine mammals, were supplemented by low quantities of several important plant foods (i.e., goosefoot, canary grass, clover, saltbush, red maids, blue dicks, and tarweed) readily available in adjacent vegetation communities. Only two primary plant taxa, manzanita and acorn, may have been acquired (via transport or trade) at some distance from the coast. Logistical acquisition of these key resources, which may not have been at peak productivity during the summer, coincides well with CPF expectations.

In contrast, people established shorter-term residential bases at the Pericoastal site during the late spring/early summer and also during the late fall, before and after the primary season of occupation at the Coastal site. Occupation at this location may represent periods of dispersal as people focused on the acquisition of highly seasonal terrestrial food resources located away from the coast. Along with an increased reliance on plant food resources (particularly clover, canary grass, and manzanita), people transported great quantities of large California mussel—complemented by very low quantities of portions of marine mammals and large-bodied fish—with them to supplement their diet while living just one kilometer away from the coast.

These general spatial trends become amplified as people moved three kilometers further up the watershed to the Interior site during multiple seasons throughout the year. This location served as a primary residential base, particularly during the fall/early winter. It is evident that while living at the Interior site, people preferentially transported even larger fish (albeit in lower densities) and larger California mussels to complement large quantities of dietary staples such as blue dicks, canary grass, manzanita, and acorns collected within close proximity of the Interior site. Seasonal occupation of this location was certainly related to the acquisition of these valuable food resources. Similarly, other researchers have recently identified fall exploitation of blue dicks at interior site locations on Santa Cruz Island (Gill 2014). The increased size of mussels suggests that people living at the Interior site during the fall/early winter sought to maximize returns from logistical foraging trips to the coast. Similarly, clear preference for dietary protein from mussels rather than fish may also reflect the relative cost of transporting resources from the coast. Meat from mussels, if left in the shell and wrapped in cool seaweed, preserves well for several days, minimizing the frequency of logistical forays to the coast.

Important Lessons from Paleoethnobotanical Studies on the Northern Channel Islands

This complex and nuanced reconstruction of short-term seasonal and small-scale spatial trends that structured land and resource use on Santa Cruz Island during the Late Holocene supports long-standing assumptions regarding the exploitation of important plant food resources. Indeed, it is clear that the prehistoric inhabitants of the Cañada Christy watershed did move toward the island interior to exploit abundant terrestrial plant resources as frequently asserted—though sans supporting data (*sensu* Kennett 2005). Nonetheless, the general characterization distinguishing coastal fishers/shellfishers and interior gatherers creates a false dichotomy that minimizes expectations of variation in plant use across the island landscape. Not all non-coastal sites were the same, nor should they be expected to have been the same. Just as plant communities, each offering a distinctive combination of useful plants, occur within relatively short distances of one another, the unique array and abundance of plant taxa exploited at any two (or three, or four...) given sites also varied over relatively short distances. Significant differences between the Coastal and Pericoastal sites, alongside even greater differences between the Pericoastal and Interior sites, acutely demonstrate this pattern. Additional macrobotanical studies from the interior of Santa Cruz Island further underscore the multifaceted nature of plant exploitation across the island landscape. Hoppa (2014:113) encountered a notable absence of plant foods and a very low density of medicinal plants in the macrobotanical assemblages recovered from three sites located in the Central Valley of Santa Cruz Island. Gill (2014:128) reported a remarkable abundance of geophyte remains recovered from a site near Diablo Peak, the highest point on Santa Cruz Island.

Apparent differences between interior sites likely reflect not only seasonal and spatial variation in the abundance and distribution of plant taxa, but also site type, site function, and an array of taphonomic processes (see Thakar 2014b:58–60). Identifying the significance of differences between sites requires quantitative comparison between multiple sites, in diverse habitats, with varying function. The study presented here demonstrates the usefulness of relatively simple statistical measures for evaluating the significance of seasonal and spatial variations in resource use. Similarly, Arnold and Martin (2014) integrate paleoethnobotanical data derived from three coastal shell middens to demonstrate significant shifts in the specific array of plant taxa exploited during a period of recurrent drought. In both studies, paleoethnobotanical assemblages from multiple sites across time and through space are evaluated quantitatively to reveal significant patterns in plant use. As paleoethnobotanical studies become a standard component of archaeological investigation on the Northern Channel Islands, and throughout California, it is imperative that we push beyond descriptive taxa lists and begin to consider how quantitative evaluation can reveal underlying patterns in human foraging behavior.

CONCLUSION

This article integrates the analysis of well-preserved macrobotanical and faunal assemblages with seasonality assessments based on oxygen isotope analysis of marine shell to provide a holistic reconstruction of foraging behavior on Santa Cruz Island during the Late Holocene. I assert that understanding any subsistence system from an archaeological standpoint requires an integration of as many kinds of data as possible. For too long researchers have relied on assumptions regarding the nature of plant resource use on the Northern Channel Islands, and indeed throughout coastal California. This has significantly diminished our understanding of the diversity of ways in which short-term seasonal and small-scale spatial variability in plant resources structured patterns of land and resource use, impacting not only the acquisition of terrestrial plant foods, but also of marine animal foods. Increasing analyses of paleoethnobotanical remains contribute to a more refined understanding of diet choice; however, analysis of any one component of the subsistence assemblage, be it plant remains, fish bone, or shellfish, is not inherently better than another. We must be cautious and not repeat the mistakes of the past by relying solely on any one line of subsistence data in our reconstruction of foraging behavior. Thus, it is imperative that all archaeologists understand the value of holistic subsistence reconstruction and prioritize the recovery of samples suitable for integrative foodways studies.

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