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Food & Fertility in Prehistoric California: A Case-study of Risk-Reducing Foraging Behavior and Population Growth from Santa Cruz Island, California

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Food & Fertility in Prehistoric California: A Case-study of Risk-Reducing Foraging Behavior and Population Growth from Santa Cruz Island, California

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy in Anthropology

by

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DEDICATION

This dissertation is dedicated to the greatest man I have ever known,
my Grandfather, H. Wyatt Bartlett.

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This dissertation would not have been possible without the support of many mentors, colleagues, friends, and family. My deepest gratitude goes to Michael Glassow, Barbara Voorhies, Amber VanDerwarker, Michael Jochim, and Douglas Kennett, my dissertation committee members and friends. Both my professional and personal development have benefitted immensely from their consistent support, guidance, and faith in my abilities. Mike Glassow, my committee chair, has been an exemplary academic advisor. He has generously shared his passion for archaeology in our weekly meetings (which will be sorely missed as I move on from UCSB), in addition to reading every draft of every dissertation chapter, article manuscript, grant application, and job letter that I have written over the last eight years. Mike is my role model for an advisor and it is my goal to support my graduate students one day in the same way that he supported me.

Barbara Voorhies, Amber VanDerwarker, and Mike Jochim expanded my archaeological horizons by inviting me to their field sites in Mexico and Germany and providing me with hands-on experience in a variety of unique field and laboratory methods that I might otherwise never have learned. After a life-changing field season in Chiapas with Barbara, she unofficially became a secondary advisor, keeping me in line and on track. Barbara never cut me any slack. I know that my current and future successes are due, in part, to her unfailing straightforward and honest critique of my work. Amber VanDerwarker is largely responsible for the quantitative and methodological approach to this dissertation. Without her, I would not have the paleoethnobotanical and zooarchaeological skill sets required to collect the rich and robust datasets that I rely on in this project. Amber not only provided me with the necessary training, but also with access to laboratory space and equipment, as well as the statistical software required to complete this analysis. Michael Jochim introduced me to hunter-gatherer ethnography in my first year of graduate school. Ever since then he has supported my interest in hunter-gatherer research, providing welcome conversational interludes on the subject during the seemingly endless hours I spent writing my final dissertation chapters in his laboratory. Doug Kennett and his student Brendan Culleton provided invaluable instruction and critique of my efforts to master oxygen isotope analysis as well as the development of Bayesian chronological models. Their assistance contributed significantly to the primary goals of this research.

Many other members of the UCSB faculty have supported me over the years, with Stuart Smith, Katharina Schreiber, and Lynn Gamble providing much needed courses, insights, and funding opportunities. I also owe a special debt of gratitude to Michael Gurven and his lab group. Mike's courses on demography, hunter-gatherers, and behavioral ecology significantly influenced my approach to this research project and the scope of my theoretical interests. His lab group (particularly Melanie Martin, Anne Pisor, and Adrian Jaeggi) welcomed me and challenged me to consider hunter-gatherer research beyond the realm of archaeology.

This project could not have been completed without the assistance of many wonderful field and lab assistants, including fellow graduate students Sarah Kerchusky, Allison Jaqua, Matthew Edwards, Mariam Dahdul, Carola Flores-Fernandez, Sarah Mellinger, and Jennifer Clinton, as well as a cadre of undergraduate interns. Lyndal Laughrin and Brian Guererro at the Santa Cruz Island field station provided invaluable logistical support throughout all phases of the fieldwork from survey to excavation. Even more, both Lyndal and Brian

offered their friendship and companionship making fieldwork on the island as rewarding personally, as it was professionally.

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On a more personal note, my dearest friends Carola Flores-Fernandez, Maritza Maksimov, and Jennifer Taylor made even the longest days joyful. I will forever treasure our late-night dance breaks in the office, crazy weekends, and the boundless support that you offered me throughout the most harrowing years of graduate school. Myrtle Shock, Megan Carney, Katie Hinde, Lindsay Vogt, Anne Pisor, Melanie Martin, Amy Gusick and Jen Alvarado round out the list of incredible, intelligent, and inspiring women that I have had the pleasure of sharing my graduate school experience with. I will forever be grateful to UCSB for bringing us all together. Finally—and most importantly—I would like to acknowledge my family, Fernando, Louisa, Mom, Anita, Sarah, Charles, Naomi, Kevin, Emily, and David. Nothing I do in this life would have significance without you to share it with.

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2014 (In Press) “Sites Forlorn: Dating Intervals of Abandonment at Three Shell Middens on Santa Cruz Island, California using Bayesian Chronological Models”. *Journal of Archaeological Science*, special issue *Dates as Data: New Applications of Radiocarbon Dating to Archaeological Problems*, edited by Robert L. Kelly and Nicholas Naudinot.

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2013 "Dates, Diet, and Demography: A Detailed Chronological Framework for Evaluating Diachronic Subsistence Variation and Population Growth". Paper Presented at the Society for American Archaeology 78th Annual Conference, Honolulu, HI.

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2012 "Before CA-SCRI-236 was Ch'olosush: 3000 Years of Occupation, Subsistence and Mobility". Paper Presented at the Society for American Archaeology 77th Annual Conference, Memphis, TN.

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2012 "Methods for Evaluating Seasonal Nutritional Sufficiency in Prehistoric Hunter-Gatherer Population". Paper Presented at 2nd Annual Anthropology Graduate Student Symposium, Santa Barbara, CA.

2011 “If Floors Could Talk: Investigation of Clay Floors at the Tlacuachero Shell Mound". Paper Presented at the Society for American Archaeology 76th Annual Conference, Sacramento, CA.

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2012 Whither the Twain Shall Meet: Paleoethnobotany and California Archaeology. Society for California Archaeology Annual Meeting, San Diego, CA. (with discussants Bill Hildebrandt and Amber VanDerwarker)

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ELECTED AND APPOINTED POSTS

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ABSTRACT

Food & Fertility in Prehistoric California: A Case-study of Risk-Reducing Foraging Behavior and Population Growth from Santa Cruz Island, California

by

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This archaeological dissertation research project integrates a rigorous chronological framework, geochemical data (δO^{18}), and subsistence data (macrobotanical and faunal) to evaluate dynamic interrelationships between foodways, the environment, and human population growth in prehistory. Specifically, this case study elucidates temporal variation in risk-reducing foraging behaviors relative to a period of significant and intrinsic population growth ca. 1600 cal B.P. on the Northern Channel Islands of California. I integrate the energetic focus of reproductive ecology with a behavioral ecological perspective to provide a unique framework for understanding prehistoric demographic shifts within foraging populations.

The outcome of this research includes the most complete integrated foodways research ever conducted along the central coast of California. The integration of a multiscalar chronological framework and multiple lines of subsistence data provides a unique methodological approach for investigating the role of seasonal subsistence stability in population regulation. Each line of evidence helps in unraveling a complex story of human occupation and foraging behavior at three archaeological sites that I excavated. A thorough and rigorous program of radiometric dating and Bayesian chronological models control the century-level resolution and site seasonality studies based on oxygen isotope analysis the provide seasonal resolution, necessary to infer diachronic shifts in mobility patterns. I also rely on and highlight the importance of analyzing and integrating both faunal and macrobotanical data in order to answer questions of resource exploitation and dietary sufficiency.

Together these diverse lines of mobility and subsistence data allow me to reconstruct significant diachronic changes in foraging behavior and evaluate these changes with respect to evidence of climate-induced environmental change and prehistoric population growth. These results suggest that prehistoric human population growth did not always instigate major shifts in food acquisition, but rather was, in some cases, a product of subtle changes in the type, quantity, and quality of food resources upon which human foragers relied. Although this research specifically evaluates dietary and foraging behaviors on Santa Cruz Island, the broad theoretical perspective that macro-scale population level shifts among hunter-gatherers may be an unintended outcome of subtle shifts in foraging behavior—related to a variety of social, environmental, or economic variables—that inform dynamic biological processes is widely applicable to hunter-gatherer studies. Ultimately, this research sheds new light on how significant demographic shifts occurred throughout human history, prior to the adoption of domesticated foods.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

RISK-REDUCING FORAGING BEHAVIORS AND POPULATION GROWTH ON THE NORTHERN CALIFORNIA CHANNEL ISLANDS: AN INTRODUCTION

High population density is truly an exception to the rules that long governed human society. Research worldwide indicates that throughout most of our existence as a species, humans lived as egalitarian foragers in small, sparsely distributed family groups that moved frequently in response to the seasonal distribution of food resources (Binford 1990; Kelly 2013). The Chumash of the Santa Barbara Channel Region and the Northern Channel Islands in California are a notable example of hunter-gatherers that abandoned this archaic lifestyle without any addition of domesticated plant or animal species to their existing subsistence economy. The ancestors of the Chumash arrived in the region by at least ca. 13,500 years ago (Erlandson et al. 1996; Johnson et al. 2002). The archaeological remains they left behind initially conform to the demographic patterns expected in simple foraging societies. For at least ten thousand years, the prehistoric Chumash experienced cyclical periods of population increase and decrease, resulting in slow and incremental population growth. Yet, there is an abrupt shift approximately 1500 years ago, when for unknown reasons population levels grew significantly throughout the region of coastal California (Culleton et al. 2006a; Glassow 1999:56; Kennett et al. 2009:310). At the time of Spanish contact in A.D. 1542, the seafaring Chumash lived in large villages governed by hereditary chiefs and maintained extensive trade networks supported by craft specialists. Many researchers attribute the development of such complex social structures to increased population density (Erlandson and Rick 2002a;

Kennett et al. 2009; Raab and Larson 1997; Raab et al. 2002; Winterhalder et al. 2010); however, in most of these models population growth is treated as an exogenous variable. Few researchers interested in Chumash prehistory explore the fundamental question of how and why population growth initially occurred (c.f. Arnold 1996, 2001, 2004; Kennett 2005, which consider economic intensification as context for population increase) and none consider the actual biological mechanisms that regulate human demography.

Consistent with anthropological demographers inspired by Malthus (1960,[1830]) and Boserup (1965), archaeologists interested in paleodemography often interpret the slow rate of hunter-gatherer population growth throughout prehistory as a natural product of carrying capacity constraints on technologically primitive peoples (Cohen 1980:278). Following Malthus, researchers assumed that population size among foraging populations would rise exponentially (due to high fertility) until restricted by the bounds of natural resources via a series of positive mortality checks (i.e., famine, disease, warfare) as well as cultural practices (i.e. abstinence, infanticide, abortion) (Bentley 1996:26). Integrating the basic assumptions of Malthus and the tenets of Boserup, Wood (1998:113-114) proposed the MaB (Malthus and Boserup) ratchet as an explanatory mechanism that can lead to significant demographic increase. According to this approach, increasing demographic saturation could stimulate technological developments and economic innovations leading to a relaxation of positive Malthusian checks as the total food available increases, raising the Malthusian ceiling and fueling subsequent increases in population (Bentley 1996:28; Wood 1998:114).

Accordingly, the slow rate of population growth evident throughout the early occupational sequence on the Northern Channel Islands is easily comprehended as long as Malthusian constraints on technologically primitive humans are invoked as an explanation (see Malthus (1960,[1830]). Yet, a simplistic system of positive population checks (i.e., famine, disease, warfare, abstinence, infanticide, abortion) based on demographic saturation and technological determinism obscures understanding of mechanisms at least one-step removed from Malthusian limits on total available food. Recent ethnographic and demographic data from modern foraging populations suggests that physiological constraints intimately associated with the processes by which energy is captured from the environment and allocated to metabolic purposes, such as dietary and foraging behaviors (Ellison 2008; Sorensen and Leonard 2001). Thus, archaeologists can contribute to a more refined understanding of the timing and nature of macro-demographic changes by shifting our attention from concepts such as carrying capacity to the energy implications of foraging behaviors. That is to say, archaeologists must look towards biologically oriented explanations for a more complete understanding of prehistoric demographic shifts.

Human demography is regulated by three mechanisms: migration, fertility, and mortality. Although significant in-migration is often responsible for macro-demographic increases at a local scale, accumulating evidence suggests that this is not the case for the prehistoric Chumash. Linguistically, the six Chumashan languages, including Cruzeño spoken on the Northern Channel Islands, constitute an isolated language family with an ancient presence in California (Golla 2007). Surviving Chumash mitochondrial lineages also appear to be ancient genetic isolates, perhaps descended from the initial colonization of the region (Johnson and Lorenz 2006). Digital morphometric analyses of human crania demonstrate overall homogeneity in cranial morphology throughout the last 7,000 years of continuous human occupation on the Northern Channel Islands, with no evidence of population replacement during any period (Sholts 2011). Linguistic, genetic, and skeletal evidence of ancient and uninterrupted Chumash occupation of the Santa Barbara Channel region are further supported by tremendous continuity in the cultural remains recovered by archaeologists (Erlandson 2002). Thus, there is no evidence of significant migration into the region (Johnson et al. 2002; Johnson and Lorenz 2006); rather, population growth was most likely intrinsic, the result of increased fertility, reduced mortality, or both within the Chumash population itself.

These two mechanisms, fertility and mortality, are biologically linked to the availability and stability of food resources year-round. Indeed, many ethnographic studies concerned with demography support the idea that population regulation and growth in natural fertility societies are broadly linked to patterns of subsistence and reproduction through behaviorally and physiologically mediated trade-offs (Bailey et al. 1992; Ellison 2008; Panter-Brick et al. 1993; Valeggia and Ellison 2001, 2004). Reproductive ecology clearly indicates that people who experience restricted energy availability related to high energy expenditure, macronutrient imbalance, or periodic intake restriction suffer increased functional, reproductive, and health deficits even when risk of starvation is low (Ellison 2008:187; Jasienska and Ellison 1998, 2004; Jasienska et al. 2006; Lager and Ellison 1990). Thus, high population mobility, restricted access to resources high in energy-producing fats and carbohydrates, and seasonal food risk are linked to suppressed fertility and frequent population decrease in hunter-gatherer populations (Ellison 2001b, 2008; Headland and Bailey 1991; Kaplan and Hill 1992). Distinct spatial and seasonal fluctuation in the abundance, distribution, accessibility, and macronutrient content of plant and animal resources certainly influenced the quantity and quality of food available to the prehistoric Chumash across space and through time (Kennett 2005:59). Shifts in foraging strategies that reduce the risk of energy imbalance can lead to substantial population increases (Blondel and Aronson 1999). Therefore, how foragers moved about and exploited prehistoric landscapes is key to understanding population growth (Winterhalder et al. 1988:320) and the emergence of sociocultural complexity among hunter-gatherers (Morgan 2009:382).

The archaeological research project presented in this dissertation engages this issue directly by evaluating evidence of risk-reducing foraging behaviors before, during, and after population expansion (3000-1000 B.P.). I integrate 1) multiscalar chronological data based on AMS radiocarbon dating and oxygen isotope analysis of marine shell carbonate to evaluate diachronic mobility patterns, and 2) dietary data based on the taxonomic identification of plant and animal food remains to evaluate diachronic subsistence patterns. A thorough conceptualization of the relationship between risk-reducing foraging behaviors and population growth is essential to contextualizing wider social and political developments that occurred in coastal California during the Late Holocene. Furthermore, the analysis presented in this dissertation will contribute to the fundamental issue of how and why intrinsic population growth occurs in hunter-gatherer societies.

Environmental Context of the Research

In general, the Santa Barbara Channel region has a semi-arid Mediterranean climate characterized by mild summers and cool, wet winters (Rick et al. 2005a:171). However, present climatic conditions do not necessarily reflect those at different periods in prehistory. Laminated sediments recovered from a Santa Barbara Basin marine sediment core (ODP 893) provide a high-resolution (25-50 year intervals) record of sea-surface temperatures and marine productivity from the center of the Santa Barbara Channel Basin (Kennett et al. 2007). This record reveals a distinct transition from cooler, productive marine waters that dominated 3800 to 2900 B.P. to warmer, less productive marine waters that dominated from 2900 to 1500 B.P. Isotopic differences between surface dwelling and benthic foraminifera indicate that reduced vertical mixing and lower marine productivity were sustained between 2800 and 1000 B.P. (Kennett 2005:67).

The bristlecone pine record from the White Mountains of Eastern California (reported by Larson and Michaelson 1989 and Stine 1994) indicates a general pattern of increased precipitation that began ca. 2300 years ago and lasted until ca. 1500 years ago (Kennett et al. 2007:355). Although the bristlecone pine record is not derived from the immediate area, researchers indicate broad correlation between periods of warm sea surface temperatures evident in the Santa Barbara Basin record and increased precipitation evident in the bristlecone pine record (Kennett et al. 2007:355; also see Graham et al. 2006). Local pollen and macrobotanical analyses provide further support for increased precipitation between 2100 and 1900 B.P. (Wigand 2005).

Although overall environmental variability was reduced from 2900 to 1500 B.P., there is a general correlation between cooler sea surface temperature (SST) and low precipitation between 4000 and 2300 B.P., and warmer SST and higher precipitation between 2300 and 1500 B.P. (Kennett et al. 2007). This climatic transition would have altered the geographic distribution and productivity of marine and terrestrial resources across the Northern Channel Islands and favored the adoption of novel foraging behaviors.

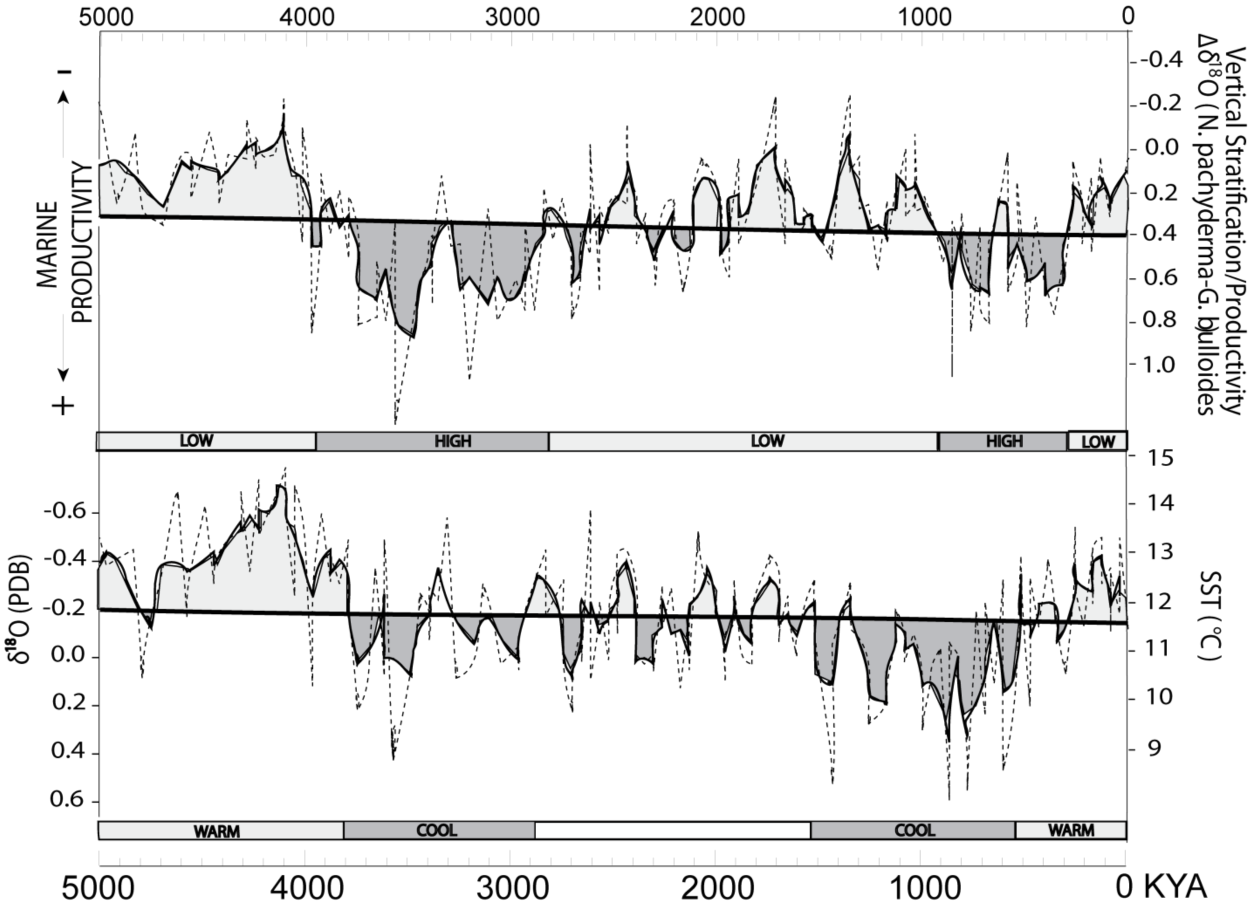


Figure 1.1. Sea-surface temperature and inferred paleoproductivity records for the Santa Barbara Basin (ODP Site 893 A/B) based on oxygen isotope analysis of foraminifera recovered from varved sediments. Figure adapted from Kennett et al. 2007:354, Figure 2.

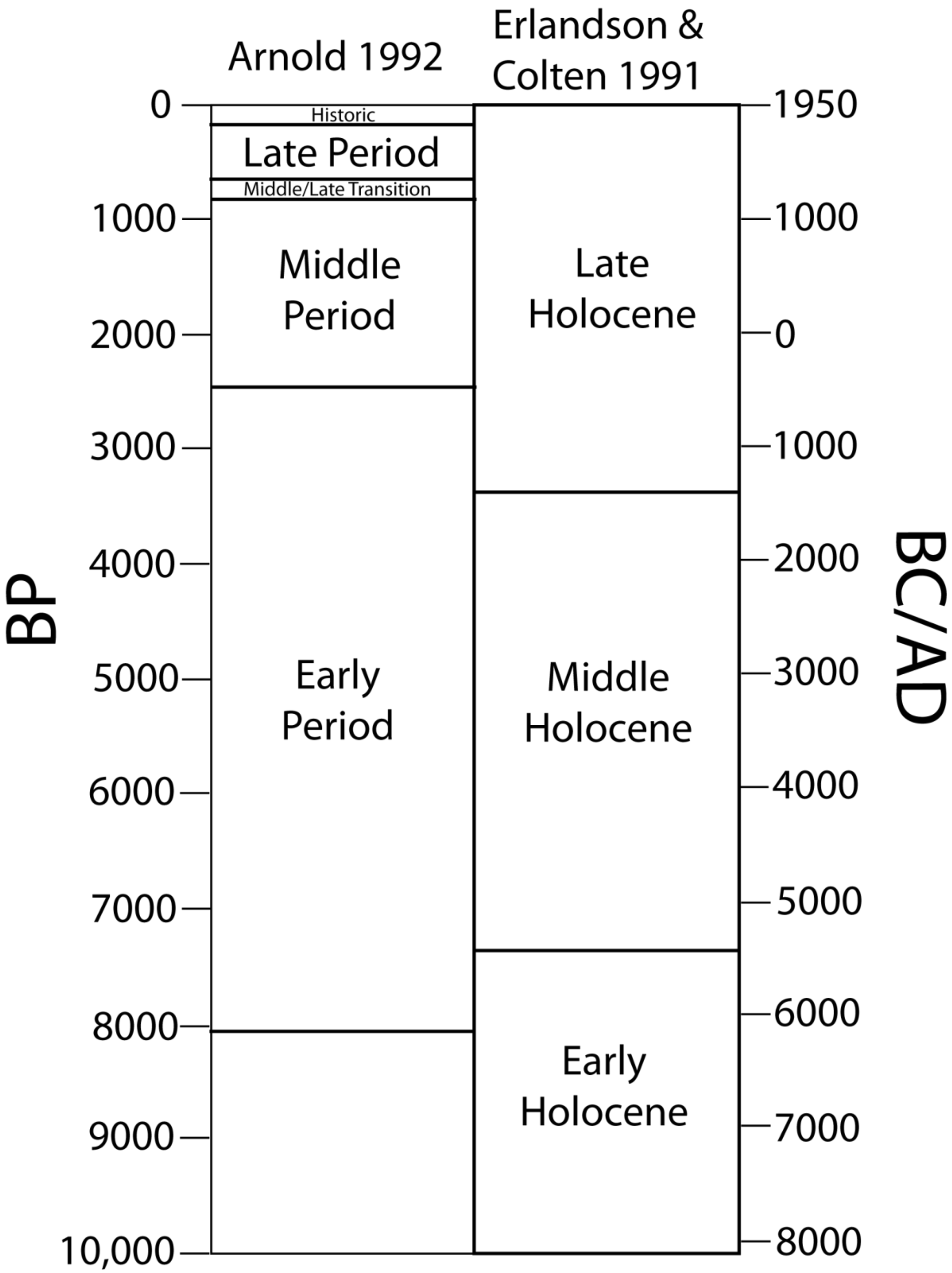


Figure 1.2. Two primary chronological schemes for the prehistory of the Santa Barbara Channel region including the Northern Channel Islands. Figure adapted

from Kennett 2005:21, Figure 13. Dates are based on calibrated calendar years.

Archaeological Context of the Research

Archaeologists working on the Northern Channel Islands of California identify significant population growth beginning ca. 1500 cal B.P. based on the increasing frequency of radiocarbon-dated site components (e.g., Arnold 1992; Culleton et al. 2006a; Glassow 1999). Rather than assuming a linear relationship between numbers of radiocarbon dates from archaeological site components and human population numbers, this method regards major peaks and troughs in the frequency of radiocarbon-dated archaeological components through time as an indication of increased or decreased amounts of archaeological materials and, by extension, higher or lower population densities. Archaeologists working on the Northern Channel Islands of California have interpreted significant changes in radiocarbon frequencies as demographic changes in response to climatic instability, introduction of disease, or social transformation (Arnold 1992; Kennett and Kennett 2000; Kennett 2005). Figure 1.3 depicts the distribution of dated components derived from the ever-increasing Northern Channels Islands Radiocarbon Database, which suggests gradually increasing population through the Holocene until a sharp rise and large fluctuations after 1500 cal B.P.

A number of interpretive challenges are presented when using radiocarbon dates to estimate changes in population due to the inherent limits of accuracy and precision in radiocarbon chronologies, insufficient radiocarbon data (Munns and Arnold 2002:134), and sampling biases (Raab et al. 2002:16). Nonetheless, there is a great deal of consistency in the broad patterns represented in radiocarbon records throughout coastal California, which lend confidence to the trends depicted above (see Glassow 1999). Kennett (2005:155) examined the cumulative distribution of components for the Northern Channel Islands and concluded that, if population size can be even roughly measured from site component frequency, then population size may have increased more than three-fold during the Middle Period (see Figure 1.2 for local chronologies). Additional evidence that the number of permanent residential sites expanded rapidly around the coastal zones of the three largest of the Northern Channel Islands (Arnold 2001; Kennett 2005; Kennett et al. 2013) accompanied by evidence of environmental in-filling and increased occupation of lower ranked habitats (Kennett et al. 2009; Winterhalder et al. 2010) further supports the assessment that a major demographic transition occurred ca. 1500 cal B.P.

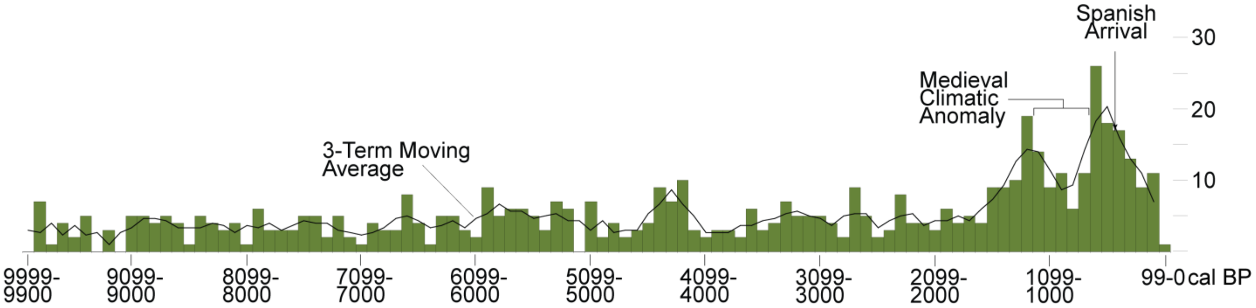


Figure 1.3. Northern Channel Islands calibrated radiocarbon component frequencies, as a proxy for population density 10,000 - 0 cal B.P. Graph adapted from Culleton et al. 2006a.

The archaeological record on the Northern Channel Islands immediately prior to and after this period of significant population growth ca. 1500 cal B.P is poorly known. Most research efforts have concentrated on the earliest periods of occupation during the Terminal Pleistocene/Early Holocene (Erlandson 1993, 1994, 2002; Erlandson and Rick 2002b; Erlandson et al. 1996, 2005a, 2005b; Johnson et al. 2002; Orr 1968; Rick et al. 2001, 2005a) and the emergence of complexity during the latter portion of the Late Holocene (Arnold 1992, 1996, 2001; Arnold et al. 1997; Erlandson and Jones 2002; Erlandson and Rick 2002a; Erlandson et al. 2005b). Jeanne Arnold (1987, 1992, 1995, 2001, 2004) has conducted some of the most comprehensive research on Chumash culture and settlement on Santa Cruz

Island. However, this research has focused primarily on large village sites that date within the last 1500 years, with comparatively little attention given to the earlier half of the Late Holocene, or site types other than villages (Rick et al. 2005a). Despite this overall paucity of archaeological data pertaining directly to the temporal interval under consideration (3000 to 1000 B.P.), comparison of the preceding and following temporal periods demonstrates a general transition in subsistence and settlement patterns (See Figure 1.2 for local chronologies).

Archaeological deposits dating to the Middle Holocene/Early Period, and prior to significant population growth, are widely distributed across the island landscape, found along the coastlines and throughout the interior of Santa Cruz Island (Clifford 2001; Glassow 1993; Kennett 2005; Perry 2003; Wilcoxon 1993). These deposits appear to represent an equally wide variety of site types, ranging from small ephemeral deposits, suggesting single usage, to large, deeply stratified sites representing repeated use or more permanent settlement (Kennett et al. 2007:356). Kennett et al. (2007:359) suggest that small groups of 50-100 people lived in semi-permanent settlements in optimal locations on Santa Cruz Island and that the total number of island inhabitants did not exceed 400-600 individuals (Kennett 2005:153). Settlement locations and faunal assemblages suggest that plant foods from the interior of the island complemented the protein-rich marine foods, particularly shellfish (Kennett et al. 2007:356). Bioarchaeological data from Early Period burials on nearby Santa Rosa Island support this subsistence assessment. Human remains that date between 4000 and 3000 B.P. (late Early Period) have a very high incidence of dental caries, likely due to a carbohydrate-rich diet (Walker and Erlandson 1986). This evidence is supported by the presence of milling equipment and digging stick weights with burials and at sites in the interior (Kennett

2005:148). In contrast, stable nitrogen and carbon isotopic analysis of Early Period burial populations on Santa Cruz Island and Santa Rosa Island also reveal a relatively high dependence on marine foods (Walker and DeNiro 1986). Thus it appears that during the Early Period people moved periodically between the coast and the interior, supplementing a diet rich in shellfish with seasonally available plant foods (Kennett 2005:153; Kennett et al. 2007:362).

These patterns contrast sharply to those evident during the latter portion of the Late Holocene/Late Period. On Santa Cruz Island, archaeological deposits dating to this temporal period, and after significant population growth, are concentrated along the coastline. Substantial domestic features, high-density midden deposits and greater artifact diversity at these sites suggest increased sedentism (Kennett et al. 2009:308). Arnold (1992:66) estimates Late Period villages consisted of 50-250 people on average and that the total number of island inhabitants living in ten primary villages reached 1500-1700 individuals (Arnold 2001:31). Settlement locations and faunal assemblages indicate an increased focus on marine resources (Colten 2001; Glassow 1993; Perry 2003). Bioarchaeological data from Late Period burials on nearby Santa Rosa Island also support this assessment. Human remains that date between 800 and 168 B.P. (Late Period) had a relatively lower incidence of dental caries than earlier (Walker and Erlandson 1986). Furthermore, nitrogen and carbon stable isotope analysis of burials from Santa Cruz Island that date between 800 B.P. and 168 B.P. (Late Period) suggest an increased dependence on marine resources later in time (Walker and DeNiro 1986).

Although very limited data pertain directly to the temporal interval in question, 3000-1000 B.P., immediately prior to and during significant population growth on Santa Cruz

Island, it is evident that this was a transitional period. Patterns in the archaeological and bioarchaeological data reflect a great deal of contrast between foraging behaviors of the Early and Late Periods. The evidence suggests significant mobility and dietary shifts occurred on Santa Cruz Island during the Middle Period (2440-800 B.P. in the local chronology), particularly in the relative contribution of carbohydrates (plants) and protein (meat) (Walker and Erlandson 1986). Along with this shift, specialized tools for exploiting the marine environment first appear during this period, including the plank canoe (between 2000 and 1500 B.P., see Gamble 2002; Arnold 2007), the single-piece shell fishhook (between 2500 and 2100 B.P., see Rick et al. 2002b), and other specialized fishing equipment (Glassow 1977; Salls 1988).

Broad Research Questions

In order to evaluate whether risk-reducing foraging behaviors contributed to macro-demographic shifts, it is necessary to characterize how people moved about the landscape and exploited the resources available to them throughout the Middle Period, prior to and concurrent with early evidence of population growth. This requires that we answer basic questions regarding local subsistence and mobility practices, such as: What foods were people eating? To what extent did people rely on marine versus terrestrial resources? How varied were subsistence practices through time and across space? Did people narrow or diversify their resource base through time? How predictable were plant and animal resources across the Island? How did climatic variation affect the distribution and predictability of these resources? Once these basic questions are answered we can begin to address more complex questions linking subsistence practices to social, technological, and demographic developments. What was the nature of foraging behaviors prior to, coincident with, and immediately after initial evidence of population growth? What specific foraging behaviors were adopted and what were the energetic consequences of those behaviors? Did changes in foraging behavior reduce population mobility, increase access to resources high in energy-producing fats and carbohydrates, or decrease seasonal food risk? If so, what was the timing of new risk-reducing foraging behaviors relative to initial evidence of population growth, and how does this timing relate to technological developments and climatic shifts?

Study Area

Addressing these questions requires multiple lines of evidence that are directly relevant to the reconstruction of foraging behaviors. This evidence includes rigorous chronological control on century and seasonal timescales, in addition to well preserved archaeobotanical and zooarchaeological materials. Santa Cruz Island is particularly well suited for recovery of these essential data. Unlike the mainland California coast, archaeological sites on the Island demonstrate a remarkable degree of stratigraphic integrity due to the absence of burrowing animals and land development. Furthermore, Santa Cruz Island is the largest and most ecologically diverse of the four Northern Channel Islands, offering prehistoric residents access to a similar diversity of marine and terrestrial microenvironments as those enjoyed by their mainland relatives.

Nonetheless, plant and animal food resources available to the prehistoric inhabitants were distributed unevenly across the landscape 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 types of nearshore marine habitats (Kennett 2005:29). These coastal habitats provide an assortment of protein-dense resources, often located away from terrestrial microenvironments that provide a great diversity of carbohydrate-rich plant resources offering seasonally high carbohydrate rewards. The relative dietary contributions of these different resources depended on their relative abundance, distribution, and accessibility throughout the year (Kennett 2005:38).

All my field studies focus on the Cañada Christy watershed in the western sector of Santa Cruz Island (see Figure 1.4). This portion of the island incorporates a cross-section of all interior and coastal environments available for resource exploitation on the island within a naturally defined geographic area. 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) (Junak et al. 1995:3). Within the geographic confines of this watershed, 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, as well as productive stretches of sandy beach, rocky intertidal reefs, and kelp forest. The abundance of archaeological sites, denoted by shell midden on almost every low-lying knoll, speaks to the importance of the Cañada Christy watershed throughout prehistory. From the initial occupation of Santa Cruz Island (Gusick 2012:91-92) until historic abandonment by the indigenous inhabitants, this portion of the island was a focus of human habitation.

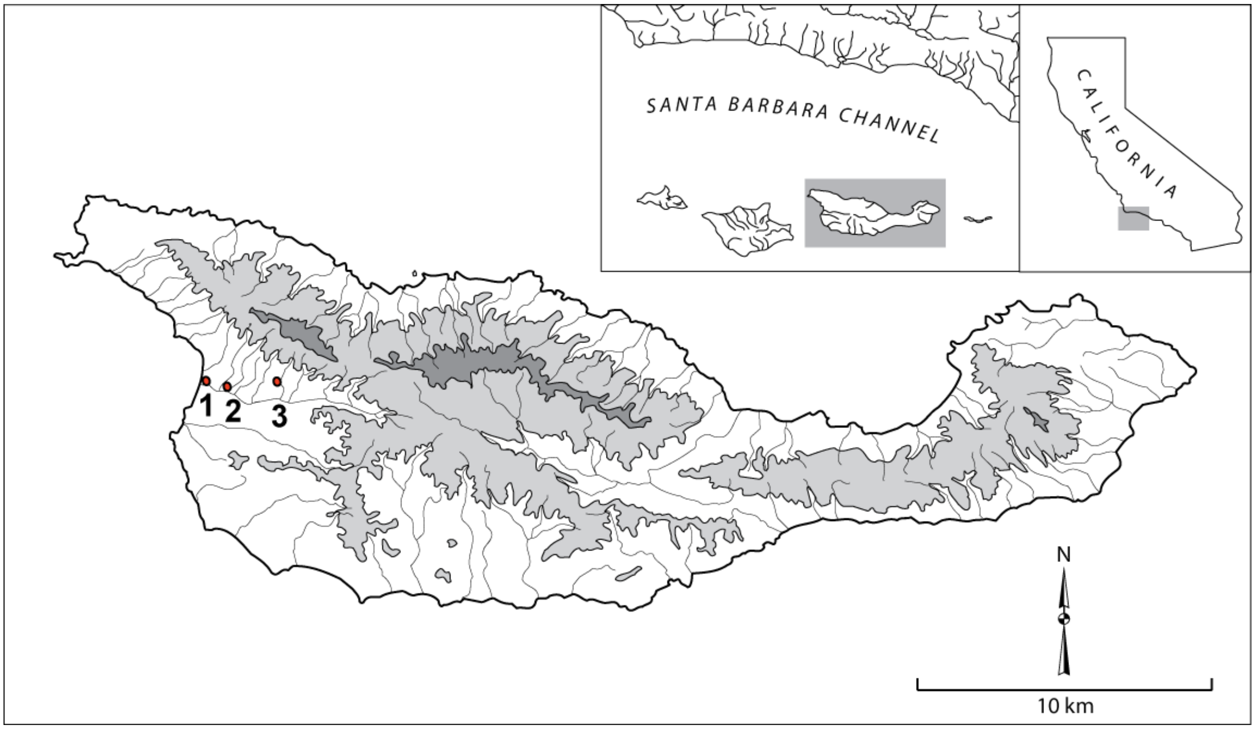


Figure 1.4 Location of the three archaeological sites considered on Santa Cruz Island, California. Light shading is land above 250 m and dark shading is above 500 m elevation. The three archaeological sites considered in this dissertation are: 1) CA-SCRI-236, 2) CA-SCRI-823, and 3) CA-SCRI-568.

Research Aims and Significance

This research contributes significantly toward understanding the context in which significant population growth occurred in hunter-gatherer populations on the Northern Channel Islands, and more generally, elsewhere, prior to the adoption of plant or animal domesticates. The integration of diachronic subsistence data (macrobotanical and faunal) and geochemical data (stable oxygen isotope [$\delta^{18}O$] of prehistoric mollusk shells) provides a unique methodological approach for investigating the role of seasonal subsistence stability in population regulation. Definitive assessment of season of occupation has long been elusive; however, the intensive application of oxygen isotope analysis in this research will clarify this important aspect of foraging behavior. The incorporation of data from floral remains is a novel approach for this region, where faunal analysis dominates subsistence studies. Although these types of data are rarely considered together in California archaeology, they bear directly on the research questions, as they represent the direct residues of past subsistence economies. This study highlights the importance of analyzing and integrating both faunal and macrobotanical data in order to answer questions of resource exploitation and dietary sufficiency. These key analyses will provide a basis for understanding the interrelationship between prehistoric hunter-gatherer population demography and risk-averse foraging behaviors on Santa Cruz Island.

CHAPTER 2

THE EVOLUTIONARY ECOLOGY OF POPULATION DYNAMICS AND FORAGING BEHAVIOR IN HUNTER GATHERER SOCIETIES

The relationship between foodways, the environment, and human demography has long been recognized and theorized in anthropological and archaeological discourse. As indicated in Chapter 1, research worldwide demonstrates that throughout most of our existence as a species, humans lived as egalitarian foragers in small, sparsely distributed family groups that moved frequently in response to the seasonal distribution of food resources. Inspired by Malthus and Boserup, archaeologists often interpreted this slow rate of hunter-gatherer population growth throughout prehistory as a natural product of carrying capacity constraints on technologically archaic peoples, alleviated only by the adoption of agriculture (Cohen 1980:278). However, it is now clear that in some cases, such as among the Chumash of the Santa Barbara Channel Region, significant intrinsic population growth did occur in prehistory independent of agriculture. New evolutionary perspectives on the role of energetics derived from the field of human reproductive ecology provide a more nuanced view of biological mechanisms at least one step removed from strict Malthusian controls that regulate human demography (Cohen 1980:278). This theory links dietary and foraging behaviors that capture energy from the environment and allocate it formetabolic purposes that may facilitate population growth within hunter-gatherer populations.

In this chapter, I integrate the energetic focus of reproductive ecology with a behavioral ecological perspective to provide a framework for understanding the timing and nature of prehistoric population growth on the Northern Channel Islands. In order to provide context for the development of this framework, I first consider how archaeologists conceive of, reconstruct, and understand evidence of prehistoric demographic shifts.

Defining and Evaluating Prehistoric Demographic Shifts

As evidenced throughout the early occupational sequence on the Northern Channel Islands, imperceptibly slow population growth defined human demographic patterns throughout most of prehistory (Cohen 1980:275; Pennington 2001:170). Ethnographic data from extant foragers suggest that mean annual population growth rates vary greatly between hunter-gatherer populations, from as low as 0.5 percent for the Ju/'hoansi of Southern Africa (Howell 1979) to 2.5 percent for the Ache of South America (Hill and Hurtado 1996). Yet, even if the Ju/'hoansi's very low growth rate of just 0.5 percent characterized prehistoric hunter-gatherer societies it is certain that the world's population "should have reached one billion long before it actually did in the early nineteenth century" (Kelly 2013:166). Genetic data suggest that prior to 10,000 years ago (and the widespread adoption of agriculture) population growth rates for prehistoric foragers did not exceed 0.008 percent (Pennington 2001:195). Thus, throughout most of prehistory, births and deaths must have been closely balanced (Pennington 2001:195). This assessment is supported by more recent analyses of hunter-gatherer population structure demonstrating that despite a great deal of variation documented in ethnographic studies (see for discussion Kelly 2013:167; Hamilton and Buchanan 2007:2200), on average, ethnographic foraging populations experience low reproductive rates that are quite similar to population replacement rates (Hamilton and Buchanan 2007:2200).

Evidence of significant prehistoric population growth clearly violates the expectation of low population growth within foraging societies and has stimulated a great deal of anthropological discourse (e.g., Dumond 1974; Hassan 1973; Hayden 1972; Polgar 1972; Ward and Weiss 1976; Zubrow 1976). Discussion and understanding of prehistoric demographic shifts have long focused on the development of agriculture. However, archaeological evidence of regional population growth did occur in the prehistoric past without incorporation of domesticated plants (e.g., Flannery 1969). Effective reconstruction of population size often thwarts our understanding of prehistoric demographic shifts among hunter-gatherers (Reide 2009:310). All archaeological proxies of prehistoric demography, whether based on osteological or settlement data fall short of modern demographic standards (see Paine 1997:1-7).

Measuring Prehistoric Demographic Shifts

Summed radiocarbon probability distributions and component frequencies provide an increasingly important measure of prehistoric population size used by New World archaeologists (e.g., Rick 1987; Barrientos and Perez 2005; Buchanan et al. 2008) and Old World archaeologists (e.g., Bocquet-Appel and Demars 2000; Bocquet-Appel et al. 2009; Gamble et al. 2004, 2005, 2006; Gkiasta et al. 2003; Housley et al. 1997; Kuper and Kröpelin 2006; Riede 2009; Shennan 2009; Shennan and Edinborough 2007; Shennan et al. 2013). Rather than assuming a linear relationship between numbers of radiocarbon dates from archaeological site components and human population numbers, this method regards major peaks in probability or frequency as an indication of increased amounts of archaeological materials and, by extension, higher population densities. Conversely major troughs are thought to reflect diminished amounts of archaeological materials and lower population density, with the steepness of the slope of an increase or decrease showing the rapidity of the population rise or fall (Bamforth and Grund 2012:1769).

However, increasing use of this technique highlights additional limitations due to factors affecting the preservation and recovery of materials suitable for radiocarbon dating from archeological contexts. Apt criticism emphasizes the tenuous assumption that the number of dated entities (sites, components, or features) in the study universe is complete, or that a representative sample of those entities can be derived. As with all archaeological datasets, taphonomic processes (see Surovell and Brantingham 2007; Surovell et al. 2009) and sampling biases (see Ballenger and Mabry 2011; Louderback et al. 2011; Reide 2009; Kennett et al. 2014) complicate demographic interpretation of summed radiocarbon probability distributions and component frequencies. The quality of radiocarbon datasets varies greatly and there are no set standards for chronometric hygiene (see for discussion Kennett et al. 2014). Recent research also demonstrates that the radiocarbon calibration curve and calibration process affect the form of summed probability distributions (see Bamforth and Grund 2012; Miller and Gingerich 2013). These potential problems with the use of summed radiocarbon probability distributions and component frequencies indicate that use of this method as a proxy for prehistoric population growth and as a foundation for demographic interpretation is far from straightforward (Louderback et al. 2011:369).

Nonetheless, long continuous time-series records provided by summed probability radiocarbon distribution and component frequencies based on an ever-expanding and increasingly precise radiocarbon record retain obvious utility in archaeology. Continued and increasing use of this method in archaeological research, despite recognition of the limitations identified above, underscores the fact that accumulating large numbers of dates gives chronological resolution to regional scale demographic changes unattainable by other means (Reide 2009; Shennan et al. 2013; Williams 2012). Rather than abandoning the method altogether, researchers have made great efforts to carefully evaluate (chronometric hygiene) and improve the quality of regional radiocarbon databases (Kelly et al. 2013; Kennett et al. 2014), correct for taphonomic biases (e.g., Miller and Gingerich 2013; Surovell et al. 2009), determine appropriate sample sizes that minimize sampling bias (e.g., Williams 2012), reduce the temptation to over-interpret fluctuations evident in the radiocarbon record (e.g., Kerr and McCormick 2014), and evaluate the potential influence of the calibration process (Bamforth and Grund 2012). These researchers establish that judicious and critical interpretation of variation in the frequency of radiocarbon dates over time remains a viable and informative proxy for identifying macro-demographic shifts in human prehistory.

Prehistoric Population Growth on the Northern Channel Islands

Archaeologists working on the Northern Channel Islands of California identify significant population growth on the Northern Channel Islands beginning ca. 1500 cal B.P. based on the increasing frequency of radiocarbon-dated site components (e.g., Arnold 1992; Culleton et al. 2006a; Glassow 1999). The most recent evaluation of this dataset (depicted in Figure 1.3) by Culleton et al. (2006a), relies on over 500 radiocarbon dates (as recommended by Williams 2012), carefully considers and controls for potential influence of the calibration curve (as recommended by Bamforth and Grund 2012), and bins the date frequencies in 100-year intervals (as recommended by Kerr and McCormick 2014). This database is large enough to counteract the effects of standard deviations and other errors while maintaining a broad regional approach. The overall quality of the database is also high. Examination of the cumulative distribution of radiocarbon-dated components for the Northern Channel Islands suggests that, if population size can be even roughly measured from site component frequency, then population size may have increased more than three-fold during the Middle Period (see Figure 1.2 for local chronologies) (Kennett 2005:155). Similar trends evident in radiocarbon records throughout coastal California (see Glassow 1999) lend confidence to this assessment.

This evidence of significant population growth among a prehistoric foraging population begs the question, how and why does population growth occur among hunter-gatherers? This demographic shift clearly deviates from the patterns that long governed human demography. Yet, at the time of Spanish contact, population estimates suggest that the Chumash of the Santa Barbara Channel Region lived at population densities as high as 843-900 persons/100 km^2 (Keeley 1988)—among the highest recorded in California (Moratto 1984:2) and indeed, reported for hunter–gatherers worldwide (Kelly 2013)—with no addition of domesticated plants or animals to their foraging economy. How do we understand such dramatic prehistoric demographic shifts in the absence of agriculture?

Past Approaches to Understanding Prehistoric Demographic Shifts

Until the 1980s Malthusian assumptions dominated archaeological discourse on prehistoric demography and demographic shifts. Malthus considered human population size to be a product of uncontrolled fertility limited by positive checks operating via mortality (Wood 1998:104). Population growth was held in check by only external factors (famine, disease, war, homicide), old age, and conscious restraint (Bentley 1996:26). Thus, early anthropological demographers (e.g., Birdsell 1968; Carr-Saunders 1922; Divale 1972;

Dumond 1975; Hayden 1972; Krzywicki 1934; Pearl 1939; Polgar 1972) envisioned prehistoric populations characterized by both high levels of fertility and mortality, which was mediated by the availability of food as well as cultural practices such as abstinence, infanticide, abortion, or both (Bentley 1996:26).

Following this logic, initial efforts to understand prehistoric hunter-gatherer demography focused on population density as a product of the local carrying capacity of the environment (e.g., Casteel 1972; Divale 1972; Dumond 1975; Saunders 1976; Zubrow 1976). Researchers sought to demonstrate empirical relationships between the abundance of food in the environment and human population densities (e.g., Baumhoff 1958, 1963; Birdsell 1953, 1958; Thompson 1966; Rogers 1969; Thomas 1981). These studies implicitly invoked the Malthusian premise of density dependent limits on a population's growth rate (Kelly 2013:184), in which population size rises exponentially (due to high fertility) until restricted by the bounds of natural resources (due to high mortality) (see Kelly 2013:184-185 for further discussion). Malthus assumed that the per capita supply of food decreases as the population grows (Wood 1998:104); therefore, as population levels neared the carrying capacity of the environment, mortality checks reduced population size. Cultural mechanisms were considered especially important among hunting and gathering populations since this mode of subsistence and the carrying capacity of the environment dictated low population numbers (Bentley 1996:26). Birdsell (1968) argued, based on high (and uncontrolled) fertility deduced from genealogical data from Australian aborigines and early post-contact ethnological observations, that high rates (15-50 percent) of abortion and infanticide defined and limited long-term population growth rates for prehistoric hunter-gatherers (Bentley 1996:26; Cohen 1980:283).

Given broad acceptance of Malthusian checks on prehistoric hunter-gatherer populations, it is not surprising that consideration of prehistoric demographic shifts focused primarily on the transition to agriculture. Archaeologists, confronted with evidence of increased population size and technological innovations associated with the adoption of agriculture, integrated the basic assumptions of Malthus and the tenets of Boserup (1965). Discussions of the demographic consequences of agriculture emphasized the higher population growth rates produced by the advent of agroeconomies (Shennan 2009:340). Boserup suggested that higher population density and increasing population pressure stimulated technological development. Innovation, in turn, led to a relaxation of positive Malthusian checks and then fueled subsequent increases in population (Bentley 1996:28). Thus, interpretation of carrying capacity of the environment shifted to include consideration of prehistoric people's technological capacity to extract resources from the environment. No longer strictly constrained by Malthusian limits on total available food, researchers (e.g., Cohen 1977) posited that the rate of prehistoric population growth prior to the adoption of agriculture could be attributed to the slow rate of technological progress (Keeley 1988). Thus, the slow rate of hunter-gatherer population growth throughout prehistory was easily comprehended as long as archaeologists invoked Malthusian constraints on technologically primitive man as an explanation (Cohen 1980:278).

However, publication of ethnographic and demographic data for the Dobe !Kung San shifted this paradigm. Evidence of low fertility and low mortality accompanied by a negligible rate of abortion and infanticide in this forager society (Howell 1979) painted a very different picture of demographic patterns among foraging populations (Bentley 1996:28). These data suggested to researchers that rather than being constrained by strict

Malthusian checks some hitherto unknown physiological constraints influenced the rate of population growth in the prehistoric past (Cohen 1980:286). Thus, more recent anthropological demographic studies (e.g., Campbell and Wood 1988; Hill and Hurtado 1996; Wood and Weinstein 1988; Wood 1990, 1994) consider the existence of regulatory mechanisms at least one step removed from both strict Malthusian controls and Boserupian technological determinism (Cohen 1980:275). It is increasingly clear that understanding the biological mechanisms that regulate population growth among human foragers is crucial for a more complete understanding of prehistoric demographic shifts.

An Evolutionary Approach to Prehistoric Demographic Shifts

As with all biological populations, human demography is regulated by three mechanisms: migration, fertility, and mortality. There has been a tendency in the archaeological literature to view intrinsic demographic changes that took place in prehistoric societies in either/or terms: either fertility increased or mortality decreased. However, while reducing mortality rates can accelerate population growth, low mortality by itself cannot result in high rates of population growth without high fertility (Surovell 2000:495). Indeed, these two mechanisms are far from mutually exclusive (e.g., Sellen and Mace 1997, 1999; Pennington 1996) and may even have been complementary in prehistoric societies (Bentley et al. 2001:204). Both are tied biologically and inextricably to the availability and stability of food resources year-round. Recent ethnographic studies concerned with demography support the idea that population regulation and growth in hunter-gatherer societies are linked to patterns of subsistence and reproduction through behaviorally and physiologically mediated trade-offs (Bailey et al. 1992; Ellison 2008; Panter-Brick et al. 1993; Valeggia and Ellison

2001, 2004). Thus, although macro-scale population level shifts may occur due to changes in foraging behavior, they are considered unintended outcomes, rather than goals of regulation (Voland 1998:357).

Cultural controls on fertility, such as contraception, abortion, taboos on intercourse, and infanticide, have long been privileged in discussion of hunter-gatherer demography (see for discussion Ellison 2001a:99-106; Caldwell and Caldwell 2003:199; Kelly 2013:186-193). However, there is very limited evidence that conscious controls on fertility are as common as early researchers assumed or that they are practiced frequently enough within natural fertility societies to be significant at a macro-demographic scale (see for further discussion Caldwell and Caldwell 2003:199; Hamilton 1981:119, 123; Handwerker 1983:16-17; Kelly 2013:212; Marlowe 2010:140; Howell 2010:23). Furthermore, the simplistic Malthusian-inspired assumption that cultural controls on fertility were even necessary in our hunter-gatherer past, may very well be putting “the cart before the horse” (Kelly 2013:193). More important are the “variables and processes that, in a foraging environment, control *fecundity*,” the biological capacity to reproduce (Kelly 2013:193). In this research, I focus on the array of biological mechanisms and associated foraging behaviors known to modulate fecundity in response to ecological contexts. This understanding is derived largely from the field of reproductive ecology.

Reproductive Ecology and Human Energetics

The foundations for understanding demographic processes, whether in prehistory or the present, lie in Darwinian evolutionary theory (Shennan 2009:339). Human reproductive ecology focuses on the way in which evolution has shaped human reproductive physiology and the energetic trade-offs between reproductive effort and other competing domains of physiology (Ellison 2001a:3, 2008:198). Theoretical models based on ethnographic and clinical research posit that selection favors reproduction only if a woman’s nutritional status is substantially adequate, or there is some indication of the potential for sustaining an ongoing investment, or both (Ellison 2003:345). Although energy is not the only limiting resource considered important in optimizing reproductive effort, it is the principal one (Ellison 2001a:168-169). This perspective stresses the management of energy and energy allocation trade-offs that happen in dynamic, temporal relationship to one another (Ellison 2008:197). Fecundity is thus a function of trends in energetic status, limited either by constraints on energy input or by constraints on energy expenditure (Ellison 2008:175).

In reproductive ecology, discussions of fecundity revolve almost exclusively around factors affecting women. Considerably less attention and less research has been devoted to male reproductive ecology (Bentley 2001:205; Ellison 2008:190; Kelly 2013:293). Although this area merits further research, it is evident that female fecundity has a much greater impact on population level fertility than does male fecundity, and that female reproductive effort is more sensitive to energy availability than is male reproductive effort (Bentley 2001:205; Ellison 2008:190; Kelly 2013:293). This assertion follows logically from evolutionary theory because women are burdened physiologically with the direct metabolic cost of gestation. Thus, energy availability becomes the most important limiting factor for their reproductive success (Ellison 2008:190; Jenike 2001:218).

The responsiveness of female reproductive function to energetic conditions is now widely recognized. Empirical studies suggest that nutrition and activity levels work synergistically to affect a woman’s energy status, balance and flux (Ellison 2003:343). These three dimensions (energy status, balance and flux) refer, respectively, to how much energy a woman has stored on her body at any given moment, whether a woman is expending more or less energy than she is consuming, and the rate at which energy is coming in and going out. Although often correlated, these three aspects of human energetics are logically separable and can vary independently (Ellison 2003:343). Together, these factors inform women's fecundity via complex hormonal pathways (see Ellison 2001a:201-208). Low energy status, negative energy balance, and high energy flux, whether produced by a heavy workload, a lean season, nutritional insufficiency, or any combination thereof, can significantly depress female fecundity and overall population fertility (Ellison 2008:180).

High Energy Expenditure. In the 1970s researchers observed that female athletes in endurance sports, such as marathon running, ballet, and gymnastics ovulate irregularly, if at all (Jasienska 2001:61; Kelly 2013:197). Since then, numerous studies have demonstrated the suppressive effect of high energy expenditure on women's ovarian function and reproductive capacity (Elias and Wilson 1993; Ellison 1990). In many cases, the effects of high energy expenditure are confounded (and compounded) by the effects of negative energy balance and inadequate energy intake (Ellison 1990, 1994; Ellison et al. 1986, 1989, Ellison 2001a:184-185), such as is the case among Tamang agropastoralists in Nepal. Researchers working with the Tamang documented significant evidence of reproductive suppression only among women for whom heavy workloads were associated with weight loss during the leanest season of the year (Panter-Brick et al. 1993). However, additional studies indicate that high levels of aerobic activities may reduce female fecundity even when isolated from negative energy balance or low energy status (Bullen et al. 1985; Ellison and Lager 1986). For example, female athletes who have sufficient energy stores and eat a nutritional diet, may still experience reduced ovulation due to their high energy flux (Ellison 2001a:174-175, 182).

Similar effects have been documented among rural Polish agriculturalists (Jasienska 1996; Jasienska and Ellison 1993, 1998) and Bolivian agropastoralists (Vitzthum et al. 2009) who show seasonal ovarian suppression in response to increases in workload despite relatively high nutritional status and stable weight. In both of these cases, high-energy expenditure associated with subsistence work influenced ovarian function independently of energy balance or energy status (Ellison 2003:343). Thus, these studies show that suppression of fecundity does not only occur among women living under marginal energetic circumstances.

Periodic Intake Restriction. Many foraging and horticultural societies suffer from seasonal and inter-annual fluctuations in food resources (Bailey and Peacock 1988; Bailey et al. 1992; Hill et al. 1984; Hurtado and Hill 1990; Jenike 1995, 2001). Such periods of low food intake can restrict energy availability and negatively affect ovarian function, which responds to changes in energy availability over relatively short timescales (Bentley et al. 2001:206; Ellison 2008:176). As a result, when energetic conditions in the environment change seasonally, women's reproductive capacity changes as well (Bailey et al. 1992; Ellison et al. 2005). A nearly universal pattern of human birth seasonality evident in non-western populations, as diverse as arctic Eskimos and New Guinea highlanders, provides one of the clearest manifestations of this profound relationship (Ellison 2001a:194). Anthropologists have documented a strong synchronous association between seasonal variations in female nutritional status and profound birth seasonality among !Kung San foragers (van der Walt et al. 1978), nomadic Turkana pastoralists (Leslie and Fry 1989), and Bangladeshi agriculturalists (Becker et al. 1986).

For the Lese, subsistence farmers in the Ituri Forest, researchers have developed a more explicit model of birth seasonality, linking patterns of rainfall to patterns of human births through resource availability, nutritional status, energy balance, and ovarian function (Ellison 2001a:198). Lese women experience seasonal changes in energy balance owing primarily to fluctuations in the seasonal availability of food (Bailey et al. 1992; Bentley et al. 1998; Ellison et al. 1989). Sustained periods of weight loss (just 2 kg is sufficient to produce statistically significant impacts) during the pre-harvest “hunger season” are paralleled by steady declines in ovarian function, with fewer successful conceptions likely to occur during periods of restricted or low energy intake (Bailey et al. 1992; Ellison et al. 1989). Fecundity, and hence births, are seasonal only to the extent that energy balance is seasonal; thus, it is clear that energy balance bears a strong influence on women’s reproductive capacity (Ellison 2001a:201). Clinical research indicates that the suppressive effects of negative energy balance occur even when isolated from low energy status and high energy flux and persist even after intake restriction is alleviated (Ellison 2001a:18).

Macronutrient Imbalance. Dietary composition is another factor that can reduce ovarian function and suppress women’s fecundity (Bentley et al. 2001:207). Energy balance depends, in part, on dietary macronutrient content. Thus, the ratio of proteins, carbohydrates, and fats consumed must also be considered among the factors that influence the amount of energy available to support reproductive function in natural fertility societies. Protein is an essential macronutrient for optimum growth, health, and well-being (Speth 2010:51). However, a diet high in protein and low in energy-dense carbohydrates and fats results in the body using protein as energy. The metabolic costs required for the human body to process energy from protein (Noli and Avery 1988:396) is significantly higher than required to process energy from fats and carbohydrates (Speth 1990:152). Indeed, even if protein supply is unlimited the human body can derive no more than 50% of an individual’s energy from this macronutrient, due to intrinsic limitation on oxygen uptake by the liver (Cordain et al. 2000:688). It is evident that the elevated metabolic costs that accompany high-protein diets exacerbate periodic low-energy intake (Speth and Spielmann 1983) and may result in negative energy balance, regardless of protein sufficiency (Jenike 2001:216). Furthermore, consuming large amounts of lean protein leads to clinical symptoms of protein poisoning, or what was commonly recognized as “rabbit starvation” among early explorers (Speth 2010:76).

Although ethnographic studies rarely translate observations of dietary intake into macronutrient composition (i.e. Hill 1988; Bang et al. 1976, 1980; Bailey and Peacock 1988; Draper 1976), the data available demonstrate substantial variation (Jenike 2001:211). Among the studies that do provide information on seasonal variation, most report diets adequate in protein content during all seasons, but seasonally impoverished in fats and carbohydrates, and hence, energy (Jenike 2001:214). Variation in both the amount and/or macronutrient content of food eaten during seasons of the year may significantly affect fecundity even when the risk of starvation is relatively low (Jenike 2001:212-214; Kaplan and Hill 1992:188). Thus, the relative absence of energy dense macronutrients (fats or carbohydrates) to complement abundant protein is proposed as an important seasonal energy constraint for hunter-gatherers in a diversity of environments (Speth and Spielmann 1983; Headland and Bailey 1991; Jenike 2001:214, 218).

A Brief Review. Human ovarian function varies with energetics in similar and predictable ways across a broad range of ecological, geographical and cultural settings (Ellison 2001a:193). Reproductive ecology clearly indicates that people who experience restricted energy availability related to high energy expenditure, macronutrient imbalance, or periodic intake restriction suffer increased functional, reproductive, and health deficits even when risk of starvation is low (Ellison 1990, 2008; Jasienska and Ellison 1998, 2004; Jasienska et al. 2006; Lager and Ellison 1990). Thus, high population mobility, seasonal food risk, restricted access to resources high in energy-producing fats and carbohydrates, or any combination thereof, are linked to suppressed fecundity and frequent population decrease in hunter-gatherer populations (Ellison 2001b, 2008; Headland and Bailey 1991; Kaplan and Hill 1992).

Foraging Behavior and Human Energetics

It is impossible to isolate the physiology of human reproduction from the human behaviors that inform it. Variation in energy budgets of hunter-gatherers reflects the specific array of foraging behaviors by which they acquire energy from the environment (Ellison 2008:175; Jenike 2001:226). Ecologists have long recognized that shifts in foraging strategies that improve energy status, increase energy balance, and/or decrease energy expenditure can lead to substantial population increases. Thus, how human foragers move about and exploit landscapes directly influences human reproductive efforts and population-level demography.

Mobility and Energy Expenditure. Humans occupy their landscape in a dynamic manner, often altering their mobility patterns in response to environmental, cultural, and economic factors that fluctuate through time (Stein et al. 2003:297). Changes in mobility can set into motion a series of interrelated biological and behavioral changes that affect population-level fertility and mortality patterns (Kelly 2013:212). Ethnographic studies suggest a great deal of variability in the frequency and distance of residential moves employed by hunter-gatherers (Kelly 2013:80-84, see Table 4-1). It is commonly argued that high mobility in hunter-gatherers leads to low fertility (Surovell 2000:495) since fecundity of women could be reduced by hard daily, fat-depleting work of foraging (Shennan 2009:340). Indeed, researchers have documented significant increases in fertility rates as mobile populations become more sedentary (e.g., Binford and Chasko 1976; Ellanna 1990; Gomes 1990; Hitchcock 1982; Roth and Ray 1985). Changes in women's work associated with decreased mobility may influence energetic demands on a woman's body (Kelly 2013:210). This evaluation is compatible with evidence of reproductive suppression in populations where basic subsistence activities necessitate high levels of energy expenditure (see preceding discussion). Conversely, reduction in workload may be associated with increases in fecundity (Shennan 2009:340). For example, Gibson and Mace (2002, 2006) showed that the installation of water taps in an Ethiopian village led to increased fertility as a result of the reduced energy expenditure for women arising from not having to carry water long distances. Similarly, less time spent walking while foraging or moving camp (likely while carrying children) may reduce the aerobic quality of women's work and reduce previously high energy expenditures (Surovell 2000). Thus, significant decreases in population mobility may contribute to decreased energy flux and increased fecundity in foraging populations.

Seasonality and Periodic Intake Restriction. No environment is constant. In addition to interannual variation, seasonal variation may imply the risk of periodic intake restriction. Distinct seasonal fluctuation in the abundance, distribution, and accessibility of plant and animal resources certainly influence the quantity and quality of food available to foragers throughout the year. The "hungry season" is a feature of many foraging societies (Harrison 1988:27). A critical feature of the hungry season is that it typically occurs during the time that extensive energy expenditure is required for food procurement (Harrison 1988:28).

Foragers such as the Jua/’hoan (Hausman and Wilmsen 1984, 1985) and the River Pumé (Kramer and Greaves 2007), who have a more constant diet with less annual or seasonal fluctuation in their food supply, also have significantly higher fertility and lower mortality relative to their closely related respective counterparts, the Jua/’hoansi and the Savanna Pumé (Kelly 2013:210). Along with decreases in aerobic activity, shifts in foraging strategies that alleviate seasonal intake restriction contribute to a more constant energy balance and increased fecundity (Kelly 2013:210).

Food Resources and Macronutrient Imbalance. Both seasonal and spatial variability influence the quality and macronutrient content of food available to hunter-gatherers. Seasonal or chronic restriction in the relative dietary contribution of energy-dense food resources may contribute to macronutrient imbalance. Discussed earlier was the prospect of having to subsist for extended periods on a diet composed largely of lean meat, a problem that repeatedly confronted mobile foraging peoples wherever the climate was markedly seasonal, whether due to annual shifts in temperature, as in temperate and arctic environments, or to marked changes in rainfall over the course of the year (Speth 2010:72). In coastal environments, abundant marine resources, such as shellfish and nearshore fish, provide highly predictable and easily accessible protein-dense dietary staples (Kennett 2005:21). Although seasonal migrations of small schooling fish and aggregations of breeding sea mammals offer essential fats during portions of the year (Kennett 2005:59), these resources are often located away from plant communities that provide seasonally high carbohydrate rewards (Speth and Spielmann 1983). The spatially and temporally patchy nature of energy-dense food resources may contribute to significant macronutrient imbalance despite the steady contribution of major dietary sources of protein. Shifts in foraging strategies that increase the relative contributions of energy-dense food resources contribute to a more constant energy balance and increase fecundity (Jenike 2001:211).

A Brief Review. Human energetics and reproductive effort are biologically linked to human foraging behavior. Decreased population mobility, reduced seasonality in food intake, increased macronutrient sufficiency, or any combination thereof contribute to positive energy status, more constant long term energy balance, and decreased energy flux—any or all of which may increase women's fecundity. Thus, variation in mobility and subsistence strategies can contribute to macro-scale demographic shifts among hunter-gatherers.

An Evolutionary Approach to Prehistoric Human Foraging Behavior

Ethnography, informed by evolutionary theory, is a logical place to draw hypotheses about how and why prehistoric population growth occurred within hunter-gatherer populations. These ideas drawn from ethnography and modern evolutionary research must be tested against the archaeological record (Kelly 2013:270). Although archaeology may not be able to evaluate specific total fertility or mortality rates at a given point in time, it is possible to reconstruct changes in foraging strategies—for instance, changes from dependence on fish to dependence on plants or from high population mobility to low population mobility—that inform these dynamic biological processes (Kelly 2013:270). Coarse as it may be, the archaeological record was nevertheless the product of the behavior of individuals. In this research, I evaluate variation in foraging behaviors likely to influence human energetics and contribute to increased fecundity. Models derived from the field of human behavioral ecology provide a general conceptual framework for the analysis and interpretation of hunter-gatherer foraging behavior in the archaeological record.

Human Behavioral Ecology and Foraging Behavior

Human behavioral ecology focuses on the evolution and adaptive design of human behavior within specific ecological contexts and provides a foundation for understanding dietary and foraging behavior. Models based on ethnographic research and evolutionary theory posit that human foragers should forage optimally, that is, they should seek to maximize the net rate of energy gain. For archaeologists, optimal-foraging models provide the best way to understand variation in hunter-gatherer foraging behavior (Kelly 2013:76). They do so by providing empirically testable models and by opening productive avenues of thought into the relationships among foraging strategies and their energetic efficiencies (Kelly 2013:36). This perspective stresses the dynamic management of human subsistence and mobility trade-offs that occur in temporal and spatial relationship to the abundance, distribution, accessibility, and predictability of food resources.

Human diet has the distinct characteristic of incorporating a broad diversity of plant, animal, and aquatic resources. Archaeologists interpret evidence regarding the array of resources that prehistoric hunter-gatherers choose to exploit (subsistence strategies) and how they choose to exploit those resources (mobility strategies) in light of two key models: 1) the Diet Breadth model (DBM) and 2) the Central Place Foraging model (CPF). Theoretically these two models treat the environment, technology, and behavior of hunter-gatherers as givens; however, their underlying logic can be used to evaluate questions about long-term change in those constraints (Kaplan and Hill 1992:198).

Subsistence Strategies and the Diet Breadth Model. Although foragers exploit a variety of subsistence resources that vary in distribution, abundance, and macronutrient value (Kennett 2005:16), DBM predicts that hunter-gatherers will exploit the combination of foods that maximize the net energy intake or desired macronutrients under a changing set of ecological circumstances (Kaplan and Hill 1992:176-177, 182-184; Kennett 2005:224). Thus, whether a forager's diet is narrow, focused on a few food resources, or broad, incorporating a wide variety of the available foods, depends on how long it takes to find, harvest, and process each food resource (Kelly 2013:47). Changes in diet breadth may reduce fluctuations in long-term energy balance by reducing periodic intake restriction or macronutrient imbalance and hence, potentially increase fecundity.

Mobility Strategies and the Central Place Foraging Model. Human foragers are best described as central place foragers (Kelly 2013:65). Although they may snack on some foods collected in the field, foragers transport a large portion of food resources back to a central location where they are processed and shared (Kaplan and Hill 1992:185; Kelly 2013:65). According to this conceptual model, forager settlement patterns exist along a continuum of residential mobility to logistical mobility, which reflects diet breadth, patch choice, transportation costs, and foraging radius of hunter-gatherer groups. CPF predicts that hunter-gatherers will select settlement locales that maximize foraging efficiency within environments where resource distribution is spatially patchy and temporally uneven (Kennett 2005:225). Thus, changes in relative mobility may reduce fluctuations in both energy flux and long-term energy balance by reducing energy expenditure and facilitating changes in diet breadth that reduce periodic intake restriction or macronutrient imbalance and hence, potentially increase fecundity.

Risk-Reducing Foraging Behavior

Both the Diet Breadth and the Central Place Foraging models are based on the premise that long-term rate maximization is the goal of human foragers. However, foraging behavior is also sensitive to short-term spatial and temporal variation in food resources (e.g., Cashdan 1992). Various aspects of natural variation in resources (i.e., intensity, frequency, or predictability) contribute to food risk (Kelly 2013:68-69). Foragers who adjust their behavior to reduce expected variation are said to be risk-averse (Kaplan and Hill 1992:188). Human foragers can reduce food risk (overall or in terms of macronutrient content) in at least three ways, including: 1) shifts in diet breadth, 2) food storage, and 3) food redistribution via sharing or trade (Kaplan and Hill 1992:188). All of these strategies may entail additional costs, reduce the long-term rate of food acquisition, or both (Kaplan and Hill 1992:188). These changes may be affected through diversification or specialization (Betts and Friesen 2004:359; Kaplan and Hill 1992:188; Stiner et al. 2000; Stiner 2001). Diversification implies inclusion of a broader range of resources (including traded food resources, Kennett 2005), whereas specialization implies focus in the exploitation of a narrow range of resources potentially available in the environment (Betts and Friessen 2004). Although many scholars consider such changes in diet breadth to be an indication of intensification, it is important to note that both diversification and specialization may occur independently of increased expenditure of energy per capita *sensu* Boserup (1965).

Variation in diet breadth occurs for a wide variety of economic and ecological reasons (Winterhalder and Goland 1997) and does not necessarily imply conscious desire to reduce risk (Kelly 2013:70). For specialization to be considered a risk-reducing strategy, the focal resources must be more reliable, storable, or otherwise able to decrease periodic intake restriction or macronutrient imbalance. Similarly, in order for diversification to be considered a risk-reducing strategy, the novel resources introduced must alleviate periodic intake restriction or macronutrient imbalance. Although specialization and diversification are often considered to have an inverse relationship (Betts and Friessen 2004:358; Binford 2001:240), these risk-reducing strategies exist along a continuum and cannot be considered mutually exclusive (Betts and Friessen 2004:359). Moreover, they may operate independently within different classes of resources, i.e., diversification in exploitation of plant resources accompanied by specialization in marine animal resources. Specialization and diversification operating in concert or separately could significantly alter mobility strategies and energy expenditure, seasonal food risk and energy status, as well as access to energy-producing fats and carbohydrates and energy balance.

Specialization. Specialization effectively reduces subsistence diversity and diet breadth (Binford 2001:420); however, it is an effective risk-reducing strategy especially as investment in new technologies and storage increase stability in resource availability (Betts and Friessen 2004:358; Cashdan 1992:248). Independent of storage, specialization may also decrease macronutrient imbalance if the specific taxon focused upon increases dietary access to fats or carbohydrates. Although evidence of specialization figures prominently into debates regarding the transition to agriculture, there is abundant evidence of hunter-gatherer resource specialization in association with high population density. Northwest Coast societies are noted for specialized subsistence practices that focused on salmon production (Ames 1994). Similarly, Bettinger (1976, 1977) documents specialization in piñyon exploitation potentially correlated with local population increase in the Owens Valley. In other parts of California, specialized acorn production has also been associated with population growth

(Walker 2006). Specialization—particularly in the case of aquatic or plant resources—may correlate temporally with evidence of technological innovation that reduces the cost of capture, processing, or transport (Betts and Friessen 2004:358). Leaving aside shellfish, aquatic resources tend to be costly, requiring ocean-going boats, nets, traps, hooks, and/or lines (Kelly 2013:45). Focused exploitation of nuts or seeds that may be obtained in bulk and stored is an effective means of increasing seasonal resource stability (Bettinger 1987:126). However, this strategy also involves many costs. Increasingly specialized use and storage of food resources results in the accumulation of food at one or more locations, thus increasing the environment's patchiness, effectively encouraging decreased residential mobility (Kelly 2013:103-104; Madsen et al. 1996). Additional costs involved in the construction and maintenance of storage facilities may also encourage decreased mobility (Kelly 2013:103-104). Furthermore, field processing of large quantities of staple resources, particularly acorns and mussels, is also generally more costly than collecting and processing such resources within the foraging radius of the residential base (Bettinger et al. 1997:897). Therefore, residential bases may become increasingly tethered to locations where key staples are abundant, whereas logistical camps may be associated with the location and season of other resources (Bettinger et al. 1997:897). However, the unique characteristics each staple resource (animal or plant) may force deviation from these expectations, depending on what kinds of resources were exploited, as well as the particular predictability, patchiness, and distribution of each resource.

Diversification. Diversification has long been recognized as an important risk-reducing strategy. As early as 1968, Binford proposed substantial diversification of hunter-gatherer diets in Europe at the end of the Paleolithic. Similarly, Flannery (1969) argued that local increases in diet breadth, mainly through adding new species to the diet, in foraging societies of the late Epipaleolithic, facilitated population increase. Brian Hayden (1981) proposed that hunter-gatherers purposefully diversify their resource base, making it more stable and reliable. However, diversification relates not only to an increase in the number of resources, but also to an emphasis on novel resources (Morrison 1994:144). Emphasis on a larger quantity of less variable, although potentially lower-ranked resources (in terms of DBM), is a risk-averse subsistence strategy with explicit implications for the archaeological record (Kaplan and Hill 1992:188; Reitz and Wing 2008). Diversification may correlate temporally with evidence of technological innovation that facilitates the inclusion of new resources (Betts and Friessen 2004:358) and increased population mobility as people incorporate new resource patches within a spatially heterogeneous environment (Bettinger 1987:126). CPF indicates that diet choice is constrained significantly when a population forages from a central location due to costs associated with round-trip travel (Kennett 2005:30). Therefore, hunter-gatherers who employ diversification strategies that include spatially and temporally patchy resources often increase mobility as they map onto and exploit a greater diversity of subsistence resources (Betts and Friessen 2004). This foraging strategy mitigates seasonal and spatial resource fluctuation with a high degree of efficiency. However, as mentioned above, the unique characteristics of introduced resources may force deviation from these expectations, and indeed diversification in subsistence strategies may result in a diversification of mobility strategies dependent on what kinds of resources were exploited as well as the particular predictability, mobility, patchiness, and distribution of each resource.

Toward an Evolutionary Ecology of Prehistoric Demographic Shifts

Integrating the energetic focus of reproductive ecology with a behavioral ecological perspective provides a unique framework for understanding prehistoric demographic shifts within foraging populations. Low population growth rates defined much of human prehistory due to energetic trade-offs. Hunter-gatherer populations confronted with seasonal and spatial variation in resources experienced low energy status, negative energy balance, and high energy flux contributing to low fecundity. Almost imperceptibly slow rates of population growth throughout most of human prehistory may be related to high population mobility, periodic intake restriction, macronutrient imbalance, or any combination of these variables. Thus, I propose that risk-reducing foraging behaviors, such as specialization or diversification, that alleviated energetic stress also contributed to increased fecundity and higher rates of population growth within prehistoric foraging societies. Ultimately, evaluation of this hypothesis must come from archaeological data where population dynamics are recorded over long spans of time (Kelly 2013:185). Thus, in the following chapters I evaluate evidence of macro-scale demographic shifts relative to changes in foraging behavior and the energetic implications of such changes.

CHAPTER 3

EVALUATING PREHISTORIC HUMAN FORAGING BEHAVIOR: FIELD, LABORATORY, AND ANALYTICAL METHODS

In order to document changes in risk-reducing foraging behaviors (subsistence strategies and associated mobility patterns) that may contribute to prehistoric population growth and regulation, this study incorporates: 1) systematic collection and sort of midden constituents, 2) tight chronological control based on radiocarbon dating and temporally diagnostic artifacts (Chapter 4), 3) analysis of site seasonality using stable oxygen isotopic values of mollusk shells (Chapter 4), and 4) quantitative analysis of macrobotanical (Chapter 5) and faunal (Chapter 6) assemblages. These data reflect diachronic variation in diet breadth prior to and during the known period of population growth on Santa Cruz Island and provide a means for evaluating the proposed research questions.

Field Methods and Sample Recovery

During the summer of 2009, I completed a pedestrian survey of all previously uninvestigated habitable landforms in the Cañada Christy watershed with funding from the Mildred E. Mathias Graduate Student Research Grant, University of California Natural Reserve System. This survey resulted in the documentation of 25 previously unrecorded archaeological sites, including CA-SCRI-823, one of the three sites considered in this study. I described the surface constituents, estimated site size, and collected GPS points for each site.

A formal survey report containing these data is on file at the Central Coast Information Center at the University of California, Santa Barbara. I also relocated several recorded sites whose official site records indicated the presence of well-developed archaeological deposits pertaining to the temporal period of interest. Completion of this survey contributed to a comprehensive database regarding the quantity, location, and nature of surface archaeological deposits within the Cañada Christy watershed.

Figure 3.1. Photograph of Cañada Christy watershed looking west from the head of the watershed out towards the ocean. Photo provided courtesy of Michael Glassow.

The results of this survey also facilitated selection of ten archaeological sites for limited testing. I selected these particular sites based on the density of visible midden, distance from the coast, and proximity to distinct vegetation communities. The purpose of this sampling program was to determine the depth and primary constituents of the midden deposits, to collect samples for radiocarbon dating, and to assess the preservation quality of faunal and macrobotanical remains. I collected at least one auger sample representing the full depth of deposits from each of these sites. Auger sample placement was judgmental, based on the density of surface deposits. I retained the entire bulk soil sample from each interval, approximately 15 cm in depth, for flotation. Marine shell (California mussel) samples from eight of the sites, previously undated, were sent to the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) at the Woods Hole Oceanographic Institution for AMS radiocarbon dating. Two dates from each site were obtained, one from the lowermost auger interval, presumably representing the earliest period of site occupation, and another from the uppermost auger interval, presumably representing the latest period of site occupation.

Table 3.1. Survey/Auger sites including dates, the estimated depth of cultural deposits, as well as distance from the coast and elevation. Sites selected for excavation are highlighted in grey.

Site	Lab ID	Measured Radiocarbon Age B.P.	Estimated Depth of Deposits	Distance from the Coast	Elevation above sea level
CA-SCRI-236	Reported in Glassow 1973:79	4435±100	270 cm	0 km	50 ft
CA-SCRI-823	NOSAMS 79270 NOSAMS 79271	1670 ± 25 6280 ± 35	125 cm	1.0 km	250 ft
CA-SCRI-526	NOSAMS 79276 NOSAMS 79277	2030 ± 30 4020 ± 30	60 cm	1.3 km	250 ft
CA-SCRI-568	NOSAMS 79280 NOSAMS 79281	1050 ± 30 6160 ± 40	180 cm	3.0 km	450 ft
CA-SCRI-322	NOSAMS 79268 NOSAMS 79269	4410 ± 40 4560 ± 40	60 cm	3.0 km	1175 ft
CA-SCRI-536	NOSAMS 79278 NOSAMS 79279	780 ± 30 900 ± 25	50 cm	3.15 km	450 ft
CA-SCRI-576	NOSAMS 79274 NOSAMS 79275	2130 ± 25 4060 ± 30	80 cm	3.20 km	420 ft
CA-SCRI-758	Beta 298684 Beta 298686	4150 ± 40 5750 ± 40	60 cm	6.0 km	1450 ft
TEMP-CWS-23	NOSAMS 79272 NOSAMS 79273	4740 ± 40 4700 ± 40	85 cm	6.0 km	1400 ft

The results of this preliminary site testing and radiocarbon dating (presented in Table 3.1) provided the basis for final selection of archaeological sites to be included in this study. The three fundamental criteria I relied on for site selection were: 1) AMS radiocarbon dates from the uppermost and lowermost deposits that verified occupation before and after the period of significant population growth, ca. 1500 cal B.P., 2) the presence of well-preserved faunal and macrobotanical remains suitable for quantitative and stable isotope analyses, and 3) proximity to a diversity of ecological habitats located at varying distances from the coast. Just three of the ten sites met all three criteria, CA-SCRI-236, CA-SCRI-823, and CA-SCRI-568.

Descriptions of the Study Sites

This dissertation and all field and laboratory methods discussed henceforth pertain to the evaluation of spatial and temporal variation in the exploitation of marine and terrestrial food resources at three substantial shell middens (CA-SCRI-236, CA-SCRI-823, and CA-SCRI-568). Each of these sites represents considerable accumulation of archaeological deposits and exhibits a remarkable degree of stratigraphic integrity due to the absence of burrowing animals and land development.

The Coastal Site. CA-SCRI-236 is an impressively large archaeological site long associated with the historic Chumash village of Ch'oloshush (Arnold 2001). Archaeological deposits, including evidence of at least 15 large house depressions and laterally extensive surface deposits are dispersed over a minimum of 5400 square meters. However, both the allure and temporal span of this site far exceed Late Period/Historic village associations. A column sample excavated by Michael Glassow in 1974 and the auger sample I collected in 2009 indicate almost three meters of dense midden deposits accumulated over the last 4500 years. Perched along the edge of a large marine terrace, this coastal site overlooks an expansive sandy beach with easy access to a diversity of marine resources, including those of nearby rocky intertidal zones and kelp forests. 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. This site is ideally situated for exploitation of a diversity of marine and terrestrial food resources and secure access to fresh water.

The Pericoastal Site. CA-SCRI-823 is another dense shell midden located at the tip of a low-lying ridge, approximately one kilometer from Christy beach, overlooking the flat marine terraces that are adjacent to the coast. This is a newly recorded site with no known history of archaeological investigation prior to my auger sampling in the summer of 2009. The initial auger sample indicated that the Pericoastal site is a multi-component site with several distinct strata accumulated over the last 6000 years (see Table 3.1). Surface deposits are visible over a large ovoid area (approximately 2500 square meters) completely covering the apex of a knoll. This is the smallest of the three sites included in this study; nonetheless, it contains evidence of significant and recurring occupation over several millennia. Set back less than 150 meters from the reliable fresh water of Cañada Christy, the prehistoric occupants of this site would have enjoyed secure access to water throughout the year as well as abundant annual seeds, greens, and fruits from the surrounding grassland, riparian, coastal sage scrub, and island chaparral vegetation communities.

The Interior Site. CA-SCRI-823 is a substantial shell midden with a minimum of 10 large discernible house depressions located on a prominent knoll along the spine of a long north-south trending ridge, approximately three kilometers inland from the coast. Surface deposits are laterally extensive and cover the entire landform (approximately 5000 square meters) with increased density toward the leeward side. This interior site was initially recorded in 1995 by an undergraduate field class under the direction of Michael Glassow. No archaeological samples or subsurface testing was conducted prior to my auger sampling in the summer of 2009. This initial auger sample indicated that the natural prominence of the knoll was enhanced by a full two meters of archaeological deposits accumulated over the last 6000 years (see Table 3.1). 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. Surface deposits, though obscured by thick vegetation, are laterally extensive and cover the entire landform, with increased density toward the leeward side (see Figure 3.4). 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. The canyon bottom below appears to be a favored grassland habitat where blue dicks grow in much greater abundance than elsewhere in the watershed. This site appears to be ideally situated for exploitation of a diversity of terrestrial food resources.

Excavation and Field Recovery Procedures

The explicit purpose of excavation at all three sites was to collect samples appropriate for detailed quantitative paleoethnobotanical, zooarchaeological, isotopic, and chronological analyses. These samples provide the foundation for evaluating diachronic variation in diet breadth and associated patterns of mobility. My principal concern was to ensure comparability among the assemblages recovered from each site. For this reason, I used the same general sampling and recovery methods at each locality. At least one volumetrically controlled unit was excavated by trowel to the full depth of archaeological deposits at each site. To ensure that excavated deposits were not contaminated by loose materials falling down into the unit, the ground surface and area around the unit was cleared of vegetation and debris. We defined excavation levels based on visible stratigraphic variation in the composition and density of natural or cultural constituents. Each excavation level represents a unique stratum of variable depth. Strata exceeding 10 cm in depth were excavated in multiple arbitrary intervals of 10 cm or less. We systematically collected 50 x 50 cm bulk soil samples from each level of excavation. At the Coastal site this represented one-half of the excavation unit, and at the Pericoastal and Interior sites this represented one-quarter of the excavation units. The depth and volume of each bulk soil sample varied with the relative depth of the stratum. These samples were collected in their entirety, without sifting or sorting, for flotation in the Collections Processing Laboratory at the University of California, Santa Barbara. Cultural material from these samples constitutes the "floated" samples from each site. Samples excavated from the remaining portion of each excavation level were screened through 1/8th inch mesh in the field in order to reduce the amount of excess soil transported to the University of California, Santa Barbara, while maintaining reliable recovery of smaller constituents. All screen residuals were collected and transported to the Collections Processing Laboratory at the University of California, Santa Barbara for wet screening. This material constitutes the "screened" samples from each site. A unique field sample (FS) number was assigned to each sample transported from the excavation site to UCSB along with all the relevant provenience information. As we collected at least two types of samples from each excavation level, there are at least two FS numbers associated with each excavation level. In some cases, when individual or fragile artifacts required separate collection, they were also assigned a unique field sample designation. General excavation observations and level records (including depths, soil color/type, and detailed constituent descriptions) were maintained in a dedicated excavation journal. Once the final excavation level sample was extracted, we drew detailed stratigraphic profiles of a minimum of two walls of the excavation unit. The particular walls selected depended on the presence of unique features and lighting conditions. I collected a small trowel-full of soil and matrix from each stratum defined in the profile drawing for future reference. We backfilled the excavation units at the Pericoastal and Interior sites with the sediment and materials that passed through the screens supplemented by large rocks gathered from off-site. We also backfilled the two units at the Coastal site using the materials that passed through the screens. However, given the placement of the excavation units along the sea-cliff this was generally ineffective. The same general excavation and record keeping procedures were implemented at all three sites. However, the unique characteristics of each site merit additional consideration.

The Coastal Site. The erosional sea-cliff, on which the Coastal site is perched, exposes the entire depth of archaeological deposits along the western edge of this site. This visible stratigraphic exposure informed placement of the excavation units and provided a guide for excavation. In order to reduce site disturbance, I placed each excavation unit along the edge of the sea-cliff. This strategy allowed me to target dense midden deposits visible in the erosional exposure that appeared to represent the entire occupational history of the site. Even more, I was able to excavate the full three meters of archaeological deposits without expanding the size of the unit. Despite distinct advantages, this excavation strategy also posed a unique series of challenges. The steep slope of the sea-cliff varied in accessibility. In order to excavate these deposits safely from the 35-40 degree slope of the sea-cliff, I cut a small but stable platform into the erosional face of the sea-cliff. In the process of preparing the platform, I also removed vegetation and talus from on top of and around the excavation area. Erosional materials were clearly visible and easily distinguished from the horizontal stratification of intact deposits. Intact archaeological deposits in the lowermost levels extended out farther than in the uppermost levels. In order to minimize unnecessary destruction of intact archaeological deposits, I decided to "step" the excavation units to match the slope of the sea-cliff, moving the unit out in half-meter increments as needed.

My initial plan was to excavate two 1 x 1 meter units following the procedures detailed above; however, the incredible density of cultural materials encountered in the uppermost strata of both units required re-evaluation of this plan. I chose to reduce the unit size to 100 cm x 50 cm to prevent excavation of more material than could be reasonably analyzed in the time available for completion of the research project. Both units were oriented perpendicularly to the sea-cliff. The 50 cm x 50 cm bulk soil sample reserved for flotation was excavated from the interior half of the excavation unit, farthest from the sea-cliff where the soil likely experienced less variation in moisture content and macrobotanical remains were expected to have the greatest likelihood of preservation. Sediments from the remaining half of each excavation level were screened through 1/8th inch mesh in the field.

We began three excavation units but only completed two. We encountered a human cranial fragment within the first 20 cm excavated from Unit 1. This bone fragment and all archaeological materials that had been removed from this unit were returned to the same location and the unit was closed. No materials from Unit 1 were retained. I established a third excavation unit (Unit 3) several meters north of this location to replace Unit 1. We excavated Unit 2 (southern) and Unit 3 (northern) through the full depth of deposits. Bulk and screened samples from Unit 3 were processed via flotation and wet screening, respectively. However, due to budget and time constraints these samples were packaged for curation without further processing or analysis. Analysis and discussion of cultural remains from the Coastal site pertain specifically to materials excavated from Unit 2. Altogether 48 (22 screen and 26 bulk) samples were collected from 2.8 meters of cultural deposits from this unit at the Coastal site.

The Pericoastal Site. I excavated a single 1 x 1 meter unit at the Pericoastal site following the procedures detailed above. This sample size was more than sufficient to produce an abundance of faunal and macrobotanical remains. Given the fine-grained scale of analysis considered in this research project it was unreasonable to expect efficient analysis of multiple excavation units. The excavation unit was placed adjacent to the original auger sample collected during the site selection phase of fieldwork. This location is just east of the apex at the tip of the ridge where surface deposits appeared to be the densest and most well developed. This topographic context is a common characteristic of midden deposits throughout the Cañada Christy watershed. Previous analysis of the auger sample interval provided a rough guide for the depth, constituents, and stratigraphy of that portion of the site. Altogether 26 (9 screen and 17 bulk) samples were collected from 1.2 meters of cultural deposits at the Pericoastal site.

The Interior Site. This was the most interior site excavated as a part of this project. Based on my previous experience with the incredible density of cultural remains at the Coastal site and analysis of the auger sample collected previously at this particular site, I decided to excavate a single 1 x 1 meter unit at this site. I placed the excavation unit just southeast of a large depression located east of the apex of the knoll crest. This placement took advantage of deep, well developed, and stratified midden deposits identified previously in the auger sample. Previous analysis of the auger sample interval provided a rough guide for the depth, constituents, and stratigraphy of that portion of the site. Altogether 38 (19 screen and 18 bulk) samples were collected from 2.0 meters of cultural deposits at the Coastal site. Due to the depth of these deposits and in accordance with Cal-OSHA guidelines, we used plywood and two by fours to shore the upper portion of this excavation unit (See Figure 3.2).

Figure 3.2 Photo of shoring (with Michael Glassow) at the Interior site.

Sample Recovery and Processing

After excavation I transported all screened and bulk soil samples to the Collections Processing Laboratory at the University of California, Santa Barbara for processing. Over the course of Fall quarter 2010, my lab crew and I wet-screened the screened samples and floated the bulk soil samples using the procedures described below.

Screened Samples. All of the residual materials greater than 1/8th inch (3.2 mm) retained in the screens were wet-screened using the same size mesh at UCSB. The purpose of this procedure was to remove any remaining sediment adhered to the screened samples, improving the visibility of the archaeological remains and enhancing student sorter's ability to identify and separate bones and artifacts from other constituents. Once washed, I covered the screened samples with 1/16th inch mesh (to prevent contamination) and left these samples to dry outside in the sun. When completely dry we weighed and sieved the wet-screened materials through large geological sieves to separate 1/4th inch and 1/8th inch size fractions prior to analysis.

Bulk Soil Samples. Prior to flotation I measured and recorded soil volume for each sample. Most samples measured between 30 and 50 liters, with an average sample size of 42 liters. Altogether, 779 liters of archaeological sediment were processed. I floated all samples using a Flote-Tech machine-assisted flotation machine. Although not without drawbacks (see Rossen 1999), this machine provided an efficient and water-saving means for processing high-volume samples. As detailed by Hunter and Gassner (1998), during flotation, an electric water pump circulated water in a closed loop from the 50 gallon reservoir tank through silt filters into the 50 gallon flotation tank and back into the reservoir tank. A 1.0 mm screened flotation box captured the heavy fraction in the flotation tank and finely woven (0.285 mm) nylon mesh captured the light fraction as water spilled over into the reservoir tank. I constantly monitored the machine, adjusting water flow and aeration to enhance dispersal of the soil and water turbation. Soil matrix, ranging from sandy or loamy to clayey, and shell/artifact density varied greatly between samples, creating unique recovery challenges. After measuring soil volume, I poured the samples into the flotation tank slowly to reduce soil clumping at the base of the flotation box and to ensure that otherwise buoyant materials would not become trapped and water-logged. For the same reason, I also split large and particularly shell-dense samples into smaller portions, floating no more than 15-20 liters of soil at a time and pumping out all sludge settled at the bottom of the flotation tank after processing each sample portion. After all observable light fraction materials passed over the sluiceway, I inserted the baffle to intensify the water pressure at the bottom of the box, which resulted in pushing up any remaining light fraction material. Each sample portion was floated until no botanicals or other light fraction materials could be observed passing over the sluiceway for at least one full minute. I typically cleaned out the machine thoroughly every day. When I floated multiple samples in the same day, I chose to float samples from adjacent stratigraphic levels in order to minimize potential deleterious effects of cross-contamination, however unlikely. I also took great care to prevent contamination by rinsing off the walls of the flotation and reservoir tanks before returning the clean and empty flotation box and lattice tray for the next sample. I transferred heavy fraction materials into wood-framed 1/16th inch mesh screens, covered each with 1/16th inch mesh, and left them outside to dry. I gathered and tagged the light fraction mesh and hung it up to dry outside. This system proved efficient, processing 1-3 samples or up to 120 liters per day with the help of one dedicated assistant, and it provided excellent recovery of small, delicate carbonized seeds and fish bones.

Materials and Methods of Paleoethnobotanical Analysis

The recovery methods described above emphasize the importance of intensive sampling and efficient flotation in the recovery of plant remains. The paleoethnobotanical assemblages included in this study represent all carbonized plant remains recovered from both the light and heavy fractions of 19 floated bulk soil samples recovered from the Coastal (CA-SCRI-236), Pericoastal (CA-SCRI-823), and Interior (CA-SCRI-568) sites. These samples were selected based on chronological relevance to the research question.

Preservation of Plant Remains

In prehistoric contexts, patterns of deposition, preservation, recovery, and analysis heavily influence evidence of plant exploitation (Hastorf 1999:56). The recovered assemblages of charred macrobotanical remains do not directly represent the absolute quantities or importance of different plants in prehistoric subsistence economies (VanDerwarker 2006:69). The ancient macrobotanical remains considered in this study result from a series of prehistoric cultural and natural processes, including selection of plants by humans, food processing, cooking, discard, burial, decay, and weathering; as well as modern filters of sampling and recovery (Wright 2010:47). These processes shape the patterns, distorting, enhancing, or obscuring evidence of plant resource exploitation (Wright 2010:42). In order to reconstruct patterns of plant exploitation it is essential to consider the role of deposition, preservation, and recovery biases (Pearsall 2000:244). Clear understanding of the processes affecting the macrobotanical assemblages and careful application of standardized methods to these assemblages affords a general understanding of past subsistence, in spite of the biasing effects of these processes (VanDerwarker 2006:67).

Under natural conditions existing in most archaeological contexts, plant material gradually decomposes (Gale and Cutler 2000:1). Within this context, the physical characteristics of macrobotanical remains determine, in part, preservation potential. Density, size, and surface characteristics of plant remains account for some of the differential preservation evidenced among macrobotanicals (Popper and Hastorf 1988:5). Rare environmental conditions, such as extreme wetness, aridity, or cold inhibit the activity of microorganisms, effectively enhancing preservation potential (Popper 1988:57). However, these conditions are rare. Environmental conditions at most sites allow decay of all but carbonized macrobotanical remains (Popper 1988:57). Plant materials combusted under poor oxygen availability or low heat exposure are reduced to carbonized forms that more or less maintain their characteristic morphology (van der Veen 2007:977). The elemental carbon of carbonized macrobotanicals resists fungal, bacterial, and microbial activity, allowing plant remains to preserve in moist oxygenated environments that would otherwise facilitate rapid decomposition (Gale and Cutler 2000:2). Charring of macrobotanical remains is the most common cause of preservation in temperate climates, such as the climate of Santa Cruz Island.

Ancient, charred macrobotanical remains enter the archaeological record through direct and indirect resource use (Minnis 1981:144-145; Pearsall 1988:104); thus further differentiation of ancient sources of charred macrobotanical remains is considerably more complicated. The likelihood of carbonization, preservation, and subsequent recovery depend on the type of plant materials, methods of collection, preparation and use, as well as the relative size, density, and fragility of the plant materials (VanDerwarker 2006:68). Charring occurs due to burning during food preparation, burning for fuel, disposal and burning of refuse, or larger conflagrations within or outside of the site boundaries (Lennstrom and Hastorf 1995:704). In the absence of conflagration, not all botanical remains have an equal chance of being charred and preserved (Pearsall 2000:240). Plant parts eaten whole enter the archaeological record disproportionately less than inedible plant parts (e.g., acorn nutshell), which once removed often find their way into a fire and the archaeological record (VanDerwarker 2006:68). The simple process of direct cooking over a fire, parching, or baking increases the likelihood of carbonization. Plant foods eaten raw, with minimal processing, lack this opportunity for carbonization, and enter the archaeological record disproportionately less than cooked plant foods (VanDerwarker 2006:69). Non-food plants also find their way into the archaeological record via carbonization. Wood fuel cleaned from hearths, surface vegetation cleared and burned, and seeds blown into fires by the wind all contribute to the ancient, charred macrobotanical assemblage (VanDerwarker 2006:69). Ethnographic and ethnoarchaeological literature provides analogy for plant types likely used as economic resources versus those likely introduced indirectly (Hather and Mason 2002:2); as well as potential contexts of use and processing techniques that leave distinctive archaeological signatures (van der Veen 2007:974). Such observations and considerations allow us to disentangle some of the depositional factors that influence patterning among ancient, charred macrobotanical remains (Minnis 1981:147-148).

Procedures for Paleoethnobotanical Analysis

Excellent preservation and recovery rates resulted in great quantities of plant remains for analysis. Over the course of eighteen months, I sorted and analyzed the light and heavy fractions with guidance from Dr. Amber VanDerwarker in the Integrative Subsistence Laboratory at the University of California, Santa Barbara. Although I processed and sorted materials from the light and heavy fractions separately, I combine data from the two fractions for the purpose of analysis. Large, dense light fractions posed a challenge for analysis. Jennifer Alvarado, Dr. VanDerwarker's experienced paleoethnobotanical lab manager, assisted me with initial sorting of the light fraction material. We weighed each sample and, when necessary, split them using a riffle box sample splitter. I limited analysis to a maximum of 250 grams of light fraction material by splitting samples that exceeded this size in half until one fraction weighed less than 250 grams. We recorded all sample provenience information, the volume of the original bulk soil sample, total light-fraction weight, and the weight of the subsample (if any) on a data form. These data were used to extrapolate final counts and weights back to the whole sample for the purpose of quantitative analysis. We then passed the light-fraction sample to be analyzed through a set of geological sieves (2.0 mm, 1.4 mm, 1.0 mm, 0.5 mm) to size-fractionate the sample and increase ease of identification. This resulted in five distinct size fractions, including the materials greater than 0.5 mm, all of which we analyzed separately with the aid of a stereoscopic microscope (10-40X).

To ensure maximum efficiency and collection of useful data, I established different sorting procedures for each size-fraction. From the 2.0 mm size-fraction, we completely sorted all materials to recover carbonized plant materials and bone, which I later identified to taxa following the procedures detailed below. The remaining 2.0 mm non-carbonized plants, rootlets, dirt, rocks, shell fragments, and modern insects were separated as contaminants and not included in further analysis. From the 1.4 mm size fraction, we removed all carbonized non-wood plant taxa, 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. From the 1.0 mm size-fraction, we pulled all acorn nutshell and seeds (whole and broken fragments), with the remaining material left as residue. We scanned 0.5 mm and the less than 0.5 mm size-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.

The heavy fractions from all three sites contained great quantities of shell, bone, stones, and artifacts, in addition to a few carbonized plant remains that did not manage to get decanted with the light fraction. Over the course of six academic quarters, undergraduate interns at the University of California, Santa Barbara, sorted the heavy fractions. Many interns participated in the laboratory practicum two or more quarters, developing a keen eye for carbonized plant remains. I provided detailed instructions and training to each student and personally checked each sample. According to standard practice in California archaeology, we sieved the heavy fractions through a set of large geological sieves (1/4th inch, 1/8th inch, and 1/16th inch). No materials smaller than 1/16th inch in size were recovered in the heavy fraction. Student interns completely sorted all materials from the 1/4th inch and 1/8th inch size-fractions and separated all bone and carbonized plant material from the 1/16th inch size fraction. Once students completed this initial rough sort, I combined and weighed all of the recovered carbonized plant remains for each sample. For the purpose of paleoethnobotanical analysis, I passed the sample through a set of geological sieves (2.0 mm, 1.4 mm, 1.0 mm). Thus, I was able to sort and identify carbonized plant remains recovered in the heavy fraction according to the same procedures (discussed above) used to sort carbonized plant remains recovered in the light fraction.

Identification of Plant 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); the publication *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 other ethnobotanical works (Goodrich et al. 1996; Largo et al. 2009; Strike and Roeder 1994) to identify plants of known economic importance to native California peoples. Previous work of archaeologists working on the Northern Channel Islands and on the mainland coast of the Santa Barbara Channel region also helped establish a baseline of plant taxa commonly recovered from local archaeological contexts (Martin and Popper 2001; Martin 2010).

I was solely responsible for identification of plant remains in this study. Dr. Amber VanDerwarker spent countless hours checking, cross-checking and generally helping me along the way. I identified archaeological specimens with reference to modern specimens housed in Dr. VanDerwarker’s Integrative Subsistence Laboratory and at the Cheadle Center for Biodiversity and Ecological Restoration, both at the University of California, Santa Barbara. I collected many of the relevant comparative specimens from Santa Cruz Island during research trips in October 2011 and June 2012. I relied on published and digital seed identification guides (CalFlora, USDA) to identify seeds for which I did not have access to physical 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. However, some carbonized plant remains no longer had identifying features due to extensive fragmentation or abrasion. I classified these as "unidentifiable." Other specimens had diagnostic features but did not compare favorably with any known taxa. I classified these as "unidentified." In some cases, where archaeological types failed to match modern types exactly or fragmentation prohibited clear taxonomic distinction, I made probable identifications, denoted by cf., before the genus or species name, depending on the level of certainty.

Once the plant specimens were sorted and identified, I recorded count, weight (in grams), portion of plants (shell versus seed), and provenience information, with the exceptions discussed below. I weighed, but did not count wood charcoal, and I did not attempt further identification within this broad category. 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 taxa as individual specimens unless I was certain that two fragments fit together (i.e., I had broken the seed). I did not record any other measurements. These raw data of counts and weights form the database I utilized for all subsequent quantitative analysis of the macrobotanical assemblage.

Methods of Quantification and Analysis

It is necessary to acknowledge that the recovered assemblages of charred macrobotanical remains do not directly represent the absolute quantities or importance of different plants in prehistoric subsistence economies (VanDerwarker 2006:69). However, high-use frequency increases the likelihood of carbonization and ultimate deposition (Scarry 1986; Yarnell 1982); thus, the most commonly used plants in any subsistence economy are also the most likely to be preserved in the archaeological record (VanDerwarker 2006:69). The preservation and recovery biases I discussed previously do not prohibit quantitative analysis of the recovered assemblages when appropriate quantitative measures are employed (VanDerwarker 2006:69).

Absolute counts and weights garnered from intensive laboratory sorting and identification form the basis of all further quantitative analyses. However, these raw values are themselves of limited interpretive and comparative value because of the variation in natural plant density and seed count, which significantly skew taxa representation (Popper 1988:60). Critical discussions of quantitative methods in paleoethnobotany highlight the lack of comparability between different plant types, inadequate control of preservation and sampling biases, and generally poor reflection of human-plant interrelationships when only absolute measures are considered (Fritz 2005; Hastorf 1999; Kadane 1988; Miller 1988; Pearsall 2000; Popper 1988; Scarry 1986; Wright 2010). As highlighted by VanDerwarker (2006:71), “absolute counts and weights are simply raw, unstandardized data—in order for them to be quantitatively useful they must be standardized.” It is necessary to consider other quantitative measures that mitigate these effects. Various manipulations of counts and weights (e.g., conversion factors, diversity indices, rankings, ratios, and ubiquity measures) help to standardize the remains and mitigate some of the biases discussed above (Wright 2010:50-51).

Ubiquity. I use ubiquity measures to evaluate the importance of specific taxa across space and through time to assess changes in the relative importance of these taxa through rank-order comparisons. Ubiquity analysis quantifies data according to the presence or absence of a specific taxon across a given number of samples from different contexts, completely disregarding abundance (Hubbard 1975:198). This method assumes that a resource will act and be treated the same across space and through time; thus, change in the occurrence frequency of a taxon is regarded as a measure of the relative change in use of that resource (Minnis 1985:106). 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, but it can give an idea of the relative importance of the taxa (Wright 2010:50). Following VanDerwarker (2006:72), I consider ubiquity to determine what types of taxa routinely find their way into specific temporal or spatial contexts.

Ubiquity effectively describes occurrence frequency of a given taxon, measured as the number of samples in which the taxon is present divided by the total number of samples considered, and expressed as a percentage (Wright 2010:50). For example, the occurrence frequency of manzanita does not influence the occurrence frequency of any other taxon (e.g., acorn) allowing independent evaluation of each taxon. It is problematic to compare ubiquity values between taxa because each plant type is subject to different processing, use, and disposal patterns that create differential opportunities for preservation (Hubbard 1980:53; Wright 2010:50; VanDerwarker 2006:72). For example, an 80% ubiquity value for acorn nutshell should not be compared to the 80% ubiquity value for manzanita seed, even if calculated for the same samples, because these two plant parts have very different preservation opportunities; acorn nutshell is more likely to be represented in the archaeological record because it is always discarded, whereas manzanita seeds represent edible portions, consumed rather than discarded.

Overall, ubiquity analysis is a useful tool to mitigate preservation biases, but it is not immune to them (Hubbard 1980:53). Importantly, ubiquity values may obscure patterns in which occurrence frequency does not change but abundance does (VanDerwarker 2006:72). For example, one seed found in one sample will have the same impact on that taxon's ubiquity in a given set of samples as 100 seeds found in one sample. Other important restrictions on the use of ubiquity require consideration of preservation, sample volume, and the number of samples included in analysis. Better preservation and larger sample volumes increase probability of recovery of rare taxa; thus, variable preservation and sample volume may influence ubiquity (Kadane 1988). Ideally, comparison of ubiquity values should be restricted to samples derived from similar volumes and preservation conditions. Furthermore, analysis must consider a sufficient number to provide meaningful results; using fewer than 10 samples increases the likelihood of sampling bias (Hubbard 1976:60). Some of the temporal and spatial groupings in my analysis do not meet this requirement. Where this is the case, I discuss this caveat and regard the findings as tentative. Despite these weaknesses, ubiquity analysis is robust enough to facilitate the comparison of data of varying quality (Hubbard 1975:198) and can provide meaningful results when used alongside other measures (VanDerwarker 2006:72).

Ratios. While ubiquity measures mitigate some of the problems inherent in absolute counts, they do not provide a means for calculating relative abundances of different plants

(VanDerwarker 2006:73). In the analysis presented in Chapter 6, I use both dependent and independent ratios to standardize absolute counts and render them useful for between and within site comparisons. The use of standardized ratios facilitates comparison of samples of unequal size or of varying depositional and preservational circumstances (Miller 1988:72). Miller (1988) defines and comments on several basic types of ratios. These include, among others, densities and comparisons. The latter, an independent ratio, allows direct comparison of two mutually exclusive categories, potentially expressed in different units of measurement. In contrast, densities are dependent ratios in which the numerator is often a subset of the denominator (Miller 1988:72). I calculate several basic density measures and comparison ratios for each sample to enhance comparability with one another and with the results of other paleoethnobotanical studies.

For initial comparisons of the paleoethnobotanical assemblages, I calculate the *plant weight density*, which is simply the total weight of all carbonized plant remains (wood charcoal, seeds, and other plant parts) in an individual sample divided by the total volume of soil floated and corrected by the proportion of the sample analyzed, if subsampled (Miller 1988:74; Pearsall 2000:196). The plant density measure corrects for variation in the initial sample size and permits comparison between large and small samples, allowing for a quick comparison of the amount of carbonized plant remains in each sample. A similar measure is *count density*, which standardizes the raw count of all non-wood taxa (seeds, nuts, and other plant parts) present in a sample by dividing the absolute count of non-wood plant remains present in a sample by the total volume of soil floated (Pearsall 2000:196). I use these two measures to test the assumption of uniform deposition, preservation, and recovery rates. Departure from the basic assumption that larger volumes of soil contain larger quantities of plant remains indicates the occurrence of activities that unevenly influenced the distribution of plant remains. In this analysis, plant weight density and count density facilitate examination of differential deposition between samples; however, these measures cannot control for the range of non-plant related activities that structure the relationship between soil volume and the size of the plant assemblage. In other words, density measures do not just consider plant remains in terms of plant related activities, but rather in terms of all of the activities that contributed material to the deposit (VanDerwarker 2006:74).

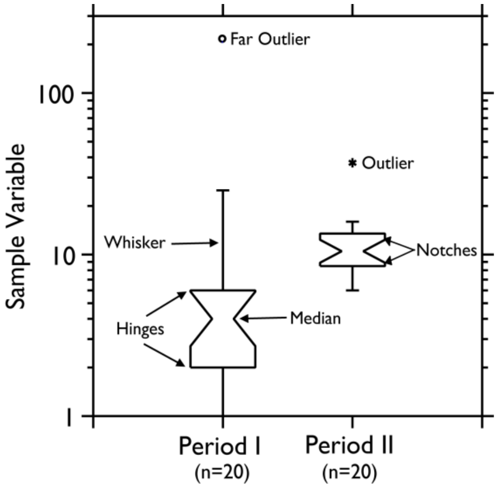
In order to evaluate the relationship of plant remains only in terms of plant related activities, I consider a series of ratios that standardize absolute counts against variable background materials (Miller 1988:75; Pearsall 2000:203). Following VanDerwarker (2006), I calculate *plant weight ratios*, which are simply the total count or weight (for taxa heavy enough for weights) of a given taxon in a sample divided by the total weight of all carbonized plant materials from the same sample (VanDerwarker 2006:74). All ratios are density-independent measures, standardized against a common component of flotation samples (such as wood charcoal or another ubiquitous plant type) that do not require adjustment for differences in soil volume or subsampling, and provide standardized values for comparison of multiple samples within and between archaeological sites. The resulting value provides an approximate measure of the importance of specific taxa relative to other plant-related activities, thus more accurately reflecting spatial and temporal differences in plant use (VanDerwarker 2006:74). This method provides some compensation for differential preservation of various taxa within a sample since all taxa are included in the denominator (plant weight) (Miller 1988). If the use of a specific taxon increased through time, we would expect it to become more common relative to other plants.

A similar measure is the *wood charcoal ratio*, calculated as the total count or weight of a given taxon in a sample divided by the total weight of wood charcoal from the same sample. Assuming that wood charcoal represents ordinary, domestic fuel use, paleoethnobotanists often use this ratio to control for differential preservation (Wright 2010:53). However, in the analysis that follows, I rely solely on plant weight ratios as wood charcoal dominates the study assemblages, and there is no statistical difference between wood charcoal ratios and plant weight ratios. Ratios provide a useful method for standardizing data and reducing some of the problems associated with absolute counts and weights. However, the true interpretive value of ratios lies in comparison to other ratios (VanDerwarker 2006:75). Comparison of ratios from varied depositional contexts, within or between sites, reveals the relative importance of plant resources (VanDerwarker 2006:75).

Boxplots. I use boxplots to summarize standardized counts from density and ratio measures, in a statistically meaningful way, following VanDerwarker (2006). This statistical method graphically represents the median and distribution of the actual data (Drennan 2010:41). Notched boxplots provide a simple way to summarize a distribution of data and statistically compare distributions from unique samples to each other (see Figure 3.3). In this analysis, I group samples by site and temporal period to illustrate broad quantitative differences across space and through time.

The narrowest part of a notched boxplot marks the median of a range of data. The box, or hinges, represents the middle 50% of the distribution with the upper hinge falling at 25th percentile and the lower hinge falling at the 75th percentile of the distribution. The difference between the upper hinge and lower hinge (that is, between the 1st and 3rd quartile) is called the hinge spread. Solid vertical lines called whiskers extend outward from the box, indicating the distribution of data points within 1.5 times of the hinge spread both above the upper hinge and below the lower hinge. These whiskers indicate the tails of the distribution. Data points more than 1.5 times the hinge spread from the upper or lower hinge are outliers, represented as asterisks. Data points more than 3 times the hinge spread above the upper hinge or below the lower hinge are extreme outliers, represented as open circles (Cleveland 1994; Shennan 1997; Velleman and Hoaglin 1981).

Figure 3.3. An example of a notched box plot from VanDerwarker 2006:76.



I add notches to each box plot to indicate statistical differences between more than one batch of data. Notches in the central part of the box around the median delineate the 95% confidence interval. If the notches of two different boxplots do not overlap, the difference between them is known to be statistically significant at the 95% confidence level. Triangular appendages, in which the notch seemingly folds back on itself, appear at the edge of the box if the 95% confidence interval extends beyond either the upper or the lower hinge. This appearance does not change interpretation of the graph (VanDerwarker 2006:76). When necessary I transform the data, typically by evaluating the log values, in order to normalize skewed distributions and facilitate recognition of patterns in the data (VanDerwarker 2006:77).

Diversity Analysis. The final quantitative measure that I calculate for relative measurement of taxon frequency between samples is diversity. This method provides a comparison of species diversity between different archaeological spatial or temporal units and offers a great deal of interpretive value for assessing differences in procurement strategies—whether people are adding/subtracting types of foods from their diet(s), or if people are focusing their efforts on specific resources (VanDerwarker 2006:77). Central to this analysis is the relationship between diet breadth and risk management (see Chapter 2). Diversification or specialization in the exploitation of plant resources may contribute to seasonal risk reduction. By measuring diversity it is possible to identify fundamental changes in subsistence practices (VanDerwarker 2006:77).

In this analysis, I consider two distinct aspects of diversity, *richness* and *evenness* (Magurran 1988; VanDerwarker 2010:67). Richness refers to the number of taxa in a given assemblage. The more taxa present, the greater the species richness (Kintigh 1984, 1989). In contrast, species evenness/equitability refers to the absolute distribution of specimens across all taxa in a given assemblage. This aspect of diversity describes the uniformity of the distribution of taxa in the assemblage (Kintigh 1984, 1989). Thus, an assemblage in which each taxon is represented by the same number of specimens has greater species evenness than an assemblage dominated by a specific taxon (Magurran 1988; VanDerwarker 2010:67).

The Shannon–Weaver index indicates the homogeneity or heterogeneity of a sample, incorporating measures of species richness and evenness to calculate diversity (H'). Diversity

(*H′*) is calculated on a scale of 0 (only one taxon present, no diversity) to a maximum number relative to the total number of taxa present (multiple taxa, evenly distributed). Equitability (*V′*) is calculated on a scale of 0 (less even, more skewed distribution of taxa) to 1 (even distribution of taxa). The Shannon–Weaver index is the most commonly used statistic among ecologists and subsistence specialists for diversity analysis (Magurran 1988; VanDerwarker 2010:67). The formulae that I employ in this analysis is as follows,

$$H' = -\sum_{i=1}^{\mathrm{S}} (p_i)(\ln p_i)$$

$$V' = H'/(\ln \mathrm{S})$$

Where, S = the total number of taxa, p_i= the relative abundance of the *i*th taxon within the sample, and ln p_i= the natural logarithm of p_i. The value of H' will increase as the number of taxa present increases, up to a maximum of lnS. Assemblages with higher numeric values for *H′* indicate greater species diversity (richness) (Magurran 1988). Assemblages with higher numeric values for *V′* indicate greater evenness in the abundance of taxa (Magurran 1988; VanDerwarker 2010:68). Comparison of *H′* and *V′* values between assemblages from different contexts and/or temporal periods facilitates examination of trends in resource utilization across space and through time (VanDerwarker 2010:68).

The Shannon-Weaver index *H′* (diversity) and *V′* values (equitability) provide simple, intuitive means for quantification of sample diversity; however, these measures are inherently linked to sample size. Larger assemblages tend to yield a richer array of taxa than smaller assemblages do. Moreover, larger samples are more likely to contain rare taxa than smaller samples (VanDerwarker 2006:77). Although I suspect minimal sample-size effects due to the large sample sizes considered in this study, I cannot be certain. It remains problematic to assume that larger assemblages with more taxa are more diverse than smaller assemblages with fewer taxa without first evaluating how much of the difference is potentially structured by sample size (VanDerwarker 2006:77). Thus, I also use DIVERS, a statistical program designed to measure the diversity of assemblages of different sample sizes (Kintigh 1984, 1989, 1991).

The DIVERS program uses a Monte Carlo approach to simulate a large number of assemblages based on the categories and sample size of a given archaeological assemblage. Aggregating the information from these simulations, the program yields a statistical expectation of diversity for comparison to the actual data (Kintigh 1984, 1989). In this analysis, I compare the actual diversity of the archaeological plant assemblage to expected values simulated for the same size assemblage (Kintigh 1984, 1989). This analysis effectively bypasses the issue of sample size and facilitates evaluation whether the richness and evenness of each sample assemblage is more or less diverse than expected (VanDerwarker 2006:78). Graphic representation of the expected richness and evenness, along with a 95% confidence interval, facilitate interpretation. Diversity and evenness values for the actual assemblages that fall *above* the line of the confidence interval are more diverse than expected. Conversely, diversity and evenness values for the actual assemblages that fall *below* the line of the confidence interval are less diverse than expected (VanDerwarker 2006:78). Together, species richness and species evenness provide a robust assessment of key variability in archaeological assemblages once controlled for variation in sample size (Kintigh 1989:25).

Materials and Methods of Zooarchaeological Analysis

The zooarchaeological assemblages included in this study represent vertebrate and invertebrate remains recovered from chronologically relevant strata at the Coastal (CA-SCRI-236), Pericoastal (CA-SCRI-823), and Interior (CA-SCRI-568) sites. Sample volumes are not consistent; they vary with the relative depth of the stratigraphic level excavated. Abundant faunal remains recovered (primarily) in the heavy fractions of these flotation samples comprise the principal source of shellfish, bird, and fish data considered in this analysis. This recovery strategy ensures adequate representation of even the smallest taxa, but may also bias against representation of larger, less abundant mammalian remains. Thus, I also consider in this analysis mammalian bone recovered from the screened samples in order to augment representation of this animal class.

Preservation of Faunal Remains

Meaningful interpretation of zooarchaeological data depends upon the careful consideration of potential taphonomic factors affecting faunal assemblages (VanDerwarker 2006:117). Recovered faunal assemblages do not include all of the materials originally deposited by humans (Peres 2010:18). In order to best interpret prehistoric human behavior it is necessary to identify possible sources of bias, from prehistoric selection and discard of animal food resources to modern archaeological recovery of faunal remains (Peres 2010:19). Researchers look to taphonomic processes to understand what has aided or inhibited a particular assemblage's preservation, and to gain a perception of what may have been lost (Klein and Cruz-Uribe 1984:6-10; Peres 2010:19; Reitz and Wing 2008:110-141). The purpose of the following discussion is to assess the fidelity of the faunal assemblages, that is, the extent to which the bones and shells occurring in the archaeological deposits reflect the full range of animal resources exploited (Kowalewski et al. 2003:45). Most of the processes discussed apply to virtually all animal taxa, vertebrate and invertebrate (Lyman 1994b:3); although I do focus on bone more than shell, as shell is extremely well preserved and abundant in the studied assemblages.

The prehistoric inhabitants of Santa Cruz Island selected certain animals from the environment to be included in their diet; these choices changed on a daily, monthly, or annual basis (Peres 2010:18). The mere absence of an animal from an assemblage does not imply avoidance; likewise, presence of an animal does not imply consumption. Interpreting the diet of human groups, using the presence or absence of animals as a criterion, can lead to a number of difficulties. Specific food processing techniques, such as butchering, marrow extraction, bone grease rendering, roasting, and drying, among others, together with waste disposal patterns, determine which foodstuffs actually make it into the archaeological record (Glassow 2011:201; Peres 2010:18).

Differential selection of animals, use, transportation and deposition of faunal remains are all cultural processes that shape what enters the archaeological record. However, once disposed, whether a bone survives deposition and subsequent recovery is largely dependent on how the animal died (Lyman 1994b:115), structural bone density (Lyman 1994b:234–258), and the conditions of the surrounding environment (Lyman 1994b:358–360). Differential preservation of the faunal assemblage is perhaps the single most important non-cultural taphonomic process that affects a faunal assemblage (Peres 2010:19). Osteological characteristics, including chemical composition (bone vs. shell), relative size of the individual, diagnostic landmarks, bone density, and friability, greatly affect bone survivorship and the likelihood of identification (Peres 2010:20). Denser, compact bones with more cortical tissue are more likely to survive than fragile bones with more cancellous tissue. Thus, long bone diaphyses will be more resilient than epiphyses, skull fragments more than vertebral fragments, large mammal bones more than small mammal bones, mammal bones more than bird bones or fish bones, etc. (VanDerwarker 2006:117). Similarly, some kinds of hard tissues found in fish are more resistant than others (Wheeler and Jones 1989:62). Elasmobranchs (henceforth referred to simply as cartilaginous fish) are usually only represented by dermal structures (denticles, teeth, and spines) or vertebral centra. Even within teleosts (henceforth referred to simply as bony fish), bones are not all of equal robusticity; considerable variation exists between families of fishes and in the elements within a single species and mediates survivorship in the archaeological record (Wheeler and Jones 1989:62-63).

Zooarchaeological assemblages recovered from shell middens or shell mound sites, such as the assemblages considered in this analysis, tend to exhibit a high degree of preservation of even the smallest of vertebrate remains (e.g., fish) (Linse 1992; Peres 2010). A high abundance of mollusk remains found in the matrix of shell midden deposits enhance the favorable preservation of the generally basic soils of southern California (Reitz and Wing 2008:141; Wheeler and Jones 1989:63). Physical and chemical weathering of faunal remains, caused by exposure to the sun, wetting and drying, and temperature variation, is a cumulative form of bone deterioration that results in fragmentation and disintegration of faunal remains (Behrensmeyer 1978:153; Lyman 1994b:358-360). Nonetheless, Glassow (2011:202) notes that, “in coastal southern California site deposits, the bone material itself is generally in good condition, even though it may be fragmented. Even small fragments do not show obvious effects of subaerial weathering, that is, they show no evidence of surface alteration consistent with Behrensmeyer's stages 2 through 4." Indeed, this appears to be the case in the faunal assemblages considered in this study, which demonstrate remarkably high preservation and little to no surface alteration other than burning and fragmentation.

Archaeologists attribute a great deal of fragmentation, destruction, dispersal, and mixing of faunal remains in southern California site deposits to the presence of burrowing animals, canids, and other scavengers (Erlandson 1984; Glassow 2011; Johnson 1989; Rick et al. 2006a). Most of the culpable species that occur in the greater Santa Barbara Channel region (coyotes, pocket gophers, and ground squirrels) do not occur on Santa Cruz Island. Thus, archaeologists often indicate that such disturbance processes minimally affected archaeological deposits on the Northern Channel Islands (Glassow 1980:79; Arnold 1992:65; Rick et al. 2006a:568). However, other native and introduced animals that burrow, dig, or disturb deposits do currently occupy the islands (Rick et al. 2006a:577). The Island spotted skunk is known to dig dens in a variety of substrates (Crooks 1994), and researchers suggest that the Island deer mouse may also dig very small burrows (Rick et al. 2006a:577). Like all rodents, the Island deer mouse and introduced harvest mouse may also gnaw on faunal remains, leaving behind characteristic rodent tooth marks. Yet, it remains unlikely that any taxon present on Santa Cruz Island could ravage the bone assemblage to the same extent as large carnivores or gophers and ground squirrels present on the mainland (see Bartram and Marean 1999; Blumenschine 1988; Blumenschine and Marean 1993; Erlandson 1984; Faith and Behrensmeyer 2006; Gifford 1981). It is clear that the impact of these native animals on Channel Island sites is more limited compared to the mainland; if present, burrows tend to be quite small in size and depth (Rick et al. 2006a:577). Of much greater concern are the digging, trampling, and other activities of introduced animals. Prior to eradication, feral pigs rooted about, occasionally digging into archaeological deposits on which plants desired by pigs grow, and undoubtedly contributing to the mixing and displacement of archaeological materials at some sites (but certainly not all) on Santa Cruz Island (Arnold 2001:33; Rick et al. 2006a:578). Thus, faunal assemblages derived from archaeological deposits close to the surface during the Historic Period may be relatively more affected by the activities of introduced animals. All of the faunal assemblages in this analysis pertain to strata excavated a minimum of 30 cm below the modern surface and are capped by intact Late Period deposits. Overall, there is very little evidence of destructive taphonomic processes and assemblage fidelity appears to be quite high.

Procedures of Zooarchaeological Analysis

Excellent preservation and recovery rates resulted in great quantities of faunal remains, particularly of shellfish and fish, for analysis. Over the course of 24 months, I sorted and analyzed vertebrate and invertebrate faunal remains recovered from the flotation and screened samples under the guidance of Dr. Michael Glassow and Dr. Amber VanDerwarker at the University of California, Santa Barbara. I processed and analyzed flotation and screened samples separately, as these samples were obtained using different techniques with different sampling strategies.

Large, dense heavy fractions comprised mainly of shellfish remains in addition to other faunal remains, artifacts, and rocks made analysis challenging and time consuming. I trained undergraduate laboratory interns to assist with separating vertebrate and invertebrate faunal remains from the rest of the heavy fraction materials. I provided detailed instructions and training to each student, and personally checked each sample. Many interns participated in the laboratory practicum two or more quarters, becoming quite adept at distinguishing bone from other materials.

Student interns completely sorted all materials from the 1/4th inch (6.4 mm) and 1/8th inch (3.2 mm) size-fractions. However, we collected only identifiable bone elements (e.g., fish vertebrae) and carbonized plant material from the 1/16th inch (1.6 mm) size fraction. The use of 1/8th inch and 1/16th inch meshes allows for a more complete recovery of small, delicate animal remains (i.e., small fishes) (Peres 2010:22). Once students completed this initial rough sort, I combined and weighed all of the recovered vertebrate remains as well as all of the recovered shellfish remains. I encountered very few faunal remains in the light fractions, which were primarily composed of carbonized plant materials. Thus, I simply added those few small fish bones I recovered in the light fraction to the heavy fraction sample for the purpose of zooarchaeological analysis.

The screened samples were processed and analyzed separately at all stages from initial identification to quantification. We sieved wet-screened materials through large geological sieves to separate 1/4th inch and 1/8th inch size fraction. These samples were not sorted completely. Student interns separated all bone and artifacts from the 1/4th inch (6.4 mm) size fraction. No faunal material was separated or analyzed from the 1/8th inch (3.2 mm) size-fractions. Abundant faunal material recovered from this size fraction in the heavy fraction of the flotation samples provided ample materials for quantitative analysis. Although we separated all bone from the 1/4th inch (6.4 mm) size fraction, I identified only mammal bone beyond Class. In the analysis presented in Chapter 6, I do not consider any other faunal category represented in the screened samples, as all other Classes were well represented in the heavy fraction of the flotation samples.

Identification of Vertebrate Remains

Once separated from all other cultural and non-cultural remains, I personally sorted and weighed all vertebrate remains recovered by category (e.g., mammal, bird, fish, and unidentified). The zooarchaeological assemblages considered here include and all bone specimens greater than 1/8th inch (3.2 mm) and all identifiable bone elements (e.g., fish vertebrae) greater than 1/16th inch (1.6 mm) from the flotation samples, as well as mammal bone specimens greater than 1/4th inch (6.4 mm) from the screened samples.

I completed identification of all vertebrate remains in this study to the lowest possible taxonomic category through direct comparison to reference collections housed in the Faunal Analysis Laboratory at the University of California, Santa Barbara and the Santa Barbara Museum of Natural History. I relied on previous research by archaeologists working on the Northern Channel Islands and on the mainland coast of the Santa Barbara Channel region to establish a baseline of terrestrial and marine animals commonly recovered from local archaeological contexts (Glassow and Joslin 2011). Michael Glassow at the University of California, Santa Barbara checked my identification of numerous terrestrial and marine mammal specimens, and Amber VanDerwarker confirmed most terrestrial mammal identifications. John Johnson at the Santa Barbara Natural History Museum and Thomas Wake at the UCLA Cotsen Institute of Archaeology’s Zooarchaeology Laboratory graciously checked, corrected, and confirmed identification of fish remains.

For the sake of efficiency, I identified specimens within one taxonomic class at a time. I identified each bone specimen to the most specific taxonomic level possible based on diagnostic attributes of skeletal elements. In some cases, if I determined a bone specimen compared favorably with a particular taxon, but I was not completely certain of the identification, I recorded the taxonomic name followed with “cf.” (Reitz and Wing 2008:36). In other cases, if I could confidently assign a bone specimen to a genus, but not to a specific species, I simply recorded the genus name followed by “sp.” to indicate species or “spp.” to indicate the possibility of more than one species (Reitz and Wing 2008:36). In the absence of distinctive osteological characteristics, or when the bone was too fragmentary to observe characteristics diagnostic at the genus or species level, I classified specimens into broad categories by class based on the size and thickness of the cortical bone. Following Wake (2011:4) for mammals, the size categories are defined as follows: *large* represents deer size or larger, *medium* represents smaller than a deer but larger than a jackrabbit, *small* represents jackrabbit to woodrat size, and *very small* represents mouse size or smaller.

For fish remains, I attempted identification of most elements (excluding ribs, spines, pterygiophores, and nondescript fragments) and all vertebrae—the most frequently recovered diagnostic bones—to the lowest possible taxon. Common and scientific names follow Love (2011). Consistent with regional practice and as recommended by Gobalet (2001), my identification of fish remains is conservative, limiting attempts to discriminate between ecologically and morphologically similar taxa unlikely to be distinguished based on vertebrae and fragmentary skeletal remains (Gobalet and Jones 1995:815). For example, elements from the two species, Pacific sardine and Pacific herring (both of the family Clupeidae), are difficult to differentiate, as are vertebrae from different species within the Surfperch family (Embiotocidae), Rockfish genus (*Sebastes* spp.) (Joslin 2011:138). Consequently, I did not attempt such distinctions. I reserve simple bony fish or cartilaginous fish classifications for non-diagnostic elements and nondescript bone fragments.

Following VanDerwarker (2006), for each discretely identified bone, I recorded complete provenience, sample type and screen size information, animal class, genus and species (if possible), number of specimens, element, portion of the element represented, side of element (when applicable), observations regarding age/sex of the animal, and evidence of burning. Although I evaluated each bone for evidence of a variety of other natural and cultural modifications, including cut marks, gnaw marks, and artifact manufacture, I did not encounter any evidence of modification other than burning. After identification, I counted all bones and weighed (in grams) each using electronic scales.

Identification of Invertebrate Remains

The invertebrate assemblage considered here includes all shellfish remains greater than 1/8th inch (3.2 mm) retained in the heavy fraction of the flotation samples. I do not include shellfish remains less than 1/8th inch but greater than 1/16th inch, which made up a relatively small proportion of the well-preserved assemblages, from the flotation samples or any size shellfish remains from the screened samples.

After completing initial sorting of heavy fractions into broad categories (bone, shellfish, charcoal, debitage, groundstone, or other artifact types), several of the more experienced undergraduate interns at the University of California, Santa Barbara, also assisted me with the identification of invertebrate remains. I provided each intern ample instruction, access to the extensive archaeomalacological comparative collections housed in the Faunal Analysis Laboratory at the University of California, Santa Barbara, and I personally checked all taxonomic identifications. Modern ecological surveys and shellfish identification manuals aided identifications and provided habitat information (Coan et al. 2000; Jensen 1995; Patyten 2006; Ricketts et al. 1985; Russo and Olhausen 1981). Common and scientific names follow standards set forth by the California Department of Fish and Wildlife (Patyten 2006). After identification, we weighed (in grams) all of the shells of each taxon using electronic scales.

Methods of Quantification and Analysis

Quantification of zooarchaeological remains, though approaches are much discussed and debated, assures comparability between samples and provides the foundation for statistical analyses (Peres 2010:26). In this section, I consider the three fundamental quantitative units used to describe taxonomic abundances: number of individual specimens (NISP), bone/shell weight, and minimum number of individuals (MNI). When viewed together these measures provide a means to compare relative proportions of various taxa useful for monitoring both diachronic change in relative taxonomic proportions and synchronic variation in taxa or osteological elements across geographic space (Gifford-Gonzalez and Hildebrandt 2011:97). Nonetheless, lively debate continues over the best modes for calculating these measures, limitations on their uses in various contexts (for example aggregation effects on MNI), and taphonomic interactions with the measures (Gifford-Gonzalez and Hildebrandt 2011:97).

NISP. The most basic measure by which faunal remains are tallied is the number of individual specimens (NISP). Simply, NISP is the number of identified specimens per animal taxon (Lyman 1994a:38). Each individual bone, tooth, scale, and fragments thereof, counts as a single unit (Peres 2010:26). NISP is useful in that it can easily be calculated at a variety of different scales, i.e., by species, faunal class, site, or temporal period (Lyman 1994a:38; VanDerwarker 2006:121). However, to use NISP as a measure of abundance requires the assumption of constant recovery rates for each taxon, equal opportunity for all taxa to be counted, and uniform fragmentation (Reitz and Wing 2008:202). This is problematic as taxa vary in the number and identifiability of elements that compose their skeleton. NISP is unable to control for such variation, particularly when comparing taxa across classes (Reitz and Wing 2008:202). Specimens from mollusks, fishes, birds and mammals do not survive equally in the archaeological record. Differential preservation and fragmentation may result in the overestimation of (larger/more common) taxa when quantified by NISP alone (Lyman 1994a:34; Peres 2010:26).

Weight. In this analysis, I consider NISP for vertebrate taxa only. California mussel (*Mytilus californianus*), the predominant taxa recovered in the study assemblages, is especially prone to a high degree of fragmentation that affects all parts of its shells. Given the time and resources available to complete this project, it was not feasible (nor reasonable) to count each shell fragment in the study assemblages. Following Claassen (2000:416) and Glassow (2000), I refer to shell weight as a measure of the abundance of molluscan taxa. Although specimen weight is infrequently used to evaluate frequencies of vertebrate taxa (Reitz and Wing 2008:210), recording the weight (in grams) of bone, teeth, otoliths, and shell from archaeological sites is common practice. Like NISP, bone/shell weight is a fundamental unit of data that does not require further manipulation to have meaning (Peres 2010:28). Furthermore, weight provides a second absolute measure of the relative importance of a taxon within an assemblage. Overall, bone/shell weight by itself may be no more biased than other primary measures such as NISP (Glassow 2011:219); however, there are problems with using sample weights to make substantial interpretations. One of these issues pertains to taxa representation and size. Larger animals weigh more than smaller ones; thus if weight alone is used as a relative measure of abundance, interpretations will always be biased towards large animals. In addition, this unit of measurement does not compensate for the effects of weathering or thermal alteration on specimen weight. However, bone/shell weight does provide a basis for evaluation of taphonomic fidelity. Dividing the specimen weight for a taxon by NISP is particularly helpful in quantifying the degree of fragmentation for various taxa (Reitz and Wing 2008:210).

MNI. Given the many difficulties associated with the use of absolute measures such as counts and weights to estimate the relative contribution of different animals to the diet, I also estimate the minimum number of individuals (MNI). MNI is a derived, or secondary measure, building on the primary data categories of taxonomic identification, element identification and representation, NISP, sex, and age (Lyman 1994a:38), which estimates the smallest (hence, minimum) quantity of individual animals needed to account for all of the specimens identified to a particular taxon (Peres 2010:28). Following Reitz and Wing (2008:206-207), I estimated MNI for each animal taxon, vertebrate and invertebrate, using the standard accepted procedure: the occurrence of the most abundant non-repeating element of the animal. If this element was a paired element (i.e., left and right), I use the higher count of the two; I also considered size differences and the portion represented when appropriate.

In this analysis, MNI provides a single measure by which I can calculate the relative contribution of all animal taxa, from fish to shellfish. MNI is more resistant to the issues of specimen interdependence and variation in the number of skeletal elements of different taxa, which are particularly problematic when comparing taxa across classes (Lyman 1994a:39). Indeed, it is one of the only ways to compare mammals, birds, fishes, and molluscs (Reitz and Wing 2008:210). Nonetheless, there are serious concerns with this method as well. Just as NISP tends to overestimate the importance of larger, more common taxa, MNI tends to tends to overestimate the importance of rarer taxa (VanDerwarker 2006:122) and often produces relatively low values that constrain statistical analysis. Glassow (2000:408) correctly points out that in shellfish analysis MNI tends to overestimate the importance of more robust species and those with fewer non-repeating elements (*contra* barnacles or chiton). Moreover, MNI estimates can vary greatly based on how researchers choose to aggregate data from archaeological proveniences during analysis (Reitz and Wing 2008:210). As discussed by VanDerwarker (2006:122) data can be grouped and MNI values calculated by site, feature, stratigraphic level, or even temporal period. Aggregation of samples into a "minimum distinction unit", such as site or temporal period, results in lower MNI estimates than aggregation of samples into a "maximum distinction unit", such as individual features or stratum (Reitz and Wing 2008:208).

Ratios. Ratios also provide an effective means of standardizing zooarchaeological data. The values used in the numerators and denominators are raw, unstandardized data—basic counts or weights—of independent variables from the same context. For example, the seed/plant weight ratio in paleoethnobotany calculates the count or weight of seeds divided by total plant weight (per sample); this is one way to standardize plant data in order to make them comparable. In this analysis I use a series of independent ratios (often referred to as indices in the zooarchaeological literature, see Broughton 1999 and Wake 2011) to side-step the problem of dependency inherent in relative percentages and to measure changes in the relative abundance of different animal taxa.

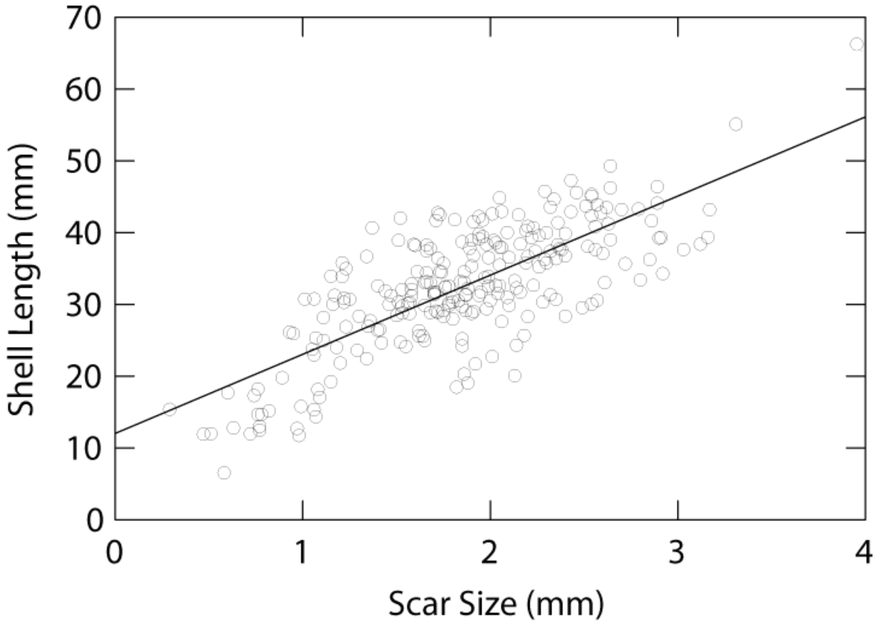
Measurement of Shellfish Size

Changes in shellfish size result from natural variations in water temperature, marine productivity, and turbidity, as well as other factors (Erlandson et al. 2008:2148). However, many researchers document reductions in the mean size of many shellfish populations resulting from heavy predation by humans and other large predators (Erlandson et al. 2008). Harvesting strategies, i.e., “stripping” versus “plucking”, influence the size of shells incorporated into midden assemblages (Jones and Richman 1995; Whitaker 2008). California archaeologists rely on size templates developed by White (1989) to infer the length of California mussel shells based on shell fragments. The width and angle of umbo, or hinge, of the California mussel is correlated with the overall length of the shell. Matching partial shells to the template allows size estimation in 1 cm increments. However, this technique has met with recent criticism due to the inherent subjectivity of visually matching valve fragments of variable size and fragmentation to set templates (Glassow 2013, personal communication). An alternative method, proposed by Michael Glassow, relies on direct measurement of the anterior muscle attachment scar (MAS) visible on the interior of the California mussel shell near the umbo. This method is based on the premise that the MAS is directly related to the size of the muscle, providing an effective proxy for the size of the animal. To evaluate the effectiveness of this method I measured the MAS size and shell length of 250 complete valves recovered in the archaeological assemblages considered in this study. A Pearson chi-squared test demonstrates that MAS size is indeed significantly, positively correlated with shell length (χ^2= (1, N=243)=0.751, p=0.000). Linear regression indicates shell length can be predicted based on MAS size (r^2= 0.564, F(1,241)=312.238, p=0.000) based on the formula (see Figure 7.38):

$$\text{Shell Length(mm)} = (11.022 \times \text{MAS size (mm)}) + 12.028$$

Based on these results, I evaluated variation in California mussel shell size using the MAS size method rather than the much more subjective template method. Altogether, one assistant and I measured 9,371 MASs from the three sites. We were consistently able to replicate each other's measurements, lending confidence to the reduced interpersonal variability that makes this method attractive. I restricted measurement to either right or left sided valves, based on which valve side determined MNI for each sample. It was not possible to measure a MAS on every single umbo, due to lack of visibility, fragmentation, or a variety of other issues.

Figure 3.8 Linear regression of California mussel size (shell length= measurement of umbo to terminal growth margin) to muscle attachment scar size (MAS). Data based on measurements from 250 complete valves recovered in the archaeological assemblages considered in this study



Analytical Units

In this analysis, each level assemblage from each site represents a unique stratigraphic event and is considered the most appropriate analytical unit. NISP, weight, and MNI values of all non-mammal taxa (birds, fish, and shellfish) are reported for level assemblages. Due to different recovery methods, I separately discuss and analyze all mammal NISP and weight values derived from screened and floated samples. However, I consider element representation of mammal remains recovered in both screened and floated samples in order to provide a single level-assemblage MNI value for each identified taxon. I group assemblages by site to consider broad spatial patterns and by temporal period to consider broad temporal patterns in faunal exploitation but I do not conflate samples or recalculate NISP, weight, or MNI values for larger aggregations. To allow for accurate comparisons of taxonomic distributions among the samples, I standardize NISP, weight, and MNI values by the original volume of sediment per sample.

Summary of the Research Methods

The nuanced analyses of human foraging behavior on Santa Cruz Island during the temporal interval ca. 3000-1000 cal B.P. presented in Chapters 4, 5, and 6 are based on samples excavated from CA-SCRI-236 (the Coastal site), CA-SCRI-823 (the Pericoastal site), and CA-SCRI-568 (the Interior site). These three substantial archaeological shell middens were carefully selected based on an intensive program of pedestrian survey, radiocarbon dating, and site testing. Substantial investment in site evaluation prior to excavation determined favorable preservation of appropriote shell samples for isotopic analysis, macrobotanical remains for paleoethnobotanical analysis, and faunal remains for zooarchaeological analysis. The basic laboratory and analytical procedures outlined in this chapter provide a useful reference for the quantitative analyses presented in Chapters 5 and 6. These diverse datasets provide the means for reconstructing how the prehistoric Chumash moved about the landscape and exploited the marine and terrestrial environment before, during,and after an interval of significant population growth.

CHAPTER 4

CONTEXT OF THE ANALYSIS: A BAYESIAN CHRONOLOGICAL FRAMEWORK FOR DETERMINING SITE SEASONALITY AND CONTEMPORANEITY

Humans occupy their landscape in a dynamic manner, often altering foraging behavior in response to climate, population size, and technology—among other cultural and economic factors—that fluctuate through time (Stein et al. 2003:297). I seek to unravel this complex story of human occupation at each of the three archaeological sites using a multiscalar approach for determining seasonal resource exploitation strategies, and, by extension, for reconstructing mobility patterns in the past (Kennett and Culleton 2012:37). This involves radiocarbon dating to control century-level resolution and site seasonality studies to provide seasonal or monthly resolution (Kennett and Culleton 2012:37). This hierarchy of chronological measures is essential when inferring mobility patterns from seasonality data from multiple sites (Kennett and Culleton 2012:37). The primary issues that I seek to resolve are whether the three sites are coeval, and if so, whether people inhabited these sites during the same or different times of the year. Secondary questions derived from these chronological data focus on the intensity and duration of occupation at each site.

Assessment and Evaluation of Site Chronology

The first step in developing a coherent picture of site seasonality and variable mobility patterns is establishing the true order of events within a given site context, and discerning whether events in different site contexts are actually contemporaneous (Culleton et al. 2012:1573). Repetitive cycles of occupation, abandonment, and reoccupation of favored locales complicate this pursuit. Stratigraphically complex sites, such as shell middens, are notoriously difficult to decipher (Stein et al. 2003:298). However, several major methodological, analytical, and statistical improvements for building archaeological site chronologies have coalesced during the last decade (see Bayliss 2009; Bronk Ramsey 2008a; 2008b; Buck and Millard 2004). I draw upon these advances to establish and interrogate high-precision chronologies for each of the three multi-component shell middens considered in this study. This refined chronological framework illuminates contemporaneous periods of occupation, variable rates of accumulation, and protracted intervals of site abandonment.

A Bayesian Approach to Chronology

The rationale for a Bayesian approach to constructing site chronologies is not only to arrive at more realistic age estimates for individual measurements (*sensu* Bicho et al. 2013; Culleton et al. 2012; Jazwa et al. 2013; Kennett et al. 201l; 2014; Nakamura et al. 2013; Outram et al. 2010, and many others) but also to provide a statistical framework for further analysis (Bronk Ramsey 1998:463,472). Although the individual dates are of considerable significance, I focus analysis on the temporal parameters of cultural processes and human behavior inferred from chronometric data (Nicholls and Jones 2001:503). As soon as radiocarbon dates are received from the lab, archaeologists begin the process of interpreting these data. Inevitably, this involves a series of assumptions, some as simple as to whether a series of dates represents multiple dates of a single synchronous event or whether those same dates represent multiple sequential events. An experienced archaeologist will judge the former or the latter to be more plausible based on prior information, such as stratigraphic relationships between contexts containing dated samples (see Bronk Ramsey 1995:426; 2008a:264). Use of these priors informs interpretation, regardless of whether they are made explicit.

A Bayesian approach to chronology building forces archaeologists to make explicit assumptions about the priors, and provides a quantitative framework to formalize and test assumptions. Agreement indices for the individual date calibrations and for the constructed chronological model as a whole quantify the correspondence between the prior and posterior distributions, while accounting for the correlation between parameters (Bronk Ramsey 2000:201; 2009:357). This statistical measure allows archaeologists to evaluate the validity of assumptions, such as the assumed stratigraphic integrity of a site, on which the model is constructed. A second statistic, convergence, measures the degree to which there is a truly representative and stable solution to the model (for more information, see Markov Chain Monte Carlo samplers, Bronk Ramsey 1995:429; 2001:359; 2009:353). These two statistics allow archaeologists to evaluate both the reliability and stability of constructed chronological models. Moreover, a well-constructed model can produce reliable date estimates (*boundaries*) for events not directly dated by single radiocarbon determinations, such as the beginning and end of deposition (Bayliss et al. 2007:6), and can be queried to derive useful information about the temporal duration of an activity (*span*) or hiatuses between events (*intervals*). Interrogating the model, as Bronk Ramsey (1998:463) refers to such queries, affords archaeologists the opportunity to extract and evaluate the significance of temporal patterning more effectively. Herein lies the true value of constructing Bayesian site chronologies—the opportunity to move beyond visual inspection of groups of calibrated dates (Bayliss et al. 2007:8-9; Whittle and Bayliss 2007:21).

In this analysis, I begin with a Bayesian approach to integrate non-quantitative contextual information (the priors), with probability distributions from radiocarbon dates (the standardized likelihood) to trim confidence intervals and refine age estimates (the posteriors) for three depositional sequences. However, I focus analysis and discussion on the temporal information derived from querying the final chronological models.

Building Site Chronologies

High precision is required when the ultimate goal is to reconstruct seasonal mobility patterns; thus, it is necessary to begin with a clear idea of site stratigraphy, sample types, and sample locations (Kennett and Culleton 2012:41).

Radiocarbon Sampling and Measurement. Marine shell, particularly California mussel (*Mytilus californianus*), is the most abundant and well-preserved cultural material in these archaeological deposits. All radiocarbon dates discussed here were produced from shell samples. Following recommendations from Culleton et al. (2006b:396), I selected the distal portions of larger mussel shells, likely from older, slower growing individuals in order to reduce the confounding influence of intrashell radiocarbon variability. These shells were recovered from the bulk soil sample removed intact from each distinct stratum. This strategy ensured control over sample location in the depositional sequence. To avoid the averaging inherent in bulk radiocarbon samples, I submitted a single shell sample, large enough for AMS radiocarbon dating, from each stratum to be dated by the National Ocean Sciences

Accelerator Mass Spectrometry Facility (NOSAMS) at the Woods Hole Oceanographic Institution. Submission was staged to gain a maximum amount of chronometric data from a minimum number of samples. The first round of submission to NOSAMS included samples selected from strata at each site that appeared to predate Late Period deposits, based on the presence of temporally diagnostic artifacts that tentatively appeared to predate Late Period deposits, based on the presence, density, and stylistic variation of temporally diagnostic shell beads and shell fishhooks (*sensu* Bennyhoff and Hughes, 1987; King, 1990). Subsequent submissions expanded the chronological sequence by dating almost every stratum that fell between terminal Early Period (ca. 3000 cal B.P.) and late Middle Period (ca.1000 cal B.P.) deposits, as indicated in the initial radiocarbon dating program. I report the AMS radiocarbon ages and their estimated errors for all 29 dates from the Coastal, Pericoastal, and Interior sites in Table 4.1.

Coastal Site Stratigraphy and Sample Selection. Figure 4.1 shows the east wall profile of Unit 2 excavated from the edge of the sea cliff at the Coastal site. Fourteen distinct strata with cultural materials dominated by marine shell extend to a maximum depth of 280 cm. The first round of samples submitted for AMS radiocarbon dating included eight samples evenly distributed from excavation Level 7 to excavation Level 21. Based on these dates, six strata, represented by excavation levels 15-22, were targeted for further analysis. The second round of radiocarbon samples submitted were selected from excavation levels 16, 20, and 22, which occurred between levels with very different radiocarbon ages and appeared likely to fall within the temporal periods of interest. Level 18 was not dated because the radiocarbon ^{14}C dates from shell in level 17 and level 19 were statistically indistinguishable based on a Ward and Wilson (1978) test of contemporeniety.

Level 15 and Level 16 are associated with Stratum IX, the uppermost stratum considered in subsequent analysis. Level 17 is associated with Stratum X, distinguished from Stratum IX by darker sediment, decreased shell and bone density, and an abundance of highly fragmented charcoal throughout. The sediment color and increased diversity of shell types in Stratum X is quite similar to Stratum XI; however, the density of shell and bone is lower. Levels 18 and 19 are associated with the black sediments of Stratum XI. Characterized by a medium density of fragmented marine shell and a high abundance of fish bone, this stratum contains more cultural remains than Stratum X or XII. Level 20 is associated with Stratum XII, distinguished from Stratum XI by lighter sediment as well as a decreased shell and bone density. Level 21 and is associated with Stratum XIII. Similar to Stratum IX, Stratum XIII is characterized by a high density and diversity of large marine shell and bone fragments. These two strata are distinguished by a slightly higher density of cultural remains and lighter sediment color in Stratum XIV. Level 22 is associated with Stratum XIV; this is the lowermost cultural deposit recovered from Unit 2 at the Coastal site.

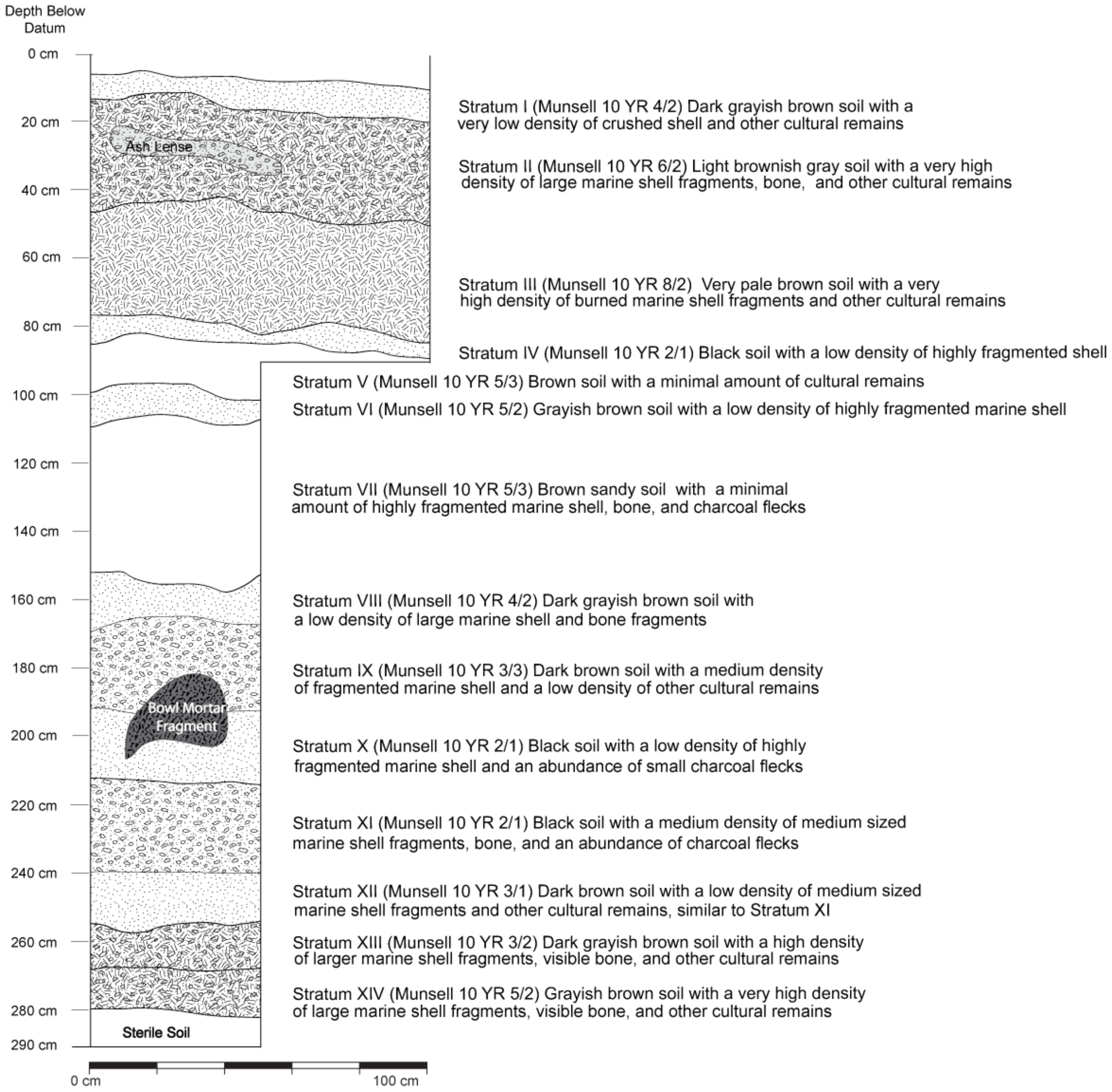


Figure 4.1. Profile of unit stratigraphy the Coastal site (CA-SCRI-236) including strata descriptions.

Pericoastal Site Stratigraphy and Sample Selection. Figure 4.2 shows the west wall profile of Unit 1 excavated at the Pericoastal site. Composed of nine distinct strata with varying density of marine shell, 120 cm of archaeological deposits overlay culturally sterile soil. The first round of samples submitted for AMS radiocarbon dating included six samples evenly dispersed from excavation Level 1 to excavation Level 8. Based on these dates, four strata, represented by excavation levels 3-6 and Feature 1, were targeted for further analysis, and one additional sample from level 5 was submitted for AMS radiocarbon dating.

Level 3 is associated with Stratum III, the uppermost of the strata considered here. The sediment in this stratum is very dark grayish brown (Munsell 10YR 3/2), slightly darker-colored than the overlying Stratum II. Characterized by a medium density of fragmented marine shell, primarily California mussel, this stratum contains fewer cultural remains than the strata immediately above or below it. Feature 1 occurs between Stratum III and Stratum IV and is distinguished, in part, by grayer sediment (Munsell 10YR 4/1, dark gray) and a slightly higher ash content. However, the defining characteristic of this discrete feature is the very high density of whole or nearly whole Pismo clam and California mussel shells. Level 4 is associated with Stratum IV, representing the next contiguous depositional stratum. The sediment in this stratum is dark grayish brown (Munsell 10YR 4/2) and is similar to Stratum III in both color and texture. There is a medium to high density of fragmented marine shell and also appears quite similar to Stratum III. Level 5 is associated with Stratum V. This relatively thin stratum is interrupted by the presence of a hearth and is bracketed by non-contiguous lenses of ash above and below. The very dark gray brown (Munsell 10YR 3/1) loamy soil of Stratum V contrasts sharply with the grayish brown (Munsell 10YR 5/2) sediments of the ash lens above and below. The ash lenses and hearth feature were excavated individually, but they did not contain any datable materials. In contrast, Level 5 contains an abundance of large unburned mussel shell fragments. Below the lower non-contiguous ash lens at the base of Level 5, Stratum VI occurs. Level 6 is associated with Stratum VI. The sediment in this distinct deposit is darker in color (Munsell 10YR 2/2, very dark brown) than

Stratum V. Cultural constituents of Level 6 include a medium to high density of fragmented marine shell, bone, and lithic flakes.

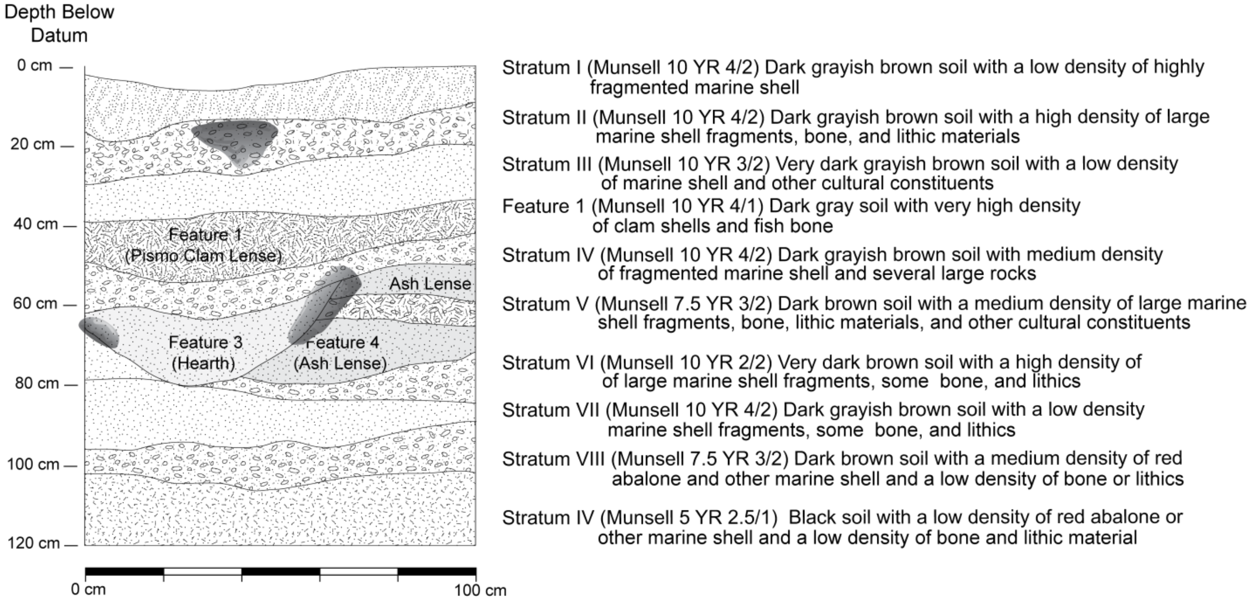


Figure 4.2. Profile of unit stratigraphy the Pericoastal site (CA-SCRI-823) including strata descriptions.

Interior Site Stratigraphy and Sample Selection. Figure 4.3 shows the south wall profile of the unit excavated at the Interior site. Dark, organic anthropogenic soils embedded with a variable density of marine shell and other cultural materials compose 12 distinct strata. A full 200 cm of cultural deposits overlies culturally sterile soil. The first round of samples submitted for AMS radiocarbon dating included eight samples evenly dispersed from excavation Level 1 to excavation Level 16. Based on these dates, four strata, represented by excavation levels 8-13, were targeted for further analysis, and three additional samples, one from Level 10, from Level 12, and from Level 13, were submitted for dating.

Level 9 is associated with Stratum VI, the uppermost of the strata considered here. The sediment in this stratum is very dark (Munsell 7.5YR 2.5/1, black), distinguished from

Stratum V above by its darker color and loamier texture, and it is capped by a non-contiguous ash lens. Cultural constituents include a high density of lithic flakes and a low density of highly fragmented marine shell. Level 10 and Level 11 are associated with Stratum VII. The sediment in this distinct deposit is slightly grayer in color (Munsell 7.5YR 3/1, very dark gray) than Stratum VI. There is a medium density of both shell and lithic flakes. Levels 12 and 13 are associated with Stratum VIII, distinguished from Stratum VII by an abrupt increase in shell density despite a similar sediment color (Munsell 7.5YR 3/1, very dark gray).

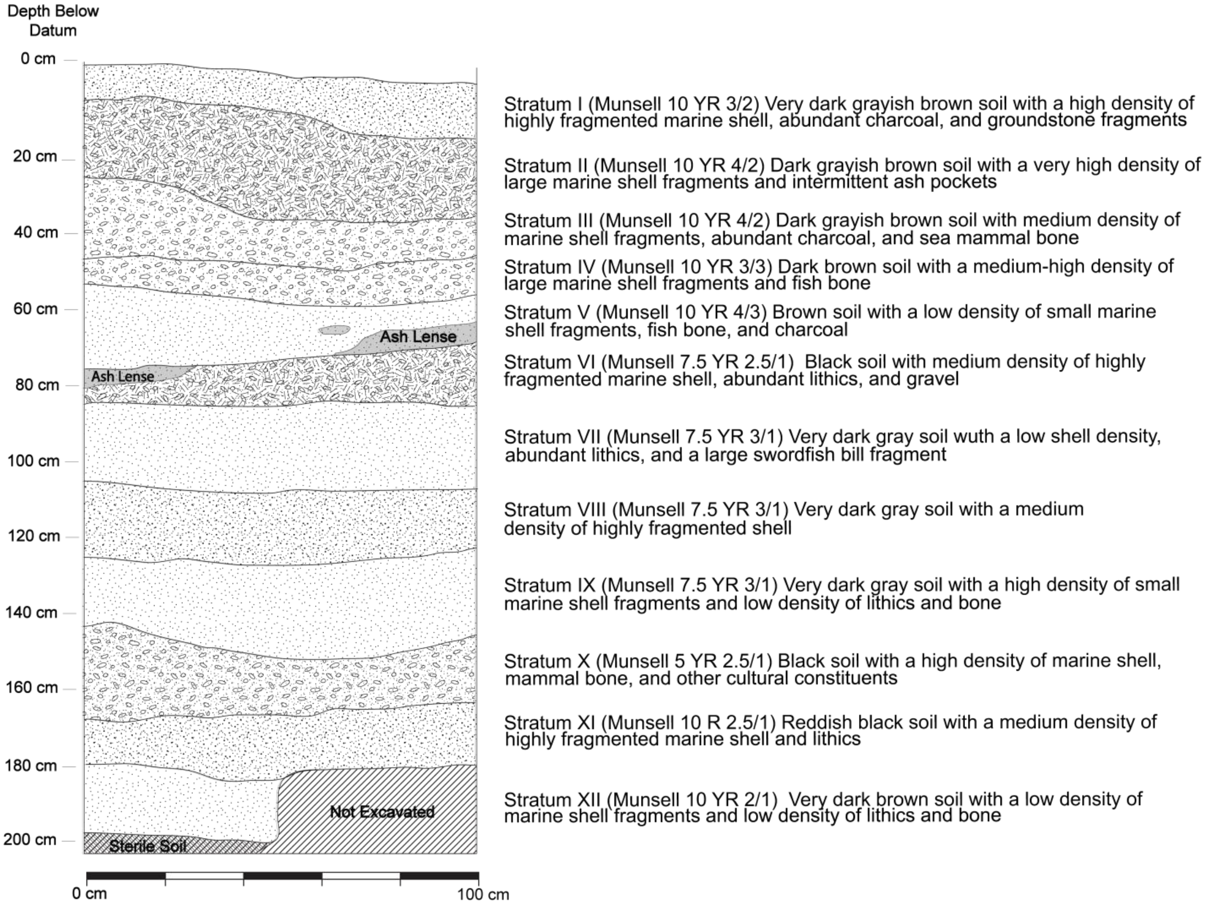


Figure 4.3. Profile of unit stratigraphy the Interior site (CA-SCRI-568) including strata descriptions.

Table 4.1. AMS ^{14}C dates as reported by NOSAMS from the Coastal, Pericoastal, and Interior sites. Excavation level selected for further analysis are shaded gray.

Site	Excavation Level	NOSAMS Sample ID	Conventional Age (^{14}C B.P.)
Coastal site (CA-SCRI-236)	Level 7	88161	1140 ± 40
	Level 9	88162	1310 ± 35
	Level 11	88163	1510 ± 40
	Level 13	88164	1600 ± 30
	Level 15	88165	1790 ± 25
	Level 16	106998	1850 ± 25
	Level 17	88166	2020 ± 35
	Level 19	88167	2070 ± 25
	Level 20	106999	2100 ± 25
	Level 21	88168	3350 ± 30
	Level 22	101029	3340 ± 25
Pericoastal site (CA-SCRI-823)	Level 1	88147	1560 ± 25
	Level 3	88155	1720 ± 25
	Feature 1	88160	1750 ± 30
	Level 4	88156	1780 ± 25
	Level 5	88157	1990 ± 25
	Level 6	88158	3530 ± 30
	Level 8	88159	4170 ± 35
Interior site (CA-SCRI-568)	Level 1	88147	915 ± 25
	Level3	88148	910 ± 25
	Level 5	88149	1140 ± 25
	Level 7	88150	1310 ±30
	Level 9	88151	1650 ± 45
	Level 10	106996	2130 ± 25
	Level 11	88152	2130 ± 25
	Level 12	106995	3640 ± 30
	Level 13	106996	3770 ± 30
	Level 14	88153	3900 ±35
	Level 16	88154	4170 ±35

Radiocarbon Calibration and Correction. Based on this intensive program of radiocarbon dating, I identified 19 excavation levels/features for further analysis. Excavation Levels 15-22 at the Coastal site, Levels 3-6 and Feature 1 at the Pericoastal site, and Levels 8-13 at the Interior site pertain to the temporal period of interest. I calibrated the radiocarbon ages reported for each of these strata in OxCal version 4.2.2 (Bronk Ramsey 2009) using the

Marine09 marine calibration (Reimer et al. 2009). The use of marine shells for dating also requires application of a marine reservoir correction to account for regional differences in the radiocarbon age of sea-surface water (see Stuvier and Polach 1977:366-367; Stuvier and Reimer 1986; and Kennett et al. 1997 for further discussion). The most recent local marine reservoir correction (ΔR) for the Santa Barbara Channel region is 261±21 radiocarbon years. This estimate is based on five AMS radiocarbon dates on pre-bomb (AD 1925) *Olivella* shells collected near Santa Barbara, California, with three existing dates on *Mytilus* reported by Ingram and Southon (1996), calculated against the Marine09 calibration curve (Kennett et al. 2013; see also Culleton et al. 2006b). However, just as marine reservoir corrections are not consistent across space, they are also not consistent through time. A recent paper by Hendy et al. (2013) demonstrates significant ΔR fluctuations, ranging from 80 to 350 years, occurred in the Santa Barbara Basin over the last ca. 2000 years. This affirms previous concerns (see Kennett et al. 1997 and Ingram 1998) that variable ΔR values for specific temporal intervals are necessary to ensure precision in high-resolution radiocarbon dating. Referencing AMS radiocarbon dates on paired organic and planktonic marine foraminiferal carbonate from laminated varves reported by Hendy et al. (2013), Brendan Culleton at Penn State University calculated variable ΔR estimates for each of the radiocarbon dates included in this study[1]. These data are reported in Table 4.1 along with the calibrated 1 and 2 sigma ages for each sample. Following Bronk Ramsey (2009:353), modeled posterior distributions (which are not usually normally distributed) discussed in the text are presented as 68% and

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[1] Comparison of Bayesian Chronological Models that incorporate the standard local marine reservoir correction (ΔR) for all dates and Chronological Models that incorporate the variable ΔR values (reported in Table 1) both reveal similar temporal patterns discussed in the Results Section below. These patterns are not an artifact of using the variable ΔR values for dates that fall within the last 2000 years. On the contrary, use of only the standard ΔR increases the weighted mean average number of years calculated for the interval of Post-terminal Early Period site abandonment an additional 100 to 200 years at all three sites.

95% probabilities in terms of cal B.P. (calibrated years before present) for comparability to traditional 1 and 2 sigma age ranges.

Table 4.2. Calibration and variable marine reservoir correction factors of selected AMS ^{14}C dates from the Coastal, Pericoastal, and Interior sites.

Site	Excavation Level	Variable ΔR	1σ cal B.P. (prior)	2σ cal B.P. (prior)
Coastal site (CA-SCRI-236)	Level 15	155 ± 44	1264 - 1156	1291 - 1075
	Level 16	143 ± 44	1305 - 1205	1355 - 1145
	Level 17	101 ± 44	1535 - 1395	1613 - 1332
	Level 19	95 ± 44	1606 - 1462	1675 - 1398
	Level 20	92 ± 44	1645 - 1505	1698 - 1420
	Level 21	261 ± 21	2913 - 2799	2961 - 2755
	Level 22	261 ± 21	2889 - 2785	2942 - 2755
Pericoastal site (CA-SCRI-823)	Level 3	185 ± 44	1165 - 1030	1219 - 962
	Feature 1	170 ± 44	1209 - 1073	1260 - 1005
	Level 4	164 ± 44	1246 - 1125	1276 - 1055
	Level 5	115 ± 44	1485 - 1359	1532 - 1301
	Level 6	261 ± 21	3174 - 3046	3220 - 2980
Interior site (CA-SCRI-568)	Level 9	210 ± 43	1053 - 918	1156 - 860
	Level 10	88 ± 44	1680 - 1545	1760 - 1485
	Level 11	88 ± 44	1680 - 1545	1760 - 1485
	Level 12	261 ± 21	3315 - 3205	3352 - 3142
	Level 13	261 ± 21	3436 - 3350	3500 - 3303

Statistical Evaluation of the Chronometric Data. Initial evaluation of the conventional and calibrated radiocarbon ages reveals clearly overlapping date ranges at each site (See Tables 4.1 and 4.2). These dates can be grouped broadly as three distinct temporal periods (terminal Early Period, Middle Period, and late Middle Period), represented at each site. For example at the Coastal site, dates from Level 15 and 16 are quite similar, both indicating late Middle Period occupation; dates from Level 17, 18, 19, and 20 are quite similar, indicating Middle Period occupation; and dates from Level 21 and 22 are also quite similar, indicating terminal Early Period occupation.

Using OxCal 4.2.2, which provides a user-friendly Bayesian statistical platform, I integrated important non-quantitative contextual information gleaned from stratigraphic context with the probability distribution of calibrated dates, using just three basic commands (*event, sequence,* and *boundary*). For the purpose of this analysis, an *event* describes a single radiocarbon date associated with a unique archaeological stratum. A *sequence* describes a series of dated events or groups of dated events linked, at a minimum, by the law of superposition. Thus, one dated event/stratum or group of dated events/strata are constrained to be in chronological order. *Boundaries* describe gaps in the stratigraphic sequence that occur between dated events or groups of dated events, such as the beginning/end of a period of occupation. It is important to note that boundaries are used to represent relative, not absolute chronological intervals. The probability distributions generated for boundary age estimates are best constrained in sequences deposited over relatively short periods. Using these methods, I constructed unique chronological models for the Coastal, Pericoastal, and Interior sites.

For each model, I began with the assumption that all of the deposits were in undisturbed stratigraphic order so the dates could be placed in an ordered sequence by depth. I base this assumption on the presence of apparently intact discrete strata. Thus, for this analysis the assumed stratigraphic order of the sampled contexts constitutes the first bit of prior knowledge incorporated into the Bayesian framework. At each site, distinctive shifts in the composition and density of constituents and cultural remains were visible in the stratigraphic profile. Thus, I added additional sequences nested within the larger stratigraphic sequence, one for each set of similar dates representing a distinct period of site occupation. I bracketed each nested sequence with boundaries at the beginning and end of the sequence, building in gaps to represent stratigraphic disconformities.

The Chronological Models

In the resulting chronological models (Figure 4.4, 4.5, and 4.6), the posterior modeled date ranges (displayed in black) are trimmed slightly in comparison to the standard calibrations (displayed as an outline in Figure 4.7). The modeled chronological sequences also include estimates for the beginning and end of each period of site occupation. The agreement index (A) for the individual calibrations and the index for each model as a whole quantify the correspondence between the prior and posterior distributions; values below a critical value (A'c) of 60% indicate that the stratigraphic assumptions of the model may be in error and should be subject to critical re-examination. This threshold value is analogous to the 0.05 level of discrimination in a chi-squared test (Bronk Ramsey 1995:429). The final models presented here have individual agreement values varying between 97.4% and 117.6% and model agreement indices (A_{model}) of 130.1% (for the Coastal site), 130.9% (for the Pericoastal site), and 113.6% (for the Interior site). Convergence values of the final models all exceed 95%. These values are all well above the critical limit, indicating strong agreement within each model. Although the posterior density estimates reported in Tables 4.3-4.5 do not dramatically refine the age ranges, this analysis demonstrates both the reliability and stability of the constructed chronological models. Thus, confidence can be held in the dates (none appear to be intrusive), and there is no evidence against the assumed stratigraphic integrity of archaeological deposits at these three sites.

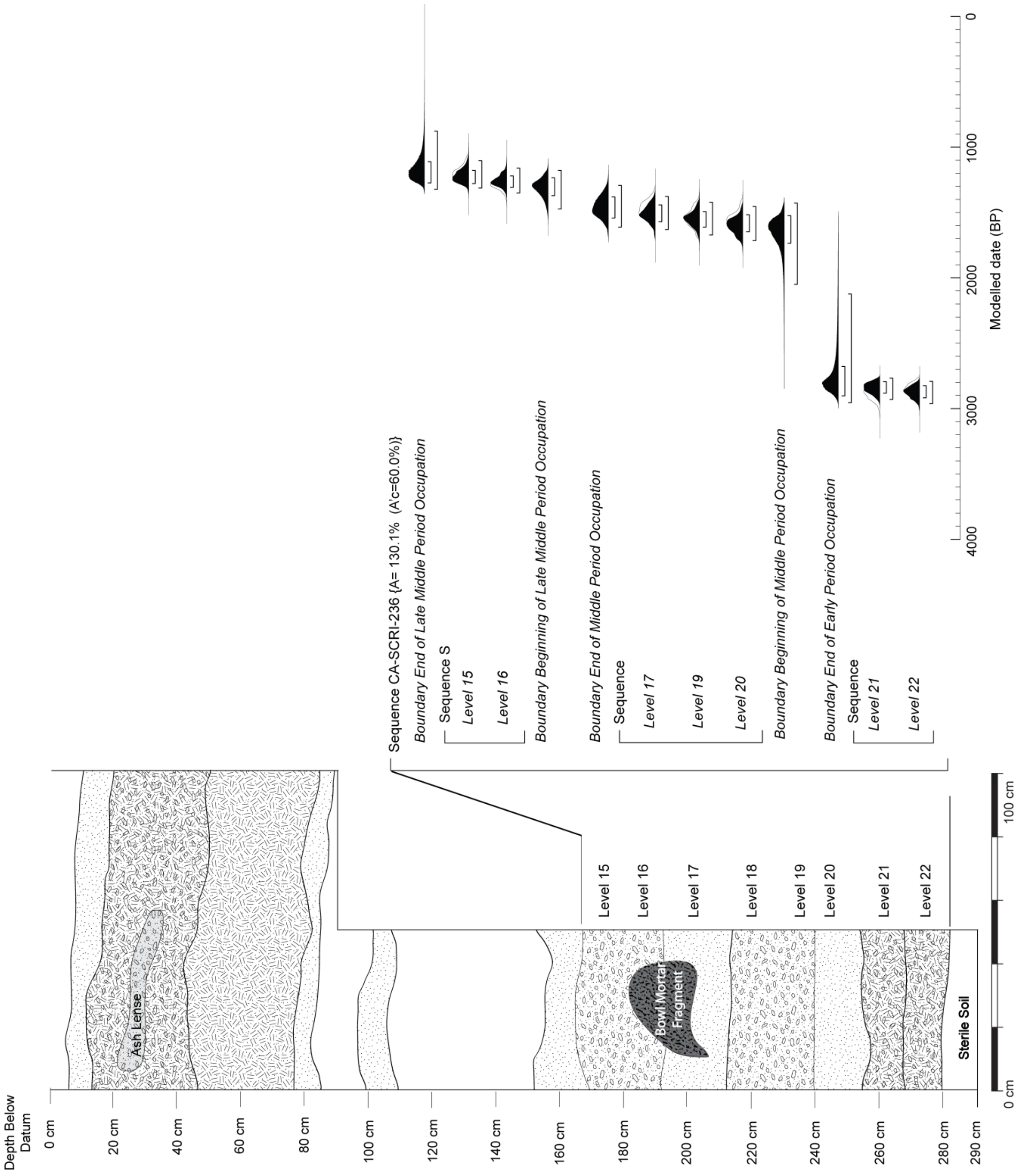

Figure 4.4. Profile of unit stratigraphy for the Coastal site (CA-SCRI-236) showing the excavation levels dated and modeled calibrations based on stratigraphic order (Model Agreement Index (A_{model})= 130.1%).

Table 4.3. Modeled results for the Coastal site stratigraphic sequence (Model Agreement Index (A_{model})= 130.1%).

Sequence	NOSAMS Sample ID	Provenience	Conventional Age (^{14}C B.P.)	Modeled 68% range cal B.P.	Modeled 95% range cal B.P.	Agreement Index
Late Middle Period (LMP)	*Boundary*	*End of LMP Deposition*		1263 - 1101	1311 - 869	
	88165	Level 15	1790 ± 25	1268 - 1167	1302 - 1093	101.70%
	106998	Level 16	1850 ± 25	1297 - 1209	1340 - 1150	105.30%
	Boundary	*Beginning of LMP Deposition*		1360 - 1224	1462 - 1167	
Middle Period (MP)	*Boundary*	*End of MP Deposition*		1530 - 1370	1600 - 1282	
	88166	Level 17	2020 ± 35	1559 - 1431	1618 - 1366	100.50%
	88167	Level 19	2070 ± 25	1600 - 1481	1660 - 1410	108.90%
	106999	Level 20	2100 ± 25	1635 - 1505	1703 - 1443	103.30%
	Boundary	*Beginning of MP Deposition*		1722 - 1513	2036 - 1417	
Terminal Early Period (TEP)	*Boundary*	*End of TEP Deposition*		2886 - 2661	2938 - 2090	
	88168	Level 21	3350 ± 30	2865 - 2778	2912 - 2751	101.80%
	101029	Level 22	3340 ± 25	2900 - 2808	2945 - 2775	103.70%

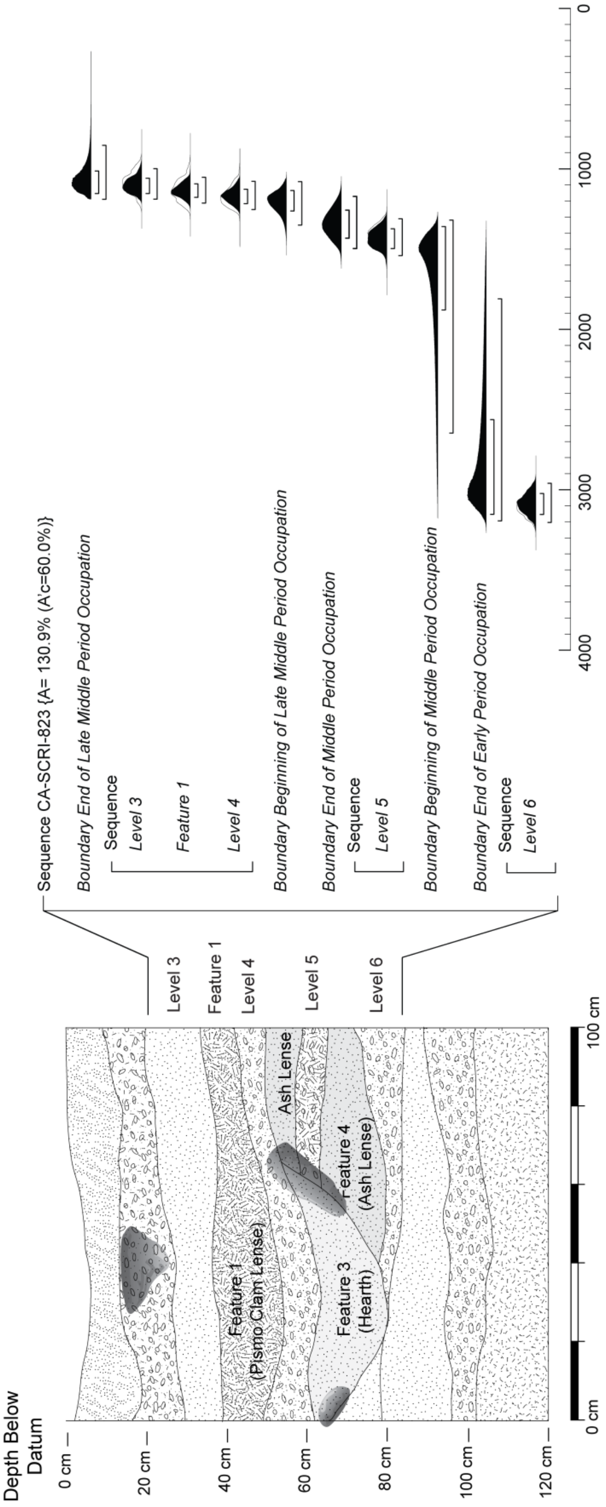

Figure 4.5. Profile of unit stratigraphy for the Pericoastal site (CA-SCRI-823) showing the excavation levels dated and modeled calibrations based on stratigraphic order (Model Agreement Index (A_{model})= 130.9%).

Table 4.4. Modeled results for the Pericoastal site stratigraphic sequence (Model Agreement Index (A_{model})= 130.9%).

Sequence	Sample ID	Provenience	Conventional Age (^{14}C B.P.)	Modeled 68% range cal B.P.	Modeled 95% range cal B.P.	Agreement Index
Late Middle Period (LMP)	*Boundary*	*End of LMP Deposition*		1153 - 1009	1204 - 840	
	88155	Level 3	1720 ± 25	1156 - 1060	1199 - 999	112.10%
	88160	Feature 1	1750 ± 30	1180 - 1095	1220 - 1055	117.60%
	88156	Level 4	1780 ± 25	1220 - 1129	1257 - 1081	110.10%
	Boundary	*Beginning of LMP Deposition*		1265 - 1136	1350 - 1082	
Middle Period (MP)	*Boundary*	*End of MP Deposition*		1437 - 1261	1502 - 1175	
	88157	Level 5	1990 ± 25	1499 - 1376	1545 - 1315	100.30%
	Boundary	*Beginning of MP Deposition*		1887 - 1361	2649 - 1325	
Terminal Early Period (TEP)	*Boundary*	*End of TEP Deposition*		3156 - 2573	3199 - 1813	
	88158	Level 6	3530 ± 30	3158 - 3027	3208 - 2964	97.40%

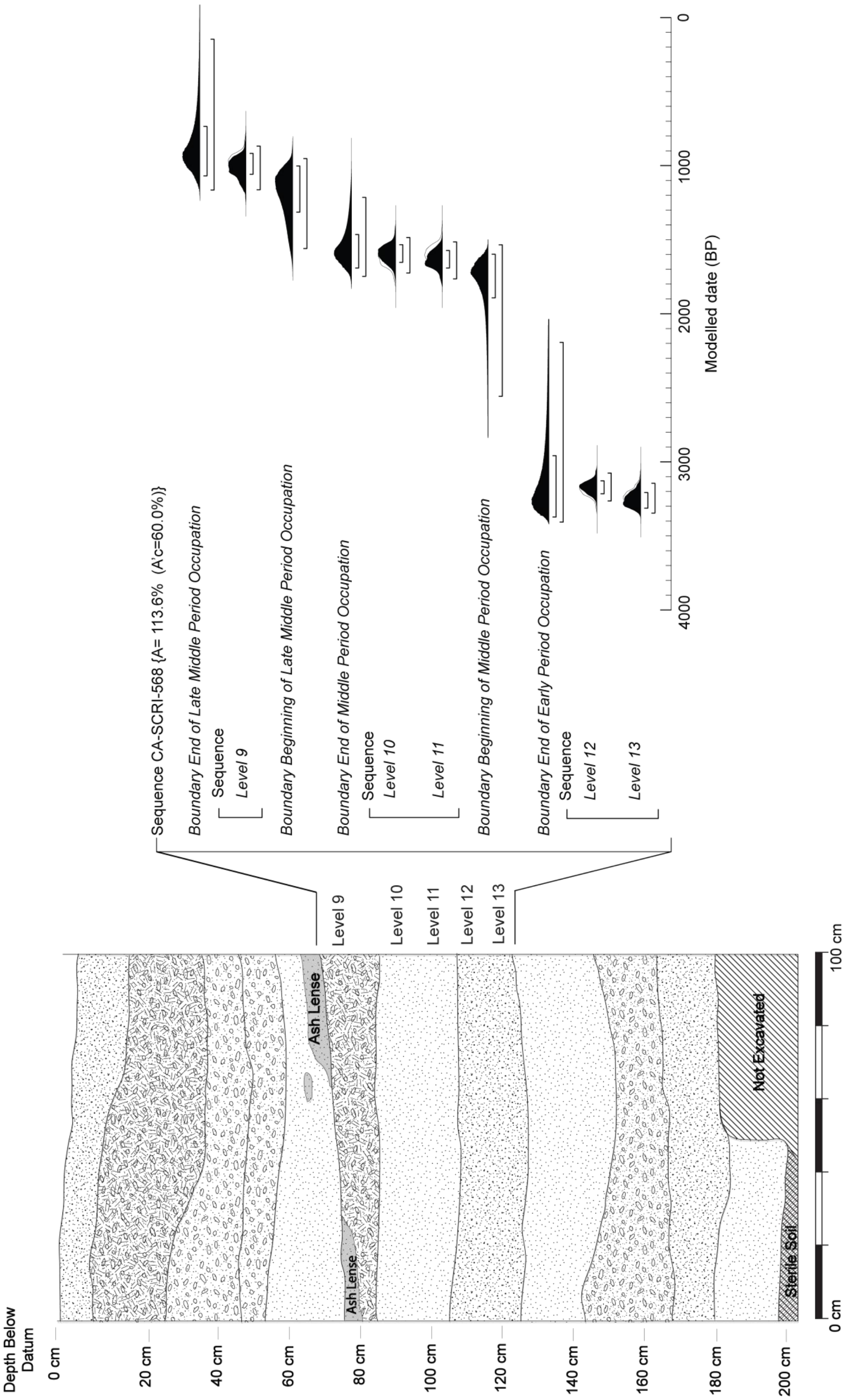

Figure 4.6. Profile of unit stratigraphy for the Interior site (CA-SCRI-568) showing the excavation levels dated and modeled calibrations based on stratigraphic sequence (Model Agreement Index (A_{model})= 113.6%).

Table 4.5. Modeled results for the Interior site stratigraphic sequence (Model Agreement Index (A_{model})= 113.6%).

Sequence	Sample ID	Provenience	Conventional Age (^{14}C B.P.)	Modeled 68% range cal B.P.	Modeled 95% range cal B.P.	Agreement Index
Late Middle Period (LMP)	*Boundary*	*End of LMP Deposition*		1072 - 740	1168 - 152	
	88151	Level 9	1650 ± 45	1061 - 921	1165 - 871	98.30%
	Boundary	*Beginning of LMP Deposition*		1275 - 964	1520 - 915	
Middle Period (MP)	*Boundary*	*End of MP Deposition*		1651 - 1426	1708 - 1176	
	106997	Level 10	2130 ± 25	1654 - 1535	1726 - 1487	104.40%
	88152	Level 11	2130 ± 25	1692 - 1574	1765 - 1516	101.20%
	Boundary	*Beginning of MP Deposition*		1853 - 1558	2515 - 1495	
Terminal Early Period (TEP)	*Boundary*	*End of TEP Deposition*		3327 - 2915	2515 - 1495	
	106995	Level 12	3640 ± 30	3324 - 3219	3357 - 3156	100.80%
	106996	Level 13	3770 ± 30	3423 - 3336	3283 - 3379	98.40%

Table 4.6. Queries and Calculations based on Chronological Models (Span). Abbreviations for sites are CST for Coastal, PER for Pericoastal, and INT for Interior. Abbreviations for temporal periods are LMP for Late Middle Period, MP for Middle Period and TEP for Terminal Early Period. Missing values indicated by a dash indicate temporal periods at a single site represented by a single radiocarbon date. Span queries require multiple dates to provide reliable estimates.

Site	Query	Provenience	Modeled 68% range cal. years	Modeled 95% range cal. years	Weighted Mean cal. years	Volume of Deposits (L)	Estimated Rate of Accumulation
CST	*Span*	LMP Occupation	0 - 52	0 - 109	39	56	1.44 liters/yr
	Span	MP Occupation	7 - 106	0 - 176	79	217	2.75 liters/yr
	Span	TEP Occupation	0 - 39	0 - 94	30	81	2.70 liters/yr
PER	*Span*	LMP Occupation	0 - 89	0 - 177	70	72	1.03 liters/yr
	Span	MP Occupation	-	-	-	-	-
	Span	TEP Occupation	-	-	-	-	-
INT	*Span*	LMP Occupation	-	-	-	-	-
	Span	MP Occupation	0 - 46	0 - 106	36	74	2.06 liters/yr
	Span	TEP Occupation	45 - 172	0 - 227	116	76	0.66 liters/yr

Table 4.7. Queries and Calculations based on Chronological Models (Interval). Abbreviations for sites are CST for Coastal, PER for Pericoastal, and INT for Interior. Abbreviations for temporal periods are LMP for Late Middle Period, MP for Middle Period and TEP for Terminal Early Period.

Site	Query	Provenience	Modeled 68% range cal. Years	Modeled 95% range cal. years	Weighted Mean cal. Years	Estimated Midpoint cal B.P.	Estimated 68% date range cal B.P.	Estimated 95% date range cal B.P.
CST	*Interval*	Post-MP Abandonment	16 - 201	0 - 304	143	1372	1465 - 1280	1524 - 1220
	Interval	Post-TEP Abandonment	918 - 1316	323 - 1399	1004	2195	2394 - 1996	2733 - 1657
PER	*Interval*	Post-MP Abandonment	0 - 172	0 - 292	132	1275	1361 - 1189	1421 - 1129
	Interval	Post-TEP Abandonment	540- 1596	26 - 1622	917	2241	2769 - 1713	3039 - 1443
INT	*Interval*	Post-MP Abandonment	110 - 512	0 - 612	318	1334	1535 - 1133	1640 - 1028
	Interval	Post-TEP Abandonment	969 - 1669	198 - 1729	1142	2412	2762 - 2062	3177 - 1646

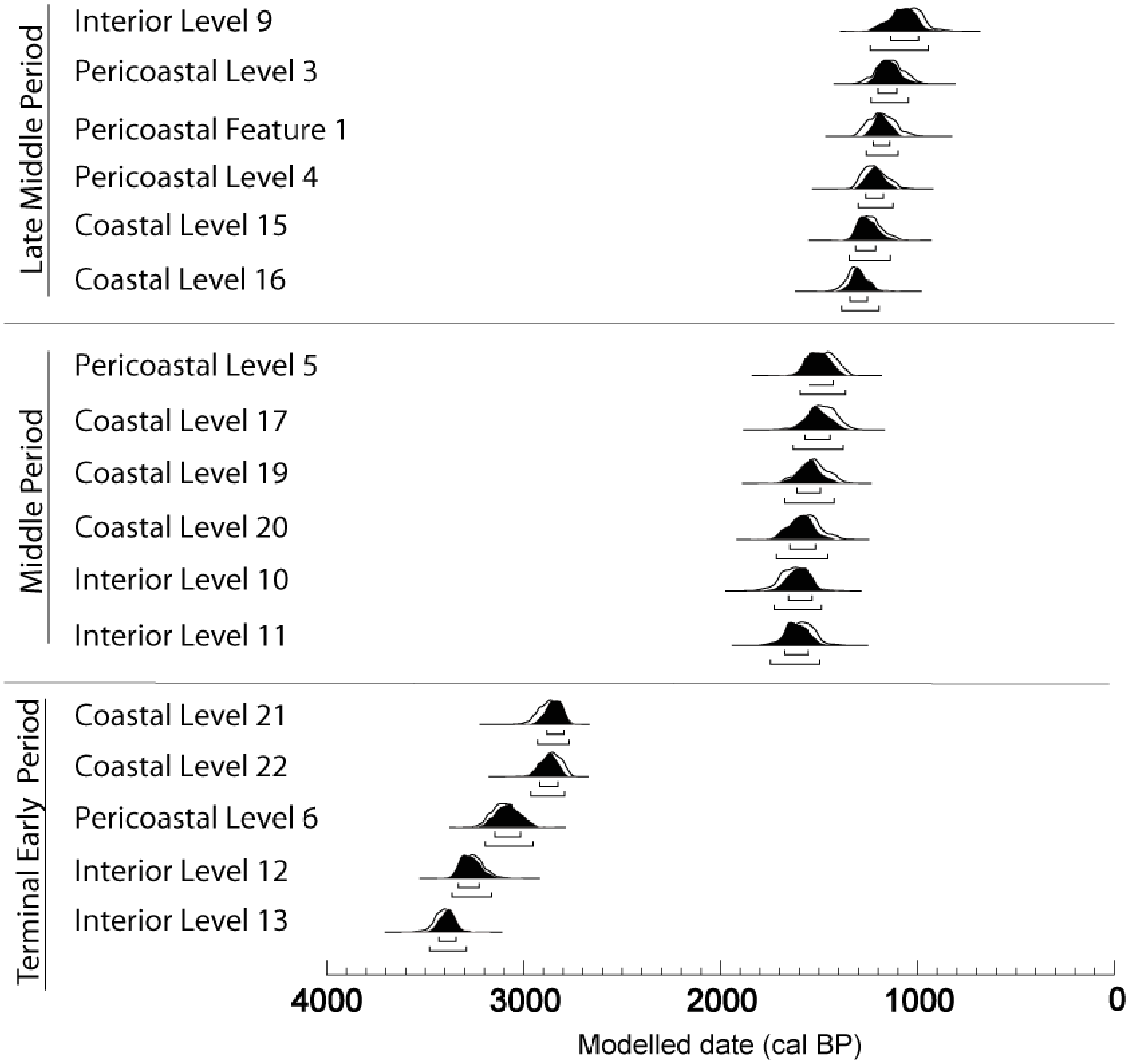

Figure 4.7. All calibrated dates modeled within individual site sequences presented in chronological order. Brackets below each modeled distribution represent the 68% and 95% calibrated date ranges.

Duration and Intensity of Site Occupation. The resulting final chronological models provide refined posterior age ranges trimmed slightly in comparison to the prior distributions. Comparison of the modeled calibrated dates reveals overlap in the 68% modeled date ranges and the 95% modeled date ranges for occupation at each of the three sites within a given temporal period (see Figure 4.7). However, it is not possible to test the statistical significance of observable overlap using the modeled calibrated date ranges. Yet, rather than an end to the analysis, these models are intended as statistical frameworks for further inquiry. The *span* query in OxCal generates 68% and 95% probability distributions that estimate the amount of time likely represented between the beginning and end of deposition during a single period of occupation at a site, represented by multiple radiocarbon dates. This query produces reliable estimates for the span of time, or duration, of site occupations based on posterior date ranges from the earliest relevant deposit and the latest relevant deposit (see Table 4.6).

The maximum date ranges for terminal Early Period occupation at the Coastal site range from 39 cal. years (68%) to 94 cal. years (95%), but the distributions are skewed towards larger values, so the duration of occupation events may have been much shorter. The weighted mean for these probability distributions suggest that terminal Early Period deposits at the Coastal site accumulated over a relatively brief period of 30 years. Using this estimated duration, I calculate the rate of accumulation within a 50 cm square unit to be approximately 2.7 liters per year. In addition to cultural deposits, this accumulation rate also reflects a fair amount of windblown sand from the adjacent beach. Nonetheless, it seems likely that the Coastal site was occupied intensively during the terminal Early Period. As only one radiocarbon date pertains to terminal Early Period occupation at the Pericoastal site it is not possible to use the *span* query in OxCal to generate an estimate for the likely duration or intensity of occupation at this site. The weighted mean for these probability distributions suggest that terminal Early Period deposits at the Interior site accumulated over a period of 76 years. Using this value, I estimate a rate of accumulation within a 50 cm square unit to be approximately 0.66 liters per year. Despite the lack of windblown deposits or evidence of significant deposition of non-cultural materials, this rate of accumulation is relatively slow, suggesting that the Interior site was not intensively occupied during the Terminal Early Period.

During the Middle Period both the Coastal and the Interior site appear to have been rather intensively occupied. The weighted means calculated for the spans of occupation suggest that Middle Period deposits accumulated over a period of 79 years at the Coastal site and over a period of 36 years at the Interior site. These estimates produce an estimated rate of accumulation of 2.75 liters (within a 50 cm square unit) per year at the Coastal site and 2.06 liters per year at the Interior site. Given the increased contribution of non-cultural windblown constituents at the Coastal site, it seems likely that both the Coastal and Interior site were occupied at a similar intensity during the Middle Period. At the Coastal site the intensity of site occupation during the Middle Period appears quite similar to the intensity of occupation during the terminal Early Period; however, at the Interior site the intensity of site occupation during the Middle Period is much higher. This suggests a fundamental shift in the function and importance of the Interior site during the Middle Period.

During the late Middle Period the weighted means calculated for the spans of occupation suggest that deposits accumulated over a period of 39 years at the Coastal site and over a period of 70 years at the Pericoastal site. These estimates produce an estimated rate of accumulation of 1.03 liters (within a 50 cm square unit) per year at the Coastal site and 1.44 liters (within a 50 cm square unit) per year at the Pericoastal site. Given the increased contribution of non-cultural windblown constituents at the Coastal site, it seems likely that both the Coastal and Pericoastal site were occupied at a similar intensity during the late Middle Period. At the Coastal site the intensity of site occupation during the late Middle Period is significantly reduced in comparison to the two preceding temporal periods. This may reflect further shifts in land use and mobility occurred during the late Middle Period. Unfortunately, it is not possible to evaluate whether these shifts also occurred at the Interior site based on the duration and intensity of occupation.

Contemporaneous Intervals of Abandonment. When it comes to understanding mobility and land use patterns, knowing when a site was occupied, for how long, and at what intensity is only half of the story. Equally important (and often just as interesting) is when a site was not occupied. Although there is no way to directly date periods of site abandonment, which are defined by the absence of cultural materials, it is possible to produce reliable estimates of these events based on the posterior date ranges and estimated *boundaries.* The *interval* query in OxCal generates 68% and 95% probability distributions that estimate the amount of time likely represented between the end of deposition during one period and the beginning of deposition during the subsequent period.

Two temporal gaps, the first following terminal Early Period occupation and the second following Middle Period occupation, are evident in the chronological model established for each site. Based on the boundary events that bracket the beginning and end of each period of site occupation, I used the interval function in Oxcal to generate probability distributions estimating the amount of time likely represented by the post-terminal Early Period occupation and the post-Middle Period occupation intervals of abandonment at each site. Table 4.6 provides the modeled 68% and 95% range of time of abandonment in years. Based on the weighted means for the probability distributions, the results of this analysis suggest that following terminal Early Period occupation people abandoned and likely did not re-occupy any of these three sites for at least a millennium. The second, much shorter interval of abandonment following Middle Period occupation ranges from a weighted average of 130 years at the Coastal and Pericoastal sites to a weighted average of 318 years at the Interior site.

Despite similarities evident in the length of time each site was abandoned following terminal Early Period and then again following Middle Period site occupation, the temporal relationship between the intervals of abandonment at each site remains unclear. To assess the contemporaneity of intervals of abandonment between sites it is necessary to tie the probability distributions estimated by OxCal to the timeline. Following Jazwa et al. (2013:195), I calculated the midpoint of the median modeled dates for the two boundary events that defined each interval of occupation. Centering the intervals of abandonment on their respective midpoints ties them to the timeline and yields a 68% and 95% date range for each interval of abandonment (see Table 4.6). The results of this analysis demonstrate substantial temporal overlap in the date ranges estimated for the intervals of abandonment from all three sites.

Following the terminal Early Period occupation, the Interior site, the most inland of the three site locations is abandoned first, as early as 3177 cal B.P. (see Figure 4.7). The Pericoastal site is abandoned as early as 3039 cal B.P. and the Coastal site, is abandoned last, as early as 2733 cal B.P.. The 95% date ranges estimated for post-terminal Early Period abandonment overlap at all three sites from 2733 to 1657 cal B.P. There is no evidence of human occupation at any of these three substantial habitation sites throughout this interval. Following Middle Period occupation, the Interior site is again the first site location abandoned and the last site location re-occupied. The length of time represented and the estimated date ranges for the Coastal and Pericoastal sites are quite similar, although the Coastal site is abandoned before and reoccupied slightly later than Pericoastal site. The 95%

date ranges estimated for post-Middle Period interval of abandonment overlap at all three sites from 1421 to 1220 cal B.P. After 1220 cal B.P. people first re-occupy the Coastal site, followed shortly by re-occupation of the Pericoastal site. There is a more substantial hiatus evident at Interior site; people do not re-occupy this site until two centuries later, ~1028 cal B.P.

Assessment and Evaluation of Site Seasonality

Research on Santa Cruz Island indicates that marine mollusks were a staple resource of the subsistence economy (Erlandson 1988, 1991). Marine shellfish are an ubiquitous feature in nearly all archaeological deposits on the island regardless of elevation or distance from the coast (Kennett 2005:176). It is well established that marine shells provide useful archives of past environmental conditions (Epstein et al. 1953). During growth, mollusks sequentially deposit new layers of shell, and consequently information about the physical and chemical environment of their growth (Wefer and Berger 1991). The stable oxygen isotopic composition of shell carbonate is a particularly useful recorder of sea-surface temperature (SST) in marine systems where changes in salinity are minimal (Emiliani 1955; Shackleton 1973). Pak et al. (2004) confirmed that oxygen isotope values of foraminiferal calcite in the adjacent Santa Barbara Channel are well correlated with Magnesium-Calcium based paleothermometers that are not influenced by salinity. Thus predictable seasonal patterning in SST in the waters surrounding Santa Cruz Island are represented with high fidelity $\delta^{18}O$ ratios (Pak et al. 2004:8). Previous work with California mussel (*Mytilus californianus*) indicates that the exterior prismatic layer (calcite) of this species is a faithful recorder of SST (Killingley 1981; Jew et al. 2013; Jones and Kennett 1999; Glassow et al. 1994, 2012;

Kennett 2005; Kennett and Kennett 2000). The incremental growth of California mussel shells records seasonal changes in water temperature. The oxygen isotopic composition of the final growth increment represents the SST that the mussel was experiencing at the time of harvest and is thus a proxy measure of season of collection (Kennett 2005:175).

The oxygen isotope analysis included in this study is based on marine shell carbonate samples from all 18 chronologically relevant excavation levels at the Coastal, Pericoastal, and Interior sites. The primary objective of this analysis is to establish season of site occupation for each depositional event (i.e., individual stratum). Assessment of season of occupation places groups of foragers at particular points on the landscape during particular seasonal windows. Importantly, sampling from different sites, site types, and stratigraphic contexts makes it possible to link the use of different places on the landscape to one another within an annual context (Eerkens et al. 2013:2015).

Selection and Preparation of Samples

From each excavation level included in paleoethnobotanical and zooarchaeological analyses, I selected a minimum of 15 whole, or nearly whole, California mussel shells from the floated assemblage. Only about half of these were ultimately included in the final analysis due to loss/breakage during shell preparation and budget constraints. To prevent duplication I chose exclusively left or right valves from a single assemblage. The side selected coincided with the side used for MNI of the same assemblage. All shells selected were well preserved with intact outer prismatic (calcite) layers and an intact terminal growth margin. The former ensured that the calcite sample could be removed without contamination with the interior aragonitic nacreous layer and the latter ensured that the final growth increment would be represented in the samples. Of the shells that met these two basic criteria, I gave preference to those in the middle of their size range to minimize the possibility of slower growth common with senescence in larger and older California mussels (following Glassow et al. 2012). Nonetheless, the best-preserved shells were selected regardless of size. Whole shells ranged in size from 40 mm to 115 mm. Following Glassow et al. (2012) all shells, or portions thereof, were large enough to obtain eight samples in 2 mm intervals, and they included the central axis of the shell where growth crenulations are broadest and most visible.

I prepared the shells selected for analysis following the established procedures of Shackleton (1973), Bailey et al. (1983), Killingley (1983), and Kennett and Voorhies (1996), Culleton et al. (2009), and Glassow et al. (1994, 2012). All specimens were individually scraped, scrubbed, and rinsed in deionized water to remove visible organic materials and adhering sediment. I then acid etched the shell surface in 0.1 N HCL to remove any diagenetically altered carbonate adhered to the surface of the shell, rinsed each shell repeatedly with deionized water, and oven dried them at 85°C for five hours. Calcite samples were extracted from the exterior surface of each shell with a rotary tool (0.8 mm engraving bit) operated by a variable-speed foot pedal. I ran the drill along the edge of the shell (sample A for a given shell) in order to sample the terminal growth margin and collected samples at 2 mm increments along the growth axis (sample B, C, D, and so on), which represent shell growth prior to harvest. During sampling, I was careful to ensure that holes drilled into the outer prismatic layer of the shell did not penetrate into the underlying nacreous layer, which is composed of aragonite and characterized by different isotope fractionation factors (Epstein et al. 1951, 1953; Keith et al. 1964). I cleaned the drill bit in an ethanol bath and the shell with compressed air between samples to avoid cross-contamination.

Previous isotopic studies in the Santa Barbara Channel Region indicate that eight calcite samples per shell are typically sufficient for characterizing at least the coolest and warmest waters during a year (see Glassow et al. 1994, 2012; Jew et al. 2013). Restricting the number of samples per shell to eight allowed me to include eight shells per excavation level. The first sample from the terminal growth margin provides the SST at the time of harvest, and the remaining seven samples contextualize this value, providing an extended view of SST variation prior to the time of harvest for both smaller rapidly growing mussels and larger slower growing mussels. This sampling strategy affords more precise seasonal resolution than methods previously employed by Kennett (2005) and Jones et al. (2008), which relied on a single reference shell to reconstruct the range of annual variation while all other shells were sampled only at the terminal growth margin (see Jew et al. 2013 for further critique).

Laboratory Procedures of Oxygen Isotope Analysis

I completed oxygen isotope analysis in two stages to maximize the number of seasonal estimates made, given the funds available. Initially I analyzed five samples per shell and five shells per excavation level (18 levels total). I found that this sampling strategy was only sufficient to capture a full annual cycle of SST variation for just a handful of faster growing individuals. In a second stage of analysis, I augmented the number of samples per shell based on the previous results. Many shells required analysis of all eight samples to capture the greater proportion of an annual cycle of SST variation. Even this number of samples was insufficient for some particularly slow-growing (large) individuals. Six to eight seasonality estimates for each excavation level are based on these extended profiles. 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) collected 1mm away from the terminal growth margin. This sampling program provides 15 seasonality estimates for each excavation level. Altogether, this analysis included 1,275 carbonate samples from 253 mussel shells analyzed at the Weldeab Stable Isotope Laboratory in the Earth Science Department at the University of California, Santa Barbara, and the Stable Isotope Laboratory in the Department of Geology at the University of California, Davis.

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. I weighed approximately 50 μg of each homogenized powdered calcite sample from archaeological shell and similar quantities of the international laboratory standard NBS-19 for analysis. Each weighed sample was reacted with 100% phosphoric acid in individual vials at 70°C. The resulting CO_2 was then cleaned through a series of cryotraps before being automatically loaded into the mass spectrometer for analysis. Based on the reproducibility of the NBS-19 standards, instrument precision (1σ) is estimated as ±0.03‰ for $\delta^{13}C$ and ±0.05‰ for $\delta^{18}O$. Unfortunately, this instrument encountered technical difficulties and was inoperable during the final stage of analysis.

I arranged to have the remaining 560 samples 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. Prior to analysis, approximately 75-100 μg of each powdered calcite sample from archaeological shell was roasted at 70°C under vacuum to eliminate absorbed water and organic contaminants. Each sample was then reacted with 105% orthophosphoric acid at 90°C using an ISOCARB automated common acid bath system. The resulting CO_2 was then purified through a series of cyrotraps and introduced into the IRMS through a dual inlet system. 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 ±0.04‰ for $\delta^{13}C$ and ±0.07‰ for $\delta^{18}O$. All measurements, from both laboratories, were calibrated to the international laboratory standard NBS-19 and are reported on the Vienna Pee Dee Belemnite (VPDB) scale. The oxygen isotope data are expressed in standard delta (δ) notation as per mil (‰), using the formula:

$$\delta^{18}O\ (or\ \delta^{13}C) = \left(\left[R_{sample}/R_{standard}\right] - 1\right)$$

Where R represents the heavy/light ratio between the abundances of any two isotopes (e.g., $^{18}O/^{16}O$ or $^{13}C/^{12}C$). A positive δ value indicates enrichment in the heavy isotope, relative to the standard, and conversely, a negative δ value indicates depletion in the heavy isotope (Wefer and Berger 1991).

Internal precision is high for both the Thermo-Finnegan MAT 253 IRMS and the GVI Micromass Optima SIRMS, and results from both labs were calibrated to the international laboratory standard NBS-19. Nonetheless, there remains the potential that results could vary due to differences in the age and configuration of these instruments. I evaluated the significance and magnitude of potential differences by analyzing a series of 26 samples on both instruments. I calculated the standard deviation of the differences between the pairs of $\delta^{18}O$ measurements to be 0.07‰, which is identical to the documented precision of each instrument, and provides a strong indication of the comparability of $\delta^{18}O$ values considered below.

Evaluation and Interpretation of Oxygen Isotope Data

For comparison to expected seasonal SST fluctuation, I used the measured δ^{18}O ratios to estimate mathematically SSTs using the Horibe and Oba (1972) calcite equation:

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

where T is in degrees Celsius, $\delta^{18}O_{c(VPDB)}$ is the isotopic value of 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. (2006b), 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‰). Due to the linear relationship between water δO^{18} and salinity, the modified SMOW value also accounts for local salinity (Culleton et al. 2009:4).

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 positively correlated with SSTs from offshore moorings (mounted at three meters depth) 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 more reliable representation of broad seasonal patterning. Figure 4.8 illustrates the mean SST inferred for each month and provides a reference for expected seasonal variation near Punta Arena, on Santa Cruz Island. Multiple studies have documented a modern seasonal SST range of 5 to 6°C for waters in the Santa Barbara Channel (Blanchette et al. 2006; Broitman et al. 2005; Pak et al. 2004:7).

However, this was certainly not always the case (see Glassow et al. 2012). Rather than rely on the explicit temperature measurements from modern data, I provide Figure 4.8 simply as a reference for broad seasonal trends, characterized below.

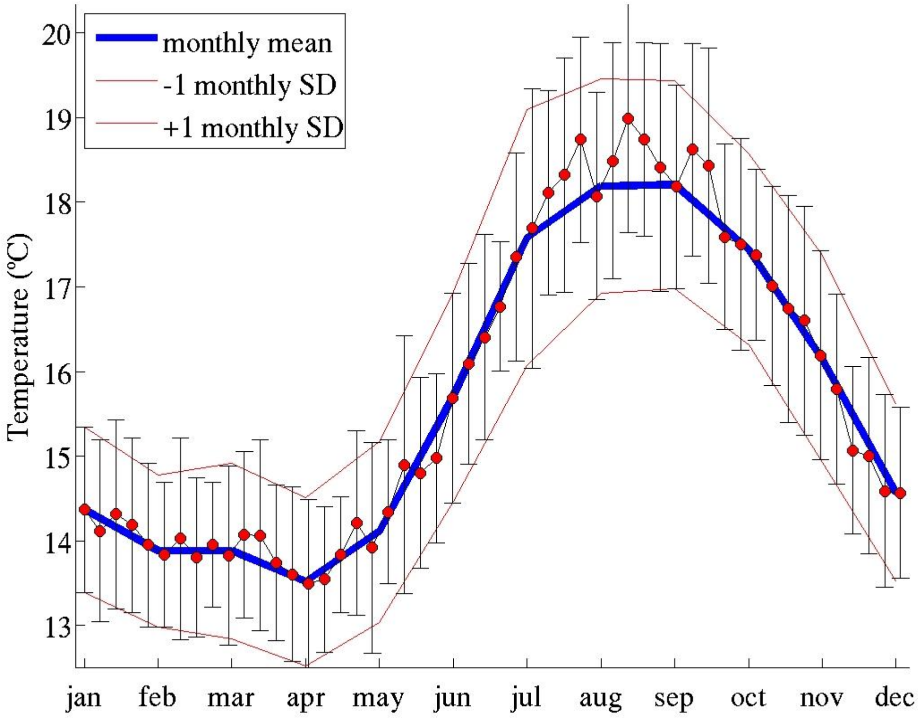

Figure 4.8 Modern monthly SST averages inferred from two decades of NOAA Advanced Very High-Resolution Radiometer (AVHRR) satellite data. Graph provided by Bernardo Broitman.

As noted by Jew et al. (2013:177) there are two extended periods of relatively stable SSTs represented in the modern averages for Santa Barbara Channel waters, one during five to six months between December and May (winter/spring), and another of two to three months duration from July to September (summer). Lowest SSTs occur during this first interval as waters upwelled off Point Conception are entrained into the Santa Barbara Basin gyre circulation (Pak et al. 2004:6). This typically occurs from March to April (spring), just prior to a period of rapid warming from May to July (late spring/early summer). Highest

SSTs occur during the second interval, typically from August to September (summer) (Pak et al. 2004:6), followed by a period of rapid cooling from September to December (fall) (Jew 2013:177). Cool winter waters from December to February complete the annual cycle.

Strong El Niño conditions periodically disrupt this general seasonal pattern, leading to anomalously warm SSTs (Pak et al. 2004). Therefore, some caution is required in the attribution of seasons. Shells from the same stratum cannot definitively be attributed to a single year or a single decade. Therefore, we cannot definitely rule out the distorting effects of anomalously warm El Niño conditions that alter typical seasonal patterns.

Whenever possible I classified the season of harvest for each analyzed shell based solely on the SST calculated for sample A, representing season of harvest, relative to the SSTs calculated for the seven comparative samples B through G, representing the season(s) prior to harvest. However, for a limited number of shells, eight samples were not sufficient to capture a full annual cycle, including a maximum and minimum SST, for reference. In such cases, I considered the value of sample A, and directionality of samples B through G in reference to the mean maximum and mean minimum SSTs obtained from all shells within the same excavation level. All seasonal attributions are comparative, based on variability evident between the SST at the time of harvest and the SST of prior season(s).

Given high instrument precision (±0.05‰ for δ^{18}O on the Thermo-Finnegan MAT 253 IRMS and ±0.07‰ for δ^{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 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 preceded by rapid cooling.

Late Spring/Early Summer (April-July): The SST calculated for the terminal edge value is intermediate 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.

Annual Sea-surface Paleotemperatures

The measured $\delta^{18}O$ and $\delta^{13}C$ isotopic values of marine shell carbonate from 253 shells (2-8 samples/shell) included in this study are provided in Appendix A (Tables A.1-A.3). The generally depleted (i.e., lower/more negative) $\delta^{18}O$ values indicate warmer SSTs. An examination of the data indicates that $\delta^{18}O$ and $\delta^{13}C$ isotopic values are highly negatively correlated within a sample. This pattern is consistent with the known relationship between cool SST (high $\delta^{18}O$ values) and high coastal upwelling (low $\delta^{13}C$ values). Figures A.1- A.17 in Appendix A represent these $\delta^{18}O$ values converted mathematically to SSTs and graphed as profiles comparing terminal (sample A) vs. interior (sample B-G) values of each shell within an excavation level. Based on these data it is clear that variation in SST is recorded in the mussel shell carbonate, with most shells exhibiting fluctuation consistent with variation between coolest and warmest annual temperatures. Most profiles for shells with 5-8 samples provide a reasonably smooth annual SST curve, capturing both a high and low SST value. Although more precise estimates of the annual minima and maxima could certainly be achieved by smaller sampling intervals, the range of values in addition to the shape of the preceding curve provides sufficient data for interpretation of seasonality.

The average SST minimum, maximum, and midpoint are presented by excavation level in Table 4.8. Average minimum and maximum values for each excavation level are calculated based only on shell profiles that confidently demonstrated an annual minimum, an annual maximum, or both. I calculate the midpoint of the temperature ranges represented by each shell profile that confidently demonstrated both an annual minimum and maximum. This value provides a reliable summary statistic that compensates for the over-representation of portions of the annual cycle, or cycles, when the shell grows more slowly. Table 4.8 presents the average of all midpoints calculated from shells in an individual excavation level along with its standard deviation. The overall midpoints derived from shells in Terminal Early Period, Middle Period, and Late Middle Period contexts at all three sites are surprisingly similar in all three summary statistics. Twenty-two shells from Terminal Early Period contexts yielded an average midpoint of 14.53 °C (s.d. 0.84). Forty shells from Middle Period contexts yielded an average midpoint of 14.69 °C (s.d. 0.80). Twenty-three shells from Late Middle Period contexts yielded an average midpoint of 14.42 °C (s.d. 1.34). Thus, local SSTs appear to be relatively stable throughout the three temporal periods considered in this study.

Table 4.8. Average, maximum, and minimum paleotemperatures with corresponding midpoint paleotemperatures. Average minimum and maximum temperatures for each excavation level are calculated based only on shell profiles that confidently demonstrated an annual minima, annual maxima, or both. Average midpoint values are calculated based only on the shell profiles that confidently demonstrated both an annual minima and maxima, allowing for calculation of the midpoint value. Excavation levels are presented in chronological order from the oldest (top) to the most recent (bottom).

		AvgMIN (°C)	AvgMAX (°C)	AvgMID (°C)	StdevMID
Terminal Early Period	Interior Level 13	11.91 *(n=6)*	16.69 *(n=6)*	14.21 *(n=5)*	0.75
	Interior Level 12	11.96 *(n=3)*	16.93 *(n=6)*	14.48 *(n=2)*	1.13
	Pericoastal Level 6	12.83 *(n=8)*	17.30 *(n=5)*	15.15 *(n=5)*	1.26
	Coastal Site Level 22	12.24 *(n=5)*	17.17 *(n=4)*	14.67 *(n=5)*	0.61
	Coastal Site Level 21	12.09 *(n=7)*	16.45 *(n=7)*	14.20 *(n=6)*	0.31
	Overall Terminal Early Period	**12.27** *(n=29)*	**16.86** *(n=28)*	**14.53** *(n=22)*	**0.84**
Middle Period	Interior Level 11	12.71 *(n=8)*	17.30 *(n=8)*	15.01 *(n=8)*	0.59
	Interior Level 10	12.71 *(n=8)*	17.09 *(n=8)*	14.89 *(n=8)*	0.66
	Coastal Site Level 20	13.35 *(n=5)*	17.74 *(n=6)*	15.47 *(n=4)*	0.62
	Coastal Site Level 19	12.49 *(n=6)*	17.17 *(n=7)*	14.49 *(n=5)*	0.56
	Coastal Site Level 18	12.92 *(n=6)*	16.51 *(n=6)*	14.73 *(n=6)*	0.72
	Coastal Site Level 17	11.60 *(n=6)*	17.23 *(n=7)*	14.19 *(n=5)*	1.00
	Pericoastal Level 5	11.72 *(n=7)*	16.41 *(n=5)*	13.96 *(n=5)*	0.76
	Overall Middle Period	**12.49** *(n=46)*	**17.13** *(n=45)*	**14.69** *(n=40)*	**0.80**
Late Middle Period	Coastal Site Level 16	13.01 *(n=3)*	17.54 *(n=5)*	15.11 *(n=3)*	1.68
	Coastal Site Level 15	12.87 *(n=5)*	16.92 *(n=5)*	15.06 *(n=4)*	0.42
	Pericoastal Level 4	11.21 *(n=8)*	15.49 *(n=8)*	13.50 *(n=8)*	1.17
	Pericoastal Level 3	12.03 *(n=7)*	17.02 *(n=5)*	14.69 *(n=3)*	1.18
	Interior Level 9	12.74 *(n=6)*	16.85 *(n=6)*	14.81 *(n=4)*	0.41
	Overall Late Middle Period	**12.20** *(n=29)*	**16.72** *(n=29)*	**14.42** *(n=23)*	**1.33**

Terminal Early Period Season of Site Occupation

Terminal Early Period occupation is represented by Levels 22 and 21 at the Coastal site, Level 6 at the Pericoastal site, and by Levels 13 and 12 at the Interior site. Figure 4.9 represents the seasonal attributions of 15 terminal edge samples for each excavation level. In the case of the Coastal site, these values suggest a bimodal seasonal pattern with two potentially discrete periods of occupation focused on summer and fall, with a stronger peak during the summer. In both excavation levels, there is evidence of minor harvesting during the winter; however, it appears unlikely that people occupied the Coastal site for any significant period of time during the winter or early spring. Occupation at the Pericoastal site peaks strongly during the late spring/early summer. All of the eight seasonal assessments based on more complete shell profiles correspond well with this attribution. Six additional seasonal assessments, based on the terminal edge value and one additional sample, are dispersed evenly throughout summer, fall, and winter/early spring. This suggests that in addition to primary occupation at the Pericoastal site during the late spring/early summer (April-June), people may have frequented this location sporadically throughout the entire year. Season of occupation at the Interior site appears to be much more variable. In both Level 13 and Level 12 there is a strong peak in occupation from late fall until early winter as well as evidence of occupation later in the winter/early spring. Terminal values from Level 13 indicate a secondary peak during early summer. This suggests that people occupied the Interior site primarily from late fall until early winter (November-January) and during the early summer (June-July), but also frequented this location intermittently throughout the year.

Based on these seasonal assessments it appears that the prehistoric Chumash were quite mobile during the terminal Early Period. Primary periods of site occupation do not appear to exceed 2-3 months at any of the three sites. This is approximately the same range of error expected based on the precision of the $\delta^{18}O$ values themselves, and thus it is possible that the duration of primary period of site occupation could be overestimated. Occupation at the Coastal site appears to be more consistent and concentrated than at the Pericoastal or Interior sites; although all three sites indicate some degree of seasonal overlap, it appears that the Coastal site was most favored during the summer and early fall and that the Interior site was favored during the late fall/early winter and early summer. The Interior and the Pericoastal sites provide greater evidence of winter and spring occupation than the Coastal site. Although there is substantial evidence of late spring occupation at the Pericoastal site, I cannot make any such determination for winter/early spring. Lack of evidence of primary late winter/early spring occupation at the three sites included in this study suggests that: 1) people dispersed during these months, leaving behind minimal evidence of occupation, 2) people occupied some other location not represented by the sites included in this study, or 3) people did not harvest shellfish with as great a frequency during these months. The third option seems improbable, given the paucity of other food resources available during this season. Additional research will be necessary to distinguish between the first two possibilities and to place terminal Early Period Foragers on the landscape during the late winter/early spring.

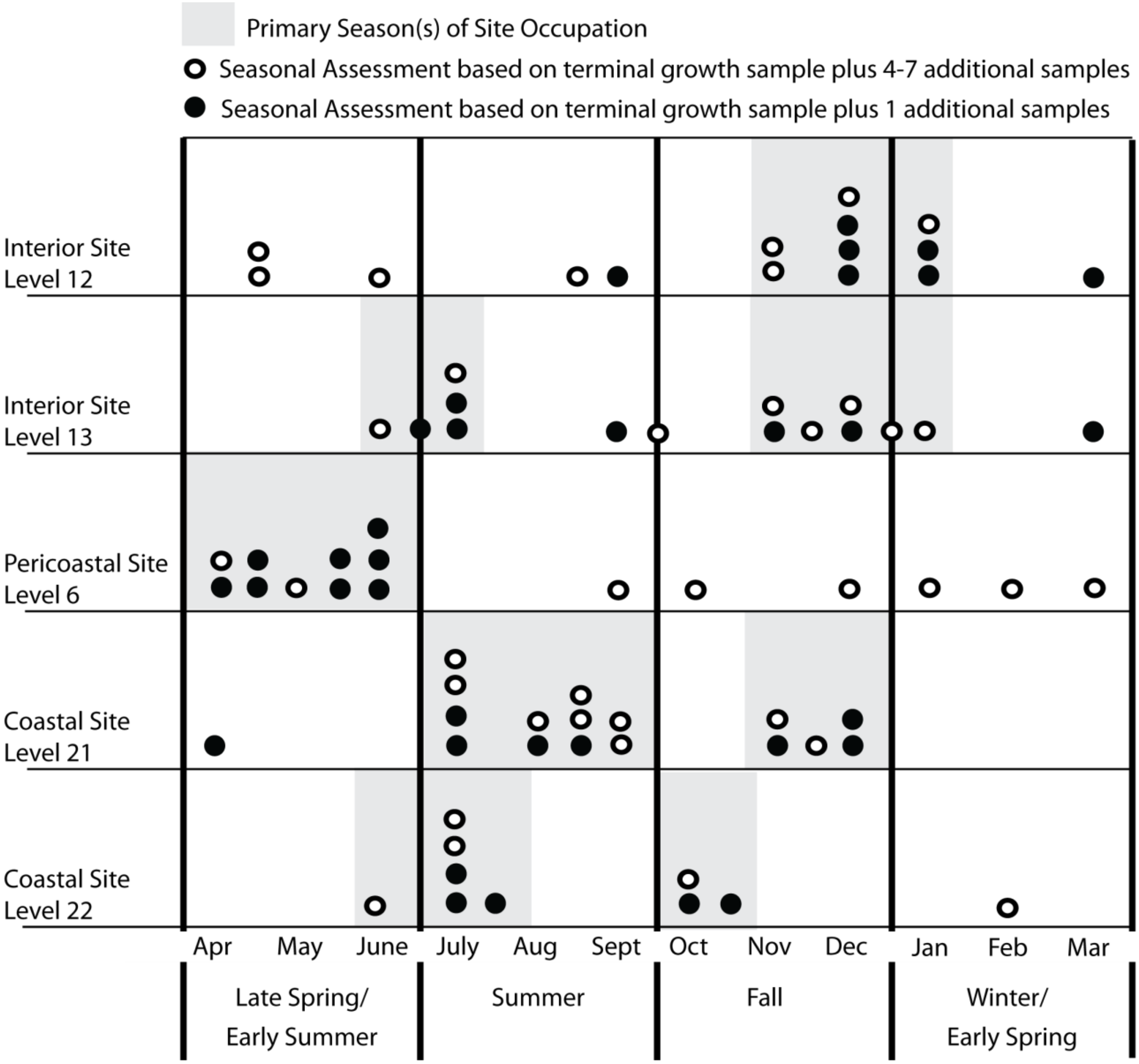

Figure 4.9. Estimated season of site occupation during the Terminal Early Period based on oxygen isotope analysis of marine shell carbonate. Each circle represents a unique seasonal assessment based on the sea-surface temperature indicated by the isotopic ratio of the terminal growth margin of an individual mussel shell.

Middle Period Season of Site Occupation

Middle Period occupation is represented by Levels 20, 19, 18, and 17 at the Coastal site, Level 5 at the Pericoastal site, and by Levels 11 and 10 at the Interior site. Figure 4.10

represents the seasonal attributions of 15 terminal edge samples for each excavation level. Terminal edge values from the Coastal site indicate that this location was occupied consistently throughout summer into the early fall (June-November). The vast majority of seasonal attributions from all four excavation levels cluster within this six-month period. There is a clear exception in Level 20. In this earliest assemblage from the Coastal site, there is evidence of a secondary peak in seasonal attribution during the late winter/early spring. It is not possible to distinguish whether this represents a discrete site visit for the purpose of shellfish collection or a bimodal pattern of site occupation. Seasonal occupation at the Pericoastal site is clearly bimodal. Two discrete clusters of seasonal attributions reveal primary occupation from late spring to early summer (May-July) and from mid-late fall (November-December). These periods of occupation appear to be of similar intensity. It is notable that no seasonal attributions fall outside of these two clusters, suggesting that the Pericoastal site was not visited as frequently throughout the year as during the preceding temporal period. Season of occupation at the Interior site again appears to be much more variable. Although, AMS radiocarbon dates on marine shell from these two excavation levels are statistically indistinguishable, patterning of seasonal attributions between these two levels appear to contrast. In both Levels 11 and 10 there is a peak in occupation during the summer. However, in Level 11 occupation appears to be consistent from early to late summer (May/June-October), and in Level 10 occupation appears to be intermittent from late spring through the fall (April-December). It is possible that what I consider to be evidence of intermittent site occupation in Level 10 is an artifact of sampling or the precision of the isotopic measurements themselves. It is also possible that the collection and transport of shellfish to the Interior site was episodic, but that occupation was consistent. That is that the season of mussel harvest/transport may not correspond directly to the season of site occupation. Thus, whether Interior site occupation was intermittent during the Middle Period remains uncertain. What is clear is that people occupied the Interior site throughout most of the year from the spring through the fall, with some minor occupation during the winter and early spring.

Based on these seasonal assessments it appears that the prehistoric Chumash were substantially less mobile during the Middle Period than during the terminal Early Period. Primary periods of site occupation extend up to eight months at the Coastal and Interior sites, but remain much shorter at the Pericoastal site. This suggests a continued focus of occupation at the Coastal site, and potentially also at the Interior site. Both provide clear evidence of primary occupation throughout the summer and the fall. It appears that the Interior site was also favored during the late spring, as was the Pericoastal site. Bimodal seasonal occupation during the late spring and late fall at the Pericoastal site appears to bracket summer and fall occupation at the Coastal site. Despite some evidence of winter occupation at the Coastal site and the Interior site, there is no clear primary occupation during this season at any of the three sites considered in this study. This pattern of dispersal or relocation to a location not represented in this study persists from the terminal Early Period.

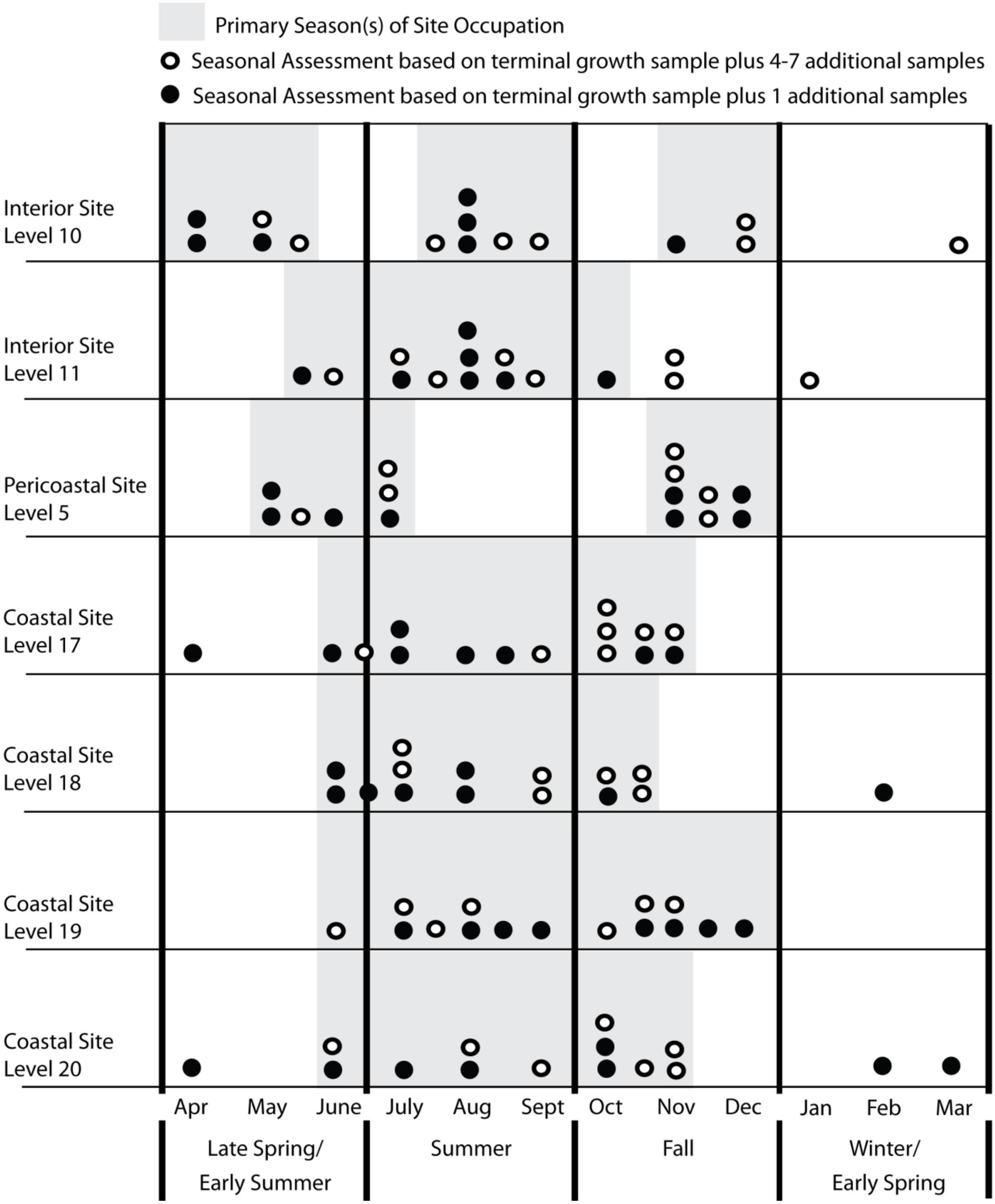

Figure 4.10. Estimated season of site occupation during the Middle Period based on oxygen isotope analysis of marine shell carbonate. Each circle represents a unique seasonal assessment based on the sea-surface temperature indicated by the isotopic ratio of the terminal growth margin of an individual mussel shell.

Late Middle Period Season of Site Occupation

Late Middle Period occupation is represented by Level 16 and Level 15 at the Coastal site, Level 3 and Level 4 at the Pericoastal site, and by Level 9 at the Interior site. Figure 4.11 represents the seasonal attributions of terminal edge samples for each excavation level. Terminal edge values from the Coastal site indicate that this location was occupied consistently throughout summer. Seasonal attributions from Level 15 suggest that primary summer occupation may have begun as early as June and continued through October. All but one seasonal attribution from these two excavation levels cluster within this five-month period, while the vast majority cluster within the peak summer months of July, August, and September. Seasonal occupation at the Pericoastal site is clearly bimodal. Two discrete clusters of seasonal attributions reveal primary occupation during the late spring into early summer and mid to late fall. Seasonal attributions from Level 4 suggest spring occupation began as early as April and ended in June or July, whereas seasonal attributions from Level 3 indicate that spring occupation began around May and ended in August. Seasonal attributions for fall occupation from both levels at the Pericoastal site all cluster around the months of October-December. Both periods of occupation at the Pericoastal site appear to be of similar intensity, and there is minimal evidence of occupation outside of these months. Season of occupation at the Interior site appears to peak in late summer into early fall (September-October) and late fall into winter (December-February). However, a very narrow period of time (1 month) appears to separate these two discrete clusters of seasonal attributions. Thus, the precision of isotopic measurements is not sufficient to determine whether occupation was consistent or intermittent throughout the fall and into the early winter. There is also evidence of some minor occupation at the Interior site during the early summer.

Based on these seasonal assessments it appears that the prehistoric Chumash were more mobile during the late Middle Period than during the Middle Period, but perhaps less mobile than during the terminal Early Period. Primary periods of site occupation exceed no more than five months at the Coastal and Interior sites, and remain much shorter at the Pericoastal site. This suggests a continued focus of occupation at the Coastal site, and potentially also at the Interior site. The Coastal site remains the focus of summertime occupation. Both the Pericoastal and Interior sites appear to be occupied during the fall. Occupation at the Interior site continues into the winter months, and spring is well represented at the Pericoastal site. Clear evidence of winter to early spring and late spring at these sites places late Middle Period foragers on the landscape during this previously elusive time of year.

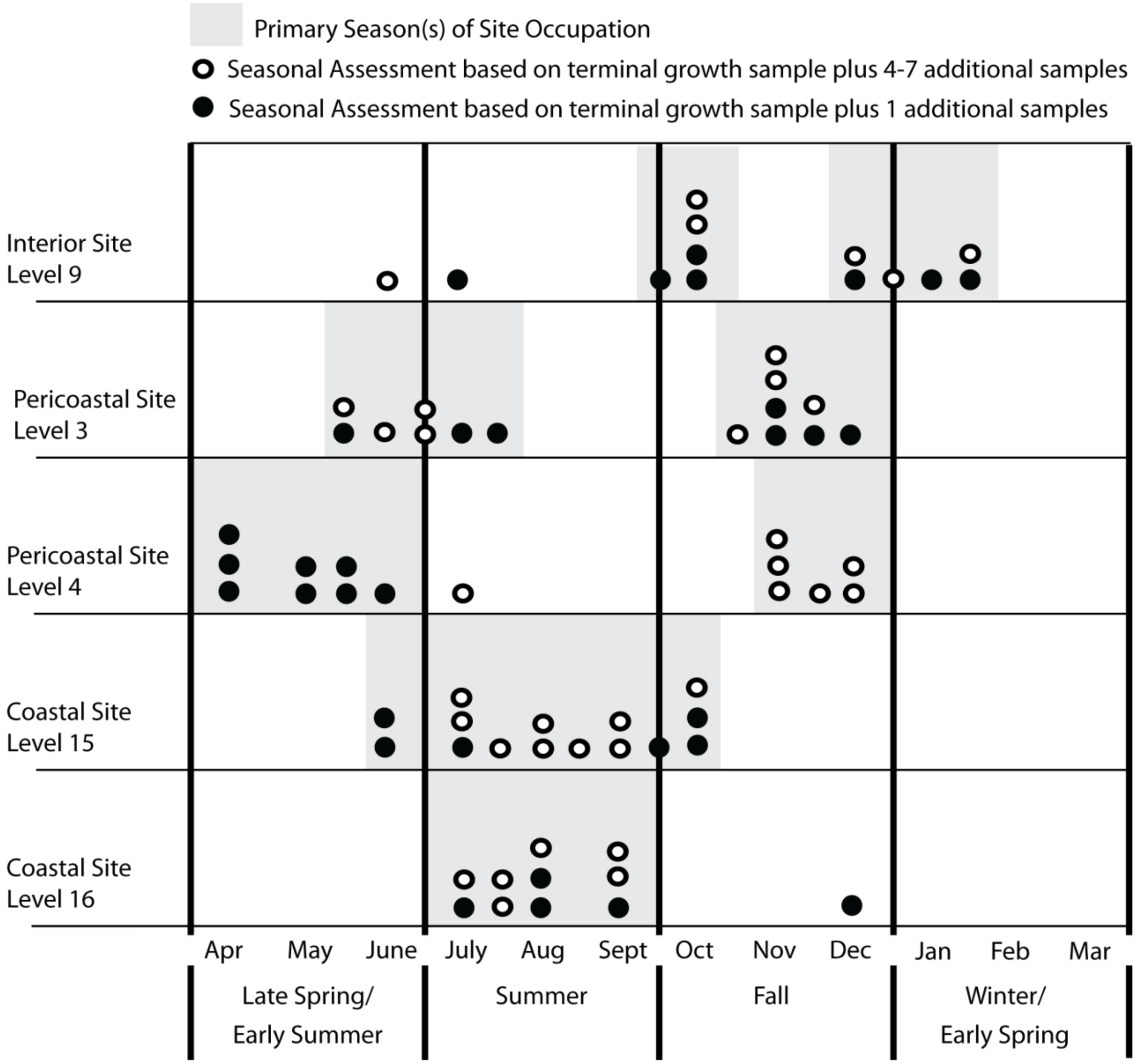

Figure 4.11. Estimated season of site occupation during the Late Middle Period based on oxygen isotope analysis of marine shell carbonate. Each circle represents a unique seasonal assessment based on the sea-surface temperature indicated by the isotopic ratio of the terminal growth margin of an individual mussel shell.

Context of the Analysis: Reconstructing Diachronic Patterns of Land-Use and Mobility

The rigorous chronological framework and assessment of site seasonality presented in this chapter provide a multiscalar framework for reconstructing diachronic patterns of land-use and mobility within the Cañada Christy watershed on Santa Cruz Island. This analysis focused on identifying contemporaneous periods of occupation at three sites located in proximity to a distinct array of marine and terrestrial food resources. The results of this analysis demonstrate that each of the three site locations were occupied prior to, during, and after the period of significant population growth on the Northern Channel Islands. Furthermore, there are clear diachronic shifts in the duration, intensity, and seasonality of site occupation relative to two intervals of abandonment that occur contemporaneously at all three sites. Thus, I suggest that these intervals of abandonment serve as temporal markers delineating a series of shifts in prehistoric land use and mobility during the terminal Early Period, Middle Period, and late Middle Period.

Terminal Early Period

During the terminal Early Period the Chumash appear to have been fairly mobile, repeatedly visiting the Coastal, Pericoastal, and Interior sites throughout the year, but rarely staying put for more than two or three months at a time. The high rate of accumulation and evidence of more consistent occupation at the Coastal site indicate that this location was a focus of repeated occupation, and perhaps aggregation, during the productive fishing months of the summer and early fall. More intermittent occupation at the Pericoastal and Interior sites, as well as a very low rate of accumulation at the Interior site, suggests that these locations were visited frequently by smaller groups perhaps during periods of dispersal and for acquisition of terrestrial food resources located away from the coast. Furthermore, evidence of slight peaks in occupation during the late spring/early summer at the Pericoastal site and the late fall/early winter at the Interior site suggest that these locations were of greater relative importance at specific times of the year. Occupation appears to have been relatively brief even during these seasons. Altogether, these data reflect a pattern of high mobility with potential periods of aggregations and dispersal tied to the seasonal availability of food resources. This pattern persists until ca. 2750 cal B.P. at which point all three sites are abandoned for approximately one millennium.

Middle Period

Coincident with the onset of rapid population growth on the Northern Channel Islands, people reoccupied all three locations almost simultaneously ca. 1650 cal B.P., during the Middle Period. Patterns of land use and mobility indicate significant reorganization. During the Middle Period the Chumash appear substantially less mobile, tied to the Coastal and Interior sites for perhaps as much as eight months of the year. High rates of accumulation and evidence of consistent occupation at the Coastal site suggest that this location may have served as a primary residential base throughout the entire summer and into the fall. Similarly high rates of accumulation at the Interior site also suggest increased intensity of occupation throughout the year, with significant peaks from the late spring into the fall. This pattern suggests that the Interior site may also have served as a residential base during the Middle Period. Limited evidence of winter and early spring occupation at any of the three sites may indicate that people dispersed from the primary residential bases during these leaner seasons. This pattern of decreased mobility focused on intensively used summer/fall residential bases and winter/spring dispersal persisted until ca. 1420 cal. B.P., at which point the Coastal, Pericoastal, and Interior sites once again appear to be abandoned for approximately 200 years.

Late Middle Period

After this brief interval of abandonment, the Coastal and Pericoastal sites were the first to be re-occupied. During the late Middle Period, these two locations were inhabited at similar levels intensity and demonstrate seasonal signatures complementary to each other and the Interior site. The data presented here suggests that people were relatively more mobile in the late Middle Period. This pattern may indicate that people are becoming seasonallly more specialized in their subsistence pursuits. Seasonal occupation does not appear to exceed a maximum of five months at the Coastal or Interior site and no more than two or three months at the Pericoastal site. The rate of accumulation at the Coastal site decreased substantially in comparison to the preceding temporal periods and is quite similar to the rate of accumulation at the Pericoastal site. Nonetheless, the Coastal site appears to maintain its importance as a summertime residential base. Occupation at the Interior site peaks in late summer and continues into the late fall/early winter after which occupation appears to peak at the Pericoastal site in the late winter and continue into the spring. This pattern of residential mobility among the three sites with elongated stays at the Coastal and Interior sites echoes patterns that emerged during the Middle Period. However, evidence of increased mobility is tempered by less evidence for low-level year-round visitation at each of these sites. Frequent short-term occupations and evidence of seasonal population dispersal that is common throughout the terminal Early Period and Middle Period is no longer evident during the late Middle Period.

CHAPTER 5

EXPLOITING THE TERRESTRIAL ENVIRONMENT: ANALYSIS OF THE PLANT DATA

Variation in the abundance and distribution of terrestrial resources on Santa Cruz Island shaped prehistoric Chumash subsistence decisions and strategies. Although Santa Cruz Island is the largest and most ecologically diverse of the four Northern Channel Islands, plant food resources available to the prehistoric inhabitants were distributed unevenly across the land and were temporally variable in abundance. A diversity of terrestrial microenvironments provided an assortment of carbohydrate-rich resources, often located away from abundant coastal resources. Seasonal abundance, distribution, and accessibility of plants would have significantly affected the relative dietary contribution of these different resources (Kennett 2005:38). In the previous chapter, I identified three contemporaneous periods of occupation at the Coastal site , Pericoastal site, and Interior site. Evidence of intervening periods of site abandonment suggests significant changes in the ways that the Island Chumash moved across the landscape from the terminal Early Period through the late Middle Period. These changes must be considered in the broader context of subsistence and mobility, including variation in the exploitation of food resources through time, the relationship of site locations to marine and terrestrial resource patches, and primary habitats exploited. This chapter examines the botanical side of foraging behavior through a quantitative analysis of the paleoethnobotanical data, in which I reconstruct broad spatial and temporal patterns of plant use from the terminal Early Period through the late Middle Period.

The Paleoethnobotanical Remains in Ecological and Cultural Perspective

Understanding a subsistence system requires knowledge of the ways in which people interact with plants in their environment. I identified 64 unique plant taxa, including seeds, greens, corms, fruits, and nuts in the flotation samples from the Coastal, Pericoastal, and Interior sites. This section reconstructs the accessibility, character, and nutritional gains of diverse plant food resources that shaped foraging decisions.

Ecological Context

Of the 64 unique taxa identified in the study assemblages, all but one, black walnut (*Juglans californica*), are native species commonly found on Santa Cruz Island. This diversity and intensity of native plant use was made possible by the environment (Bettinger and Wohlgemuth 2011:113). Santa Cruz Island is topographically and floristically varied, boasting over 480 native taxa, the richest flora of all the Channel Islands (Cobb and Mertes 2002:143; 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 produce unique vegetation communities (Schoenherr et al. 1999:293; Smith 1998:17). Ethnohistoric documentation indicates that the Chumash people living in the Santa Barbara Channel region, and on Santa Cruz Island, collected plants from a variety of ecological zones inhabited by distinct vegetation communities (Timbrook 2007:11). The precise prehistoric distributions of plants across the island landscape are unknown due to introduction of exotic grasses, grazing animals and other historic alterations (Chess et al. 2000; Colvin and Gliessemann 2000; Corry and McEachern 2000); however, the principal limiting factors determining the distribution of terrestrial vegetation remain the same as in the past. Here, I consider modern plant distributions documented by botanists as a reasonable, albeit imperfect, analogy to prehistoric plant distributions.

Following Junak et al. (1995), Philbrick and Haller (1977), and Smith (1998), 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. Unique vegetation communities occur within short distances of each other. The Cañada Christy watershed drops from an elevation of 1,250 feet (380 m) westward to the ocean, over a distance of 4.6 miles (7.4 km), crosscutting all of these major vegetation communities (Junak et al. 1995:3; Schoenherr et al. 1999:288) and facilitating access to the entire spectrum of terrestrial resources.

Coastal Strand. Coastal strand is the "pioneer community of the coastline," occurring along sandy beaches and dunes on the western and southwestern beaches of Santa Cruz Island where the coast is exposed to the full force of northeasterly winds (Schoenherr et al. 1999:237). Patches of coastal strand line Christy Beach, in immediate proximity of the Coastal site. Succulents and prostrate plants with long tap roots dominate this community (Munz 1974:1; Schoenherr et al. 1999:237). Characteristic native taxa in unstabilized dune habitats include sand verbena (*Ambronia* spp.), beach ragweed (*Ambrosia chamissonis*), and California saltbush (*Atriplex californica*) (Junak et al. 1995:14). Silver bush lupine (*Lupinus albifrons*) and coastal bush lupine (*Lupinus arboreus*) grow on more stabilized dunes (Junak et al. 1995:14; Schoenherr et al. 1999:238). All of these taxa appear in the paleoethnobotanical study assemblage. Additional coastal strand plant taxa identified in the archaeological assemblages include locoweed (*Astragalus* spp.), tobacco (*Nicotiana clevelandii*), checker mallow (*Sidalcea malviflora*) and morning glory (*Calystegia* spp.) (Junak et al. 1995).

		Coastal Strand	Coastal Marsh	Coastal Bluff Scrub	Grassland	Riparian	Coastal Sage Scrub	Island Chaparral	Island Woodland	Southern Oak Woodland	Pine Forest
Taxonomic Name	Common Name	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 *Phacelia* spp.	Phacelia						x	x	x		
cf. Brassicaceae	Mustard Family	x			x						
Brassicaceae *Lepidium cf. nitidum*	Peppergrass				x						
Cactaceae *Opuntia* 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 *Arctostaphylos* spp.	Manzanita							x	x	x	x
cf. Euphorbiaceae	Spurge Family				x		x				
Fabaceae	Bean Family	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 *Lupinus* spp.	Lupine			x	x	X	x	x	x		

Table 5.1 Summary of preferred habitat(s) of all plant taxa identified in the study assemblage. Table is based on data from Junak et al. 1995 and Schoenherr 1992.

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			
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		
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				

Table 5.1 continued. Summary of preferred habitat(s) of all plant taxa identified in the study assemblage. Table is based on data from Junak et al. 1995 and Schoenherr 1992.

Coastal Marsh. Fresh and saltwater marshes produce plants commonly used for building material, as well as roots and seeds collected for food (Bettinger and Wolhgemuth 2011:113). Coastal marsh communities are few and poorly developed around the island (Schoenherr et al. 1999:237). However, since the removal of feral sheep and pigs from the island, vegetation cover, duration of flooding, and depth of standing water have increased dramatically in small estuaries (Junak et al. 1995:23), like the one present at the mouth of the Cañada Christy, in immediate proximity to the Coastal site. Salt marsh communities occur around the mouths of canyons, in wet saline habitats, and are composed of salt tolerant plant species typical of estuaries on the mainland (Munz 1974:1; Schoenherr et al. 1999:236). Only one species that is commonly associated with coastal marsh appears in the archaeological assemblage: saltbush (*Atriplex* spp.) (Junak et al. 1995). Freshwater coastal marshes are also represented in the archaeological assemblage by the presence of bulrush (*Scirpus* spp.) and willow (*Salix* spp.) seeds (Junak et al. 1995).

Coastal Bluff Scrub. Coastal bluff scrub grows on the steep faces of sea cliffs, coastal slopes, and rock outcrops of steep canyon walls (Junak et al. 1995:14), all of which afford exposure to coastal fog (Schoenherr et al. 1999:169). Among the taxa identified archaeologically, white yarrow (*Achillea millefolium*), coast tarweed (*Madia* spp.), prickly pear (*Opuntia* spp.), saltbush (*Atriplex* spp.), morning glory (*Calystegia* spp.), lotus (*Lotus* spp.), lupine (*Lupinus* spp.) and wild cucumber (*Marah macrocarpus*) are commonly found in coastal bluff scrub communities (Junak et al. 1995:14, 16).

Grassland. Grasslands are widespread across the island, covering marine terraces, coastal foothills, and alluvial plains where soils are deep and frequently rocky (Schoenherr et al. 1999:241; Smith 1998:23). Grasslands also form the understory in more open sage scrub, chaparral, and woodland communities (Munz 1974:2; Schoenherr et al. 1999:241). The modern grassland community is dominated by introduced annual grasses; however, many native plant taxa characteristic of this community survive and suggest that grasslands, in their prehistoric state, likely consisted of perennial bunch grasses (e.g., needlegrass- *Nasella* spp.) as well as many herbaceous annual species (Schoenherr et al. 1999:241). This vegetation community produces an abundance of small seeds ripening in late spring at the end of the rainy season (Bettinger and Wohlgemuth 2011:113, 118). Common native herbaceous perennials include bulb-producing blue dicks (*Dichelstemma capitatum*) and mariposa lillies (*Calochortus spp*.) (Schoenherr et al. 1999:241). Blue-eyed grass (*Sisyrinchium bellum*) also returns each year from underground rhizomes. Similar to bulb-producers, these plants invest their energy storing food in underground organs. In both cases, everything above ground dies and the plants remain dormant underground until the rains return (Schoenherr et al. 1999:242). Blue dicks corms and blue-eyed grass seeds are both common in the archaeological assemblages.

Other annual species characteristic of grasslands are clovers (*Trifolium* spp.), lupines (*Lupinus* spp.), phacelias (*Phacelia* spp.), fiddlenecks (*Amsinckia* spp. and *Cryptantha* spp.), and poppies (*Eschscholzia* spp. and *Papaver* spp.) (Junak et al. 1995). All of these taxa appear in the archaeological assemblage. Additional taxa identified in the study assemblages and commonly found in grassland communities include white yarrow (*Achillea millefolium*), common sunflowers (*Helianthus annuus*), tarweeds (*Hemizonia* spp. and *Madia* spp.), peppergrass (*Lepidium* spp.), saltbush (*Atriplex* spp.), soaproot (*Chenopodium* spp.), checker mallow (*Sidalceae malviflora*), morning glory (*Calystegia* spp.), wild cucumber (*Marah macrocarpus*), locoweed (*Astragalus* spp.), carolina cranesbill (*Geranium carolinianum*), farewell to spring (*Clarkia* spp.), California plantain (*Plantago erecta*), brome grass (*Bromus carinatus*), wild barley (*Hordeum* spp.), canary grass (*Phalaris* spp.), gilia (*Gilia* spp.), red maids (*Calandrinia ciliata*), nightshade (*Solanum* spp.), and johnny jump-up (*Viola pedunculata)* (Junak et al. 1995). All of these taxa are ephemeral plants that invest significantly in seed production, producing enormous numbers of small seeds that germinate annually (Schoenherr et al. 1999:242).

Coastal Sage Scrub. Coastal sage scrub communities consisting of low, scrubby, drought-deciduous and aromatic shrubs, interspersed with succulents, occur on dry, rocky, south-facing slopes, coastal cliffs and headlands (Junak et al. 1995:16; Schoenherr et al. 1999:203-204; Smith 1998:23). Dense thickets of coastal sage scrub develop in foggy areas along the coast and inland where the marine layer settles about foothills and infiltrates into canyons (Smith 1998:23). Coastal sage scrub intergrades with grasslands on gentle slopes with deeper soils and with island chaparral on north-facing slopes (Junak et al. 1995:17). Historic ranching and grazing significantly reduced the extent of this vegetation community; its prehistoric extent was likely greater than represented in modern surveys (Schoenherr et al. 1999:204).

Common drought-deciduous shrubs of coastal sage scrub include California sagebrush (*Artemisia californica*), buckwheat (*Eriogonum* spp*.)* and sage (*Salvia* spp.) (Junak et al. 1995:16; Schoenherr et al. 1999:204). Characteristic evergreen species include lemonadeberry (*Rhus intergrifolia*) and coyote brush (*Baccharis pilularis)* (Schoenherr et al. 1999:204). Lemonadeberry plants dominate the coastal sage scrub community on cooler north-facing slopes that receive less sunlight; tolerant of salt spray, growth varies from prostrate shrubs on exposed windward sea cliffs to large treelike plants in more moist areas

(Schoenherr et al. 1999:168). Coyote brush dominates the coastal sage scrub community on low slopes below 500 feet and on flats with loam to sandy clay loam soils (Junak et al. 1995:17). The coastal prickly pear (*Opuntia littoralis*) and its taller treelike cousin (*Opuntia oricola*) represent the succulent component of coastal sage scrub. The coastal cholla (*Opuntis prolifera*) is also an important, though less common, cactus in the coastal sage scrub community (Schoenherr et al. 1999:204). Buckwheat, sage, lemonadeberry, and prickly pear seeds are all present in the paleoethnobotanical study assemblages.

Several genera from the legume family identified in the study assemblages are also commonly found in coastal sage scrub communities: lotus (*Lotus* spp.), clover (*Trifolium* spp.), lupine (*Lupinus* spp.) and locoweed (*Astragalus* spp.) (Junak et al. 1995). Additional taxa identified in the study assemblages that commonly occur in coastal sage scrub communities, include beach ragweed (*Ambrosia chamissonis*), white yarrow (*Achillea millefolium*), common sunflower (*Helianthus annuus*), tarweeds (*Madia* spp. and *Hemizonia* spp.), fiddleneck (*Amsinkis menziesii*), phacelia (*Phalcelia* spp.), sleepy catchfly (*Silene antirrhina*), saltbush (*Atriplex* spp.), goosefoot (*Chenopodium berlandieri*), soaproot (*Chenopodium californicum*), wild cucumber (*Marah macrocarpus*), blue-eyed grass (*Sisyrinchium bellum*), chia (*Salvia* spp.), blue dicks (*Dichelostemma capitatum*), checker mallow (*Sidalcea malviflora*), California plantain (*Plantago erecta*), brome grass (*Bromus carinatus*), wild barley (*Hordeum spp*.), fescue grass (V*ulpia spp*.), gilia (*Gilia spp*.), red maids (*Calandrinia ciliata*), miners lettuce (*Claytonia perfoliata*), toyon (*Heteromeles arbutifolia*), California wild rose (*Rosa californica*), bedstraw (*Galium* spp.), nightshade (*Solanum* spp.), tobacco (*Nicotiana clevelandii*), and Johnny jump up (*Viola pendunculata*) (Junak et al. 1995).

Island Chaparral. Chaparral is widespread above the coastal sage scrub, most notably on north-facing slopes (Munz 1974:2). Species composition varies greatly with geologic substrate and location, as does the size and stature of the dominants (Junak et al. 1995:17). In exposed windy areas near the west end of the island, chaparral vegetation grows prostrate (Junak et al. 1995:19). In contrast, what appears to be woodland on rocky north-facing slopes and in canyon bottoms are in fact unusually large, arborescent specimens of common chaparral shrubs (Schoenherr et al. 1999:175, 219). Island chaparral intergrades with coastal sage scrub on the south facing slopes and with island woodland, oak woodland, and pine forest on mesic north-facing slopes (Junak et al. 1995:17). The north-facing slopes of the middle portion of Cañada Christy, in proximity to the Interior site, provide habitat to a rich mixture of island chaparral and coastal bluff scrub species (Junak et al. 1995:19).

Characteristic plants are woody evergreen shrubs adapted to long dry summers (Schoenherr et al. 1999:170), particularly manzanita (*Arctostaphylos* spp.) and scrub oak (*Quercus pacifica*) (Schoenherr et al. 1999:217). Other characteristic species include toyon (*Heteromeles arbutifolia*) and ceanothus (*Ceanothus* spp.) (Munz 1974:2). All of these dominant taxa appear in the archaeological assemblage. Island Chaparral is distinguished from typical mainland chaparral communities by a more open, woodland aspect. Among the most conspicuous chaparral plants are several species of endemic manzanitas, particularly the Santa Cruz Island manzanita (*Arctostaphylos insularis*), which has large fruits, sometimes over 15 mm in diameter, much larger than other species in this genus (Schoenherr et al. 1999:219). Another important berry producer, toyon (*Heteromeles arbutifolia),* also grows much larger, taking on treelike proportions in shaded canyons alongside islay (*Prunus* *ilicifolia*) (Schoenherr et al. 1999:169). Thickets of scrub oak (*Quercus pacifica*) are especially common on rocky ridgetops (Junak et al. 1995:19).

Characteristic understory plants, found in the archaeological assemblages include lemonadeberry (*Rhus* spp.), sagebrush (*Artemisia* spp.), phacelia (*Phacelia* spp.), prickly pear (*Opuntia* spp.), sleepy catchfly (*Silene antirrhina*), wild cucumber (*Marah macrocarpus*), sedge (*Carex* spp.), locoweed (*Astragalus* spp.), pacific pea (*Laythrus vestitus*), lotus (*Lotus* spp.), lupine (*Lupine* spp.), chaparral pea (*Pickeringia montana*), farewell to spring (*Clarkia* spp.), California plantain (*Plantago erecta*), red maids (*Calandrinia ciliata*), miners lettuce (*Claytonia perfoliata*), bedstraw (*Galium* spp.), and nightshade (*Solanum* spp.) (Junak et al. 1995:19).

Riparian. Riparian vegetation occurs in canyon bottoms, along moist banks and seasonally flooded regions of permanent freshwater streams, like Cañada Christy (Junak et al. 1995:26; Schoenherr et al. 1999:174; Smith 1998:24). Native trees present in these wet areas include oak (*Quercus agrifolia*), toyon (*Heteromeles arbutifolia*), islay (*Prunus ilicifolia*), and willow (*Salix* spp.) (Junak et al. 1995:27; Schoenherr et al. 1999:174). These riparian woodlands intergrade with riparian herbaceous vegetation, such as smartweed (*Polygonum lapathifolium*), coast tarweed (*Madia* spp.), sleepy catchfly (*Silene antirrhina*), goosefoot (*Chenopodium berlandieri*), bulrush (*Scirpus* spp.), gilia (*Gilia* spp.), and clover (*Trifolium variegatum*) (Junak et al. 1995:27). Other associated taxa include species found on gravel floodplains and in coastal sage scrub or island chaparral communities. These species include California wild rose (*Rosa californica*), locoweed (*Astragalus* spp.), lotus (*Lotus* spp.), lupine (*Lupine* spp.), morning glory (*Calystegia* spp.), farewell to spring (*Clarkia* spp.), ceanothus (*Ceanothus* spp.), buckwheat (*Erigonum* spp.), lemonadeberry (*Rhus* *intergrifolia*), and nightshade (*Solanum* spp.) (Junak et al. 1995:27; Schoenherr et al. 1999:174). These species form dense thickets along the stream banks (Schoenherr et al. 1999:174). I identified seeds from each of these riparian taxa in the archaeological plant assemblages.

Island Woodland. The island woodland vegetation community occurs on somewhat rocky soils of north-facing slopes, ravines, and canyons, similar to island chaparral habitat, but generally in deeper, moister soils and at higher elevations (Junak et al. 1995:20; Schoenherr et al. 1999:224). Island woodland intergrades with island chaparral on drier rockier slopes and forms savannas with foothill grasslands on gentler slopes (Junak et al. 1995:20). Dominant canopy species include tall trees and treelike shrubs; most notably, toyon (*Heteromeles arbutifolia*), lemonadeberry (*Rhus intergrifolia*), island ironwood (*Lyonothammus floribundus*), islay, and (*Prunus ilicifolia* ssp.), and a variety of oaks (*Quercus* spp.), particularly the endemic island oak (*Quercus tomentella*) (Junak et al. 1995:20; Schoenherr et al. 1999:228-230). Both toyon and acorn appear in the archaeological plant assemblage. The associated understory vegetation layers are not very diverse; however, phacelia (*Phacelia* spp.), morning glory (*Calystegia* spp.), wild cucumber (*Marah macrocarpus*), lupine (*Lupinus* spp.), pacific pea (*Laythrus vestitus*), farewell to spring (*Clarkia* spp.), and miners lettuce (*Claytonia perfoliata*) may all be encountered in island woodland communities (Junak et al. 1995). Seeds from each of these taxa occur in the archaeological plant assemblages.

Southern Oak Woodland. Large stands of southern oak woodland occur across the island, primarily on deeper soils, on north facing slopes, and in shaded canyons within reach of the marine layer (Junak et al. 1995:20; Smith 1998:24). The dominant species is coast live oak (*Quercus agrifolia*). Dried, unleached acorns of this species contain 4.4% protein, 20.4% fat, and 52.7% carbohydrate (Timbrook 2007:161). Although generally inferior in protein content relative to most grains, superior fat content makes acorns a relatively nutritious plant food (Basgall 2004:88). A good mast from a single tree can produce several hundred pounds of acorns (Timbrook 2007:161); however, such significant masts occur perhaps once every two or three years (Basgall 2004:88). Toyon (*Heteromeles arbutifolia*), manzanita (*Arctostaphylos* spp.), miners lettuce (*Claytonia perfoliata*), and California wild rose (*Rosa californica*) are common understory plants that occur in this vegetation community (Junak et al. 1995; Schoenherr et al. 1999:227). Acorn, toyon, manzanita, miners lettuce, and wild rose all appear in the archaeological plant assemblages.

Pine Forest. This vegetation community is perhaps better described as a Bishop pine forest in which Bishop pine (*Pinus muricata*) is the dominant canopy species. These closed-cone pines are patchily distributed, primarily on north-facing slopes with depauperate fine-grained soils, exposed to frequent fog, “ecological islands within islands” (Schoenherr et al. 1999:233). The largest concentration of Bishop pines occurs on the north-facing slopes in the upper reaches of Cañada Christy (Junak et al. 1995:23; Schoenherr et al. 1999:232). The Christy Pines are also the most diverse in floristic composition and structure (Ostoja and Klinger 2000:168). Typical understory species include manzanita (*Arctostaphylos* spp.), ceanothus (*Ceanothus* spp.), sedge (*Carex* spp.), bedstraw (*Galium* spp.), toyon (*Heteromeles arbutifolia*), lotus (*Lotus* spp.), pacific pea (*Laythrus vestitus*), chaparral pea (*Pickeringia montana*), farewell to spring (*Clarkia* spp.), California wild rose (*Rosa californica*), scrub oak (*Quercus pacifica*), and island oak (*Quercus parvala*) (Junak et al. 1995:23), all of which are present in the archaeological plant assemblages.

Cultural Context

Native Californians, including the Chumash, relied more on wild plants for food, housing, and portable material culture than indigenous peoples in any other part of North America except the Great Basin (Bettinger and Wohlgemuth 2011:113). Plants provided an important source of food, which is the primary consideration in this study, but they were also highly valued for medicinal and economic purposes (Timbrook 2007). In this section, I limit discussion to plant taxa identified in the archaeological study assemblages. The list of plant resources used by the Chumash and Native California peoples is substantially longer and well described elsewhere (see Anderson 2006; Timbrook 2007). The archaeological plant assemblage considered in this study reflects the economic importance of just a subset of the plants likely used in prehistoric Chumash society. Each taxon identified in the archaeological assemblage correlates with ethnographically known food, medicine, or other economic use. Over 80% of the plants identified (53 of 64 taxa) represent likely food resources. I review in detail the collection, preparation, and use of identified archaeological plant taxa in Chumash subsistence economy. Medicines and other economically useful plants are indicated in Table 5.2, but are not discussed, as this topic is outside the scope of the current study. The purpose of this analysis is to understand cultural factors that influenced the use, deposition, and preservation of plant food resources that occur in the study assemblages, and to facilitate interpretation of patterns.

Ethnohistoric records indicate that Native California peoples had remarkably diverse plant diets (Anderson 2006:255). Alfred Kroeber noted that “the California Indians were perhaps the most omnivorous group of tribes on the continent” (Anderson 2006:242). Working with Chumash consultants in the early 20th century, John Harrington collected 497 plant specimens, recording traditional names, uses, and classifications for 206 unique taxa (Timbrook 1990:238-239). This ethnohistoric record is not complete, and likely does not represent the full range of botanical resources used by the Chumash (Timbrook 1990:242); yet, supplemented with ethnobotanical surveys of nearby Native California populations (i.e., Anderson 2006; Mead 2003; Moerman 2010; Strike and Roeder 1994), it does provide a foundation for understanding the cultural context of indigenous plant use in the Santa Barbara Channel region. Moving seasonally across the landscape, Chumash peoples collected fresh greens sprouting in the early spring, abundant seeds appearing in the spring and summer, fleshy fruits ripened by the summer sun, nuts maturing after the first fall rains, and roots waiting in the cold winter soil (Anderson 2006:290). These plants contributed to a rich and balanced diet (Anderson 2006:242).

Table 5.2 Summary of ethnographic use(s) of all plant taxa identified in the study assemblages. Table is based on data collected from Anderson 2006, Mead 2003, Timbrook 2007, Timbrook et al. 1982, and Strike and Roeder 1994.

Taxonomic Name	Common Name	Secondary Food Use	Medicinal	Other
SEEDS (primary food use)				
Asteraceae	Sunflower Family		x	
Asteraceae *cf. Achillea millefolium*	White Yarrow		x	
Asteraceae *cf. Helianthus annuus*	Common Sunflower			x
Asteraceae *cf. Madia* spp.	Coast Tarweed			
Asteraceae *Hemizonia* spp.	Common Tarweed			x
cf. Boraginaceae	Borage Family		x	
Boraginaceae *Amsinckia menziesii*	Fiddleneck	Greens		
Brassicaceae *Lepidium cf. nitidum*	Peppergrass		x	
Chenopodiaceae *Atriplex* spp.	Saltbush		x	x
Chenopodiaceae *C. berlandieri*	Goosefoot	Greens		
Chenopodiaceae *C. californicum*	Soaproat		x	x
Convolvulvaceae *Calystegia* spp.	Morning glory		x	
cf. Euphorbiaceae	Spurge Family		x	
Laminaceae *Salvia* spp.	Sage	Greens	x	
Laminaceae *Salvia columbariae*	Chia		x	
Onagraceae *Clarkia* spp.	Farewell to Spring			
Poaceae	Grass Family			
Poaceae *Bromus carinatus*	Brome grass			
Poaceae *Hordeum* spp.	Meadow Barley			
Poaceae *Phalaris caroliana*	Canary grass			
Poaceae *cf. Vulpia* spp.	Fescue grass			
Polemoniaceae *Gilia* spp.	Gilia			
Polygonaceae	Buckwheat Family		x	
Portulacaceae *Calandrinia ciliata*	Red maids	Greens		
GREENS (primary food use)				
Boraginaceae *Phacelia* spp.	Phacelia			
cf. Brassicaceae	Mustard Family	Seeds	x	
Cyperaceae *cf. Carex* spp.	Sedge	Roots		X
Fabaceae	Bean Family		x	
Fabaceae *Astragalus* spp.	Locoweed	Seeds		
Fabaceae *Lathyrus vestitus*	Pacific Pea	Seeds		
Fabaceae *Lotus* spp.	Lotus			
Fabaceae *Lupinus* spp.	Lupine	Seeds	x	
Fabaceae *Pickeringia montana*	Chaparral Pea			
Fabaceae *Trifolium* spp.	Clover	Seeds		
Malvaceae *Sidalcea malviflora*	Checker mallow			
cf. Papaveraceae	Poppy Family		x	
Portulacaceae *Claytonia perfoliata*	Miners lettuce	Seeds		
Rosaceae *Rosa californica*	California Wild Rose		x	
Rubiaceae *Galium* spp.	Bedstraw		x	X
Scrophulariaceae	Figwort Family		x	
Violaceae *Viola pedunculata*	Johnny jump up			
FRUITS (primary food use)				
Anacardiaceae *Rhus* spp.	Lemonadeberry/ Sugar bush			
Cactaceae *Opuntia* spp.	Prickly Pear	Greens	x	x
Ericaceae *Arctostaphylos* spp.	Manzanita		x	x
cf. Rosaceae	Rose Family			
Rosaceae *Heteromeles arbutifolia*	Toyon		x	x

Rosaceae *Prunus ilicifolia*	Island Cherry			
Solanaceae *Solanum* spp.	Nightshade		x	x
NUTS (primary food use)				
Fagaceae *Quercus* spp.	Acorn		x	x
Junglandaceae *Juglans californica*	Black Walnut			x
CORMS (primary food use)				
Lilliaceae *Dichelostemma capitatum*	Blue Dicks			
NON-FOOD				
Asteraceae *Ambrosia chamissonis*	Beach ragweed		x	
Asteraceae *Artemisia* spp.	Sagebrush		x	x
Caryophyllaceae *Silene antirrhina*	Sleepy catchfly			x
Curcubitaceae *Marah macrocarpus*	Wild cucumber		x	x
Cyperaceae *Scirpus* spp.	Bulrush		x	x
Geraniaceae *Geranium carolinianum*	Carolina cranesbill		x	
Iridaceae *Sisyrinchium bellum*	Blue eyed grass		x	
Nyctaginaceae *Abronia* spp.	Verbena		x	
Plantaginaceae *Plantago erecta*	California Plantain		x	
Rhamnaceae *cf. Ceanothus megacarpus*	Ceanothus		x	x
Salicaeae *Salix* spp.	Willow Family		x	x
Solanaceae *Nicotiana clevelandii*	Tobacco		x	

Seeds. Herbaceous annuals, including wildflowers, survive from year to year as seeds, produced in incredible quantities throughout springtime. These small seeds, ranging in from the size of a pinpoint to the size of a small sunflower seed, provided an important source of food for native peoples throughout California (Anderson 2006:256). Ethnohistoric documents indicate that Chumash collected great quantities of small oily seeds from coast tarweed (Timbrook 2007:90), common tarweed (Timbrook 2007:90), fiddleneck (Timbrook 2007:28), peppergrass (Timbrook 2007:111), goosefoot (Timbrook 2007:55), sage (Timbrook 1990:251), chia (Timbrook 2007:188), miners lettuce (Timbrook 2007:58), and red maids (Timbrook 2007:46) plants. In particular, Chumash prized the oil and protein-rich chia and red maids seeds (Timbrook 1986; Timbrook 2007:46, 188). Although both species occur on Santa Cruz Island, the Island Chumash reportedly came to the mainland to buy “hatfuls” of chia and red maids (Timbrook 2007:46). Nearby Native California peoples also collected seeds for food from the common sunflower (Mead 2003:199), morning glory (Strike and Roeder 1994:45), saltbush (Timbrook 2007:43), soaproot (Mead 2003:113), gilia (Mead 2003:371), and farewell to spring (Mead 2003:126-127). Although there is no record of whether the Chumash relied on these seed-bearing plants for food or other uses as well, it is reasonable to consider their presence in the archaeological plant assemblage as an indication of their role in subsistence.

Growing along with wildflowers, often in the same habitats, native grasses also produced many useful grains (Anderson 2006:256). Unfortunately, the ethnohistoric record of native grasses eaten by the Chumash is incomplete (see Timbrook 1990:242). By the time ethnographers began recording information about indigenous California cultures, the floral landscape had changed significantly; exotic grasses replaced native grasses, in both natural and cultural contexts (Anderson 2006:257). Brome grass (Mead 2003:83; Strike and Roeder 1994:30), wild barley (Mead 2003:207-208; Timbrook 1990:246), and canary grass, in addition to several other genera of native grasses (e.g., *Leymus, Achnatherum, Nassella, Festuca, Panicum, Eragrostis, Elymus, Deschampsia, Melica*), produce nutritious carbohydrate-rich grains consumed by many Native California peoples (Anderson 2006:256).

The Chumash harvested small seeds and wild grains in great quantities from late spring through summer. Seed beaters and gathering baskets facilitated collection of even the smallest seeds. The Chumash may also have pulled up entire plants and spread them out on swept ground to dry. Once dry the plants were beaten and shaken to dislodge the seeds, which could then be easily swept up and winnowed to remove the dirt and chaff (Timbrook 2007:46). Both collection methods undoubtedly contributed to seed dispersal and propagation of useful plant species.

People ate some species raw, by the handful, but they prepared most as pinole or seed-meal (Anderson 2006:260). The Chumash winnowed and parched the seeds with hot coals (see Anderson 2006:260 or Timbrook 2007 for further discussion of this process), before grinding or pounding the seeds into pinole. Parching is said to have made seeds oily (Timbrook 2007:91) and intensified their flavor (Anderson 2006:260). This process also enhanced the likelihood of preservation of small seeds in the archaeological record. Chumash people ate pinole dry, moistened and rolled into a ball or cake, mixed thin with water and consumed as a beverage or thick as a gruel, which could also be dried into cakes (Anderson 2006:261; Timbrook 2007:188). At the time of contact, Chumash stored large quantities of seeds in baskets hung inside homes (Timbrook 2007:46).

Greens. Native Californians ate the leaves, buds, and stems of a great assortment of plants, including wildflowers, tules, cacti, and trees (Anderson 2006:266). Wild greens contain a variety of essential vitamins and minerals (Anderson 2006:267). Many seed-producing wildflower species also provide edible stems and leaves. California peoples consumed fiddleneck greens (Mead 2003:26-27). In early spring Chumash ate young plants and new leaves of goosefoot (Timbrook 2007:55), tender young stem tips of several sage species (Timbrook 2007:185), and fresh uncurling leaves of miners lettuce (Timbrook 2007:58), wild mustard (Timbrook et al. 1982:178), and phacelia (Timbrook et al. 1982:178), in addition to the seeds that these plants produced later in the season.

The Chumash collected other species primarily for greens. They sought out rose hips of the California wild rose (Timbrook 2007:173), new shoots of tule (Timbrook 2007:206), young prickly pear cactus pads (Timbrook 2007:134), and fresh shoots, leaves, and flowers of clover (Timbrook 2007:219). More widely eaten than perhaps any other greens, fresh clover was relished by Native California peoples after a long winter of dried, stored foods (Anderson 2005:267; Timbrook 2007:219), in addition to the leaves and flowers of several additional legume species identified in the archaeological study assemblages. Ethnohistoric records do not reflect whether the Chumash also consumed the wide variety of leguminous plants available to them; however, due to the prevalence of these species as greens in the diets of neighboring native peoples, I consider these species as potential food sources. The Cahuilla collected locoweed (*Astragalus* spp.) pods in the summer and ground them to use as spice (Mead 2003:97). The Miwok ate new leaves of the Pacific pea (*Lathyrus vestitus*) during the spring and seeds during the summer (Mead 2003:224). The Luiseño ate the leaves of bishop's lotus (*Lotus strigosus*) as greens, but regarded most species of this genus as weeds or "rabbit food" (Mead 2003:241-243). The Yokuts collected the leaves of the chaparral pea (*Pickeringia montana*) (Anderson 2006:138). Despite the potential toxicity of alkaloids and protease inhibitors in several lupine species (*Lupinus* spp.), the Luiseno, Yokuts, Mono and Miwok consumed the young leaves and flowers of these plants (Mead 2003:243-246). Timbrook (2007:118) suggests that the Chumash did not consume any part of lupine plants, due, in part, to this potential toxicity. However, once boiled, leaves of lupine plants lose toxicity and may be eaten (Anderson 2006:270).

Additional species identified in the archaeological plant assemblages and eaten as greens by Native California peoples include checker mallow (Anderson 2006:270; Mead 2003:396), nightshade (Mead 2003:401), bedstraw (Strike and Roeder 1994:65), and viola (Mead 2003:440). The Maidu and Modoc ate the stems and shoots of various sedges (Strike and Roeder 1994:33). There is no available ethnographic information regarding whether the Chumash also consumed the fresh leaves and stems of these species. However, as previously noted, this record is incomplete (Timbrook 2007:15), and I include these taxa as potential food resources based on their known food-use by nearby peoples.

Collection and consumption of greens was highly seasonal. In early spring, emerging shoots, uncurling leaves, and new buds all had a fresh juicy taste without the bitter overtones of older plants (Anderson 2006:267). Although Native Californians gathered great quantities of greens, picking leaves and pinching off the desired new growth stimulated future growth rather than harming the plant (Anderson 2005:272). Chumash peoples consumed greens raw, stone-boiled in baskets, steamed in earth ovens, or dried in the sun (Anderson 2006:266, 270). Leaves, stems, and young shoots were eaten as salads, added to acorn mush, or served as accompaniments to soups and stews (Anderson 2006:266). The importance of greens in prehistoric subsistence is often underestimated, as greens are highly perishable and have no feature that resists decay, and thus, are poorly represented in the archaeological record (Anderson 2005:267). Some of the processing techniques described above likely enhanced preservation potential through exposure to fire.

Fruits. Chumash gathered fruits ripened by the summer sun from a diversity of plants and habitats. Wild fruits offer high vitamin and mineral content, with less sugar and fewer calories than modern domesticated fruits (Anderson 2005:274). The archaeological plant assemblage in this study provides a glimpse of how important fruits were in the prehistoric subsistence economy. Ethnohistoric documents indicate that Chumash peoples collected fruits and berries from prickly pear (Timbrook 2007:133-134), nightshade (Timbrook 2007:211), toyon (Timbrook 2007:91), lemonadeberry and sugarbush (Timbrook 2007:166), manzanita (Timbrook 2007:34), and island cherry (or islay) (Timbrook 2007:151).

People often gathered fruits by hand, breaking off individual fruit or fruit clusters (Anderson 2006:274). Most of these fruits and berries required little or no preparation before being cooked or eaten (Anderson 2006:277). However, the particular methods of collection, preparation, and consumption vary by species. The nasty spines of the prickly pear fruit needed to be singed off before eaten, fresh or sundried, or crushed to make a refreshing beverage (Timbrook 2007:133-134). Sour nightshade berries, although sometimes eaten fresh, required boiling to neutralize toxins (Timbrook 2007:211). The Chumash toasted toyon berries over hot coals until they bubbled, mashed them by hand, and then left them to sit for a few days before eaten (Anderson 2006:277; Timbrook 2007:91). Fruits from the lemonadeberry and sugar bush, although sometimes eaten fresh, were also ground and made into mush, or soaked to make a tart beverage (Timbrook 2007:166). The Chumash collected manzanita berries throughout the summer months by shaking the bushes or knocking them with a stick to make the berries fall off into baskets placed below (Anderson 2006:274). Once dried in the sun, the berries were pounded into a coarse flour that could be eaten raw as pinole, cooked into mush or biscuits, or made into a cider-like beverage (Anderson 2006:278; Timbrook 2007:34).

Greater efforts were required to prepare the prized island cherry, commonly known as islay, valued not for its minimal outer flesh, but for its oil and protein-rich inner seed kernel (Anderson 2006:277; Timbrook 1982:172; Timbrook 2007:151). Islay is the most common wild cherry in coastal California and was an important food resource for many Native California groups along the central coast (Anderson 2006:277; Timbrook 2007:151). During late summer and into the fall (Timbrook 1982:172), the Chumash picked the fruits, removed the pulp, and sundried the pits (Timbrook 2007:151). The pits were then cracked to remove the kernels, which could be stored indefinitely (Timbrook 2007:151). Similar to nutshell, the discarded outer pit shell enters the archaeological record at a higher rate than the inner kernel destined for consumption. Prior to consumption, the Chumash subjected the kernels to a lengthy preparation and cooking process, necessary to eliminate poisonous hydrocyanic acid (Anderson 2005:277; Bettinger and Wohlgemuth 2011:117; Timbrook 1982:170-171; Timbrook 2007:151). Timbrook (1982:166) elaborates on the specific process used by the Chumash, which included boiling for long periods. This intensive preparation provided exposure to fire and enhanced likelihood of preservation in the archaeological record. Ethnohistoric records indicate that the Chumash regarded prepared islay kernels as an important, good-tasting and prized food, as valuable as acorns and chia, all of which were traded widely between different Chumash groups and in particularly large quantities to the Island Chumash (Timbrook 1982:170-173; Timbrook 2007:153). However, some archaeologists contend that due to low abundance, patchy distribution and high processing costs, islay yielded very low return rates (Bettinger and Wohlgemuth 2011:117).

Nuts. More than a dozen species of oaks on Santa Cruz Island provided seasonal acorn mast (Junak et al. 1995). Acorns are generally represented in the ethnohistoric and archaeological literature as abundant, reliable, and storable resources that were the single most important plant food of the Chumash and other Native California peoples (Anderson 2006:286; Basgall 2004:88; Timbrook 2007:156; Bettinger and Wohlgemuth 2011:117). Ethnohistoric accounts suggest that the Chumash preferred acorns from coast live oak (*Quercus agrifolia*) to acorns from scrub oaks (*Quercus pacifica* or *Quercus dumosa*), possibly due to the lower fat content of the latter, although they ate both (Timbrook 2007:159, 163). Acorns were commonly collected in the fall, sundried, and stored in outdoor granaries before being shelled and moved indoors for long-term storage (Timbrook 2007:156-157). Ethnohistoric accounts indicate that even though people traded dry, shelled acorns widely throughout the Santa Barbara Channel region, acorns were generally less valuable than small seeds (Timbrook 2007:157). Dried, shelled acorns needed to be pulverized into fine flour and leached to remove tannins. This process is described in detail elsewhere (see Timbrook 2007:158). Leached acorn meal could be boiled into acorn mush or baked in earth ovens to make acorn bread (Timbrook 2007:159).

California black walnut trees do not currently occur and may not have ever been present on any of the four Northern Channel Islands; however, ethnohistoric documents indicate that the Chumash ate and traded black walnuts (*Juglans californica*) widely because they were considered to taste very good (Timbrook 2007:96). Walnuts were gathered in the fall, cracked, and eaten raw or roasted (Bettinger and Wohlgemuth 2011:118). The presence of this species in the archaeological plant assemblages from Santa Cruz Island provides the strongest evidence of plant foods traded to the island from the mainland. Furthermore, the presence of charred nutshell and nutmeat fragments indicates that walnuts were traded whole, without significant prior processing, in contrast to acorns.

Geophytes. Many species of perennial wildflowers with underground storage organs—bulbs, corms, rhizomes, taproots, and tubers—served as an important food source for Native California peoples (Anderson 2006:291). These geophytes store water and nutrients during favorable springtime conditions and are high in carbohydrate content, second only to seeds in the diet of Native California peoples (Anderson 2006:295). The Chumash collected these tasty, abundant, and nutritious resources in the summer, after the flowers stalks died back (Timbrook 2007:75). Ethnohistorical records suggest that various bulbs, corms, rhizomes, and tubers formed the mainstay of Native California plant foods, rivaling acorns and seed crops in parts of the state (Anderson 2005:294). Geophytes are underrepresented in the archaeological record due to the lack of hard parts or other features that resist decay. Thus, it is not surprising that only one geophyte species used for food appears in the archaeological plant assemblage considered in this study.

Blue dicks corms are ubiquitous in the archaeological plant assemblages considered in this study. Chumash peoples harvested this species using digging sticks to extract the corms, removing the leaves and stems and transporting only the corms back to the village (Timbrook 2007:75). This collection process churned the soil and dispersed cormlets, contributing to propagation of this species and potentially the vitality and size of their populations (Anderson 2006:293-294, 296-300). Native California peoples ate some geophytes raw, but cooked most by boiling, steaming, roasting, or baking (Anderson 2006:295). Substantial ethnohistoric data indicate that Island Chumash women roasted huge quantities of blue dicks in specially constructed earth ovens (Timbrook 2007:75). This processing greatly enhanced the preservation potential of blue dicks corms.

Basic Results: The Study Assemblages in Site Context

Before beginning the quantitative analysis, it is necessary to present the basic measures on which I base my analysis. This section presents the results of the taxonomic identifications of the floated paleoethnobotanical assemblages, summarized by site and excavation level in in Appendix Tables B.1-B.3, along with the soil volume, plant weight, and wood weight, which are used to standardize the data.

The Coastal Site

The archaeobotanical samples (N=8) from the Coastal site come from terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) contexts. In these samples I identified a total of 43 unique plant taxa, 34 of which represent edible plants valued for seeds, greens, fruits, nuts, or corms (see Appendix Table B.1). The archaeobotanical assemblages from Level 22 and Level 21, pertaining to terminal Early Period occupation, yielded the highest average density of plant remains by weight but the lowest abundance of plant taxa. I identified just 25 unique plant taxa in these samples, 23 of which represent edible plants valued for seeds, greens, fruits, nuts, or corms. This pattern is in contrast to the archaeobotanical assemblages from Levels 20, 19, 18, and 17 pertaining to Middle Period occupation. These assemblages yielded a high average density of plant remains by weight and a greater abundance of unique taxa. I identified 39 unique plant taxa in these samples, including all nine of the non-food taxa and the only evidence of tobacco use at this site. The archaeobotanical assemblages from Levels 16 and 15, pertaining to late Middle Period occupation, yielded a lower density of plant remains by weight and fewer unique plant taxa. I identified 26 taxa in these samples, 24 of which represent edible plants valued for seeds, greens, fruits, nuts, or corms.

Despite disparity in sample size and taxa representation between the different periods of occupation at the Coastal site, certain trends in the data are apparent. Goosefoot (*Chenopodium berlandieri*) and canary grass (*Phalaris* spp.) are ubiquitous. Small seeds and greens, particularly, saltbush (*Atriplex* spp.), phacelia (*Phacelia* spp.), clover (*Trifolium* spp.), brome grass (*Bromus* spp.), and red maids (*Calandrinia ciliata*), complemented by manzanita (*Arctostaphylos* spp.) berries and blue dicks (*Dichelostemma capitatum*) corms, appear to be the most common food resources used at the site. All of these taxa, except manzanita, are readily available in the coastal strand, coastal bluff scrub, and grassland communities that surround the Coastal site. Some isolated manzanita bushes may be encountered at the top of a nearby ridge, but do not grow in great abundance today within immediate site vicinity.

Several additional taxa, particularly fruits and nuts, appear to be common in Middle Period contexts. Prickly pear (*Opuntia* spp.), toyon (*Heteromeles arbutifolia*), and islay (*Prunus ilicifolia*), in addition to acorn (*Quercus spp*.) nutshell and nutmeat are conspicuously restricted to samples from Middle Period contexts. Although prickly pear grows in nearby grasslands and coastal sage scrub communities, the other plant taxa do not occur today in abundance within immediate proximity to the site. This suggests that people brought a greater number of plant taxa, from greater distances to the Coastal site during the Middle Period times compared to either earlier or later occupations.

The Pericoastal Site

The archaeobotanical samples (N=5) from the Pericoastal site come terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) contexts. In these samples I identified a total of 46 unique plant taxa, 39 of which represent edible plants valued for seeds, greens, fruits, nuts or corms (see Appendix Table B.2). The archaeobotanical assemblage from Level 6, pertaining to terminal Early Period occupation, yielded a lower density of charred plant material, by weight, but a greater number of unique plant taxa relative to subsequent occupation. I identified 24 taxa in this sample, 20 of which represent edible plants valued for seeds, greens, fruits, nuts or corms. This is in contrast to the archaeobotanical assemblage from Level 5, pertaining to Middle Period occupation. The density of charred plant remains, by weight, is double that of preceding and subsequent periods at this site. This higher density of plant remains during the Middle Period mirrors the pattern evident at the Coastal site. However, fewer plant taxa, relative to preceding and subsequent periods of occupation at the site, are evident. This is the reverse of the pattern evident at the Coastal site. I identified just 16 taxa in this Middle Period sample. The archaeobotanical assemblage from Level 4, Feature 1, and Level 3, pertaining to late Middle Period occupation, yielded a low average density of plant remains by weight—just 1 gram/liter of soil—but a large number of unique plant taxa. I identified 40 taxa in these samples, 33 of which represent edible plants valued for seeds, greens, fruits, nuts or corms.

As at the Coastal site, small seeds and greens are the most common food resources at the Pericoastal site. Common tarweed (*Hemizonia* spp.), goosefoot (*Chenopodium berlandieri*), brome grass (*Bromus* spp.), canary grass (*Phalaris* ssp.), red maids (*Calandrinia ciliata*), and bedstraw (*Galium* spp.) are ubiquitous. Manzanita (*Arctostaphylos* spp.) berries and blue dicks (*Dichelostemma capitatum*) corms also occur in each sample from the Pericoastal site.

Clover (*Trifolium spp*.) occurs across temporal periods and in every sample but Feature 1; thus, I also regard it among the food resources common at the Pericoastal site. All of these taxa, except manzanita, are readily available in the grassland and coastal sage scrub communities that surround the Pericoastal site. Some isolated manzanita bushes occur at the top of a nearby ridge but do not grow in great abundance within immediate site proximity.

Various fruit-bearing taxa, including lemonadeberry (*Rhus* spp.), prickly pear (*Opuntia* spp.), toyon (*Heteromeles arbutifolia*), and nightshade (*Solanum* spp.), and black walnut (*Juglans californica*) nutshell and nutmeat only occur in samples from the latest period of occupation. As noted at the Coastal site, acorn nutshell and nutmeat appear to be restricted to terminal Early Period and Middle Period occupation. The appearance of black walnut, a species that does not currently grow on Santa Cruz Island, may suggest that island-mainland trade contributed to plant food resources consumed by the prehistoric Chumash during the late Middle Period. Increased trade also provides a reasonable explanation for the disappearance of acorn nutmeat and nutshell in the later assemblages at the Pericoastal and Coastal sites. As described in the previous discussion of cultural context, the Chumash only traded dry, shelled acorns. Off-island processing of this food resource may contribute to underrepresentation in late Middle Period contexts.

The Interior Site

The archaeobotanical samples (N=6) from the Interior site come terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) contexts. In these samples I identified a total of 38 unique plant taxa, 33 of which represent edible plants valued for seeds, greens, fruits, nuts or corms (see Appendix Table B.3). Overall, the density of charred plant remains per liter of soil is significantly lower than at the Coastal or the Pericoastal site, but the number of taxa is similar. The archaeobotanical assemblage from Levels 13 and 12, pertaining to terminal Early Period occupation, yielded a slightly higher density of charred plant material relative to subsequent occupations but the least number of unique plant taxa. I identified just 17 taxa in this sample, 15 of which represent edible plants. This is in contrast to the archaeobotanical assemblage from Level 11 and Level 10, pertaining to Middle Period occupation. The density of charred plant remains, by weight, is even lower in these samples—just 0.65 grams per liter—than in preceding and subsequent temporal periods. The decreased density of plant remains during the Middle Period relative to the subsequent occupation opposes the pattern evident at the Coastal and Pericoastal sites, even as the number of unique plant taxa remains consistent. I identified 29 unique plant taxa from Middle Period contexts, 25 of which represent edible seeds, greens, fruits, nuts, and geophytes. The archaeobotanical assemblage from Level 9 and Level 8, pertaining to Late Middle Period occupation, yielded a low average density of plant remains by weight— just 1 gram/liter of soil—and 28 unique plant taxa, including five non-food taxa.

Red maids (*Calandrinia ciliata*) seeds and blue dicks (*Dichelostemma capitatum*) corms are ubiquitous throughout all periods of occupation at the Interior site. Seeds and greens from these species, common tarweed (*Hemizonia* spp.), brome grass (*Bromus* spp.), canary grass (*Phalaris spp*.), pacific pea (*Lathyrus vestitus*), and clover (*Trifolium* spp.), complemented by manzanita berries and acorns, are the most common food resources at the Interior site. All of these taxa are readily available in the coastal sage scrub, island chaparral, and island woodland vegetation communities that occur within the vicinity of the Interior site.

Common coastal strand, grassland, and coastal bluff scrub species, such as goosefoot and prickly pear, appear to be less common at the Interior site than at the Coastal and Pericoastal sites. There is no evidence that people consumed black walnut, likely traded from the mainland, at this more interior site location. Rather, acorn nutshell and nutmeat consistently appear in deposits pertaining to all periods of site occupation. This suggests that local, island collection and processing of acorns did not cease completely after Middle Period, even if trade with the mainland for acorns and other plant food resources increased during the late Middle Period.

Quantitative Analysis of the Study Assemblages

Broad patterns noted in basic results merit further consideration. In this section I explore subsistence patterns at each site and through time using the quantitative methods previously described. Although I initially consider all identified taxa in analysis of plant abundance, I focus on edible food taxa in the subsequent diversity, ubiquity, and taxon specific analyses. I present each analysis and results by site and by temporal period. Analysis by site reveals general patterns in dietary contribution and land use. Analysis by temporal period reveals how these patterns changed through time.

Abundance (Density) of Plant Remains

I quantified the abundance of charred plant remains by both count and weight. I reported these raw abundance values in Appendix B (Tables B.1 –B.3). However, plant counts ($p= 0.458$, $df= 1$) and total plant weight ($p= 0.308$, $df= 1$) are poorly correlated with the original soil volume of the sample. Deviation from the basic assumption that larger volumes of soil contain larger quantities of plant remains indicates the occurrence of activities that unevenly influenced the distribution of plant remains. In order to further evaluate patterning in plant abundance across space and through time, as well as correct for comparison between large and small samples, I standardize the total charred plant weight recovered from each sample by the original soil volume of the sample. I also standardize the total plant count recovered from each sample by the total plant weight recovered from the sample, calculating the plant weight ratios, to assess variation in plant abundance relative to plant related activities. I use box plots to explore variation in the plant weight density and the plant weight ratio by site and temporal period. Sample sizes (the number of samples from each site or pertaining to each period) are noted at the bottom of each sample grouping. The median density values between site or temporal periods are significantly different from each other at the 0.05 level if the notches in the box plots do not overlap (see the preceding materials and methods section for further discussion of this method).

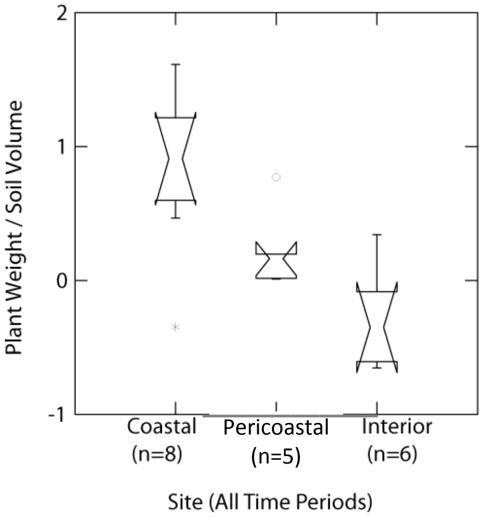

Figure 5.1. Box plots of plant weight density by site. Values graphed on Y-axis are log transformed.

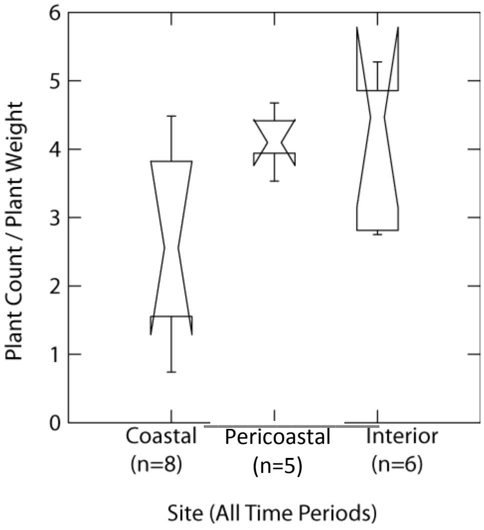

Figure 5.2. Box plots of standardized plant counts by site. Values graphed on Y-axis are log transformed.

Broad Spatial Trends. Figure 5.1 represents the distribution of plant weight density values for samples recovered from all temporal periods at each of the three sites. The box plots reveal significant differences in the overall abundance of plant remains relative to soil volume. The paleoethnobotanical assemblages from the Coastal site contain a significantly greater density of charred plant remains relative to soil volume than do the assemblages from the Pericoastal and the Interior sites. The box plots indicate that the overall abundance of plant remains at the Coastal site consistently exceeded the abundance of plant remains, throughout all temporal periods, at the Pericoastal and Interior site. Total plant weight density decreases significantly moving from the Coastal site, one kilometer up the Christy watershed to the Pericoastal site, and even more moving three kilometers up the watershed to the Interior site.

However, the abundance of wood charcoal, which dominates the paleoethnobotanical assemblages in this study, drives patterning in plant weight density. Counts standardized by the total plant weight focus the analysis on variation in non-wood plant taxa (counts do not include wood charcoal) relative to plant related activities, facilitating further analysis. In Figure 5.2, I consider variation the distribution of standardized count (total non-wood plant count/total plant weight, including wood) values for samples recovered from all periods at each of the three sites. The box plots reveal substantial differences in the standardized counts of charred plant remains from each of the three sites. The distribution of standardized counts for samples from the Coastal site is significantly lower than the distribution of standardized counts for samples from the Pericoastal site. Although there is a slightly higher distribution of standardized counts at the Interior site than at the Pericoastal site, this difference is not statistically significant. This analysis indicates that the abundance of non-wood plant taxa relative to all plant related activities increases significantly moving from the Coastal site, one kilometer up the Christy watershed to the Pericoastal site, and even more moving three kilometers up the watershed to the Interior site.

Contrasting patterns in the overall abundance of plant remains relative to soil volume (plant weight density) and the standardized counts of plant remains indicates differential deposition of plant remains occurred at each site. The overall abundance of charred plant material, including wood charcoal, relative to all other cultural and non-cultural activities that also contributed to the original sample volume, was much higher at the Coastal site than at either of the other two more interior site locations. This may reflect more frequent or more intense use of wood for fuel and/or other purposes (such as fish processing) at this site. However, standardized counts of all non-wood plant taxa, relative to just plant-related activities, was much lower at the Coastal site than at either the Pericoastal or Interior site. Thus, it appears that exploitation, processing, and/or consumption of non-wood plant resources, occurred away from the Coastal site.

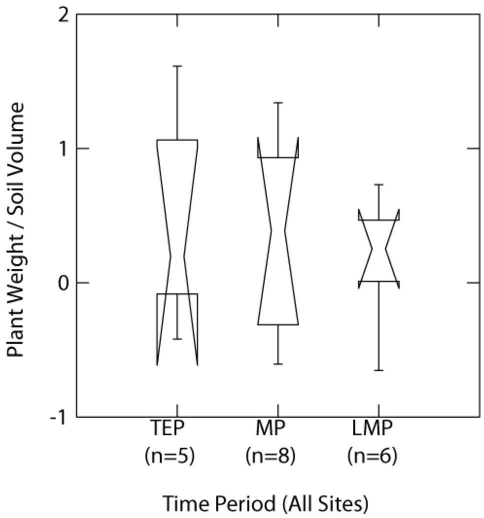

Figure 5.3. Box plots of plant weight density by temporal period. Values graphed on Y-axis are log transformed.

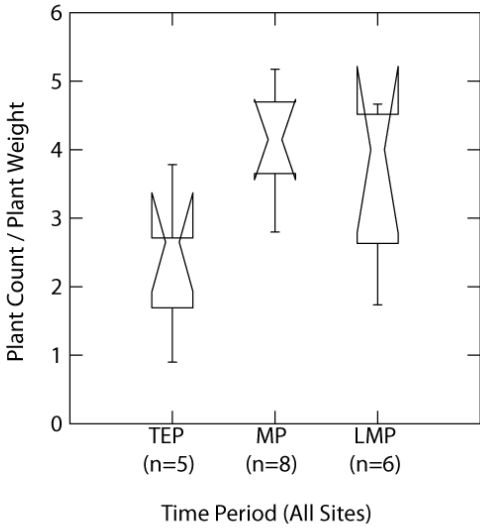

Figure 5.4. Box plots of standardized plant counts by temporal period. Values graphed on Y-axis are log transformed.

Broad Temporal Trends. Figure 5.3 represents the distributions of plant weight density values for samples recovered from all three sites, grouped by temporal period. The box plots indicate no significant difference in the overall abundance of charred plant remains relative to soil volume through time. Thus, it appears that there is no significant diachronic shift in the abundance of plant remains (by weight) relative to other cultural and non-cultural activities at these three sites.

However, Figure 5.4, which represents the distribution of standardized counts from all sites by temporal period, does reveal significant temporal variation in the abundance of non-wood plant remains, relative to other plant-related activities. Significantly fewer plant remains occur in paleoethnobotanical assemblages from terminal Early Period contexts. There is no significant difference in standardized counts of plant remains from Middle Period and late Middle Period contexts. This suggests that exploitation of plant food resources increased significantly between the terminal Early Period and the Middle Period but then remained constant throughout into the late Middle Period.

Intrasite Diachronic Trends. In the previous analysis I combined plant assemblages from all three sites to assess broad temporal patterns. Grouping the assemblages provides an important measure for understanding general diachronic trends in plant exploitation, but suppresses any evidence of variation between intrasite assemblages. Comparisons of intrasite assemblages best illustrate site-specific trends through time. Below I consider how standardized counts of charred plant remains, via density and ratio measures, vary through time at each site. Due to low sample sizes per temporal period, statistical analysis of the site-based assemblages is not possible. Thus, I simply present these data as a series of line graphs.

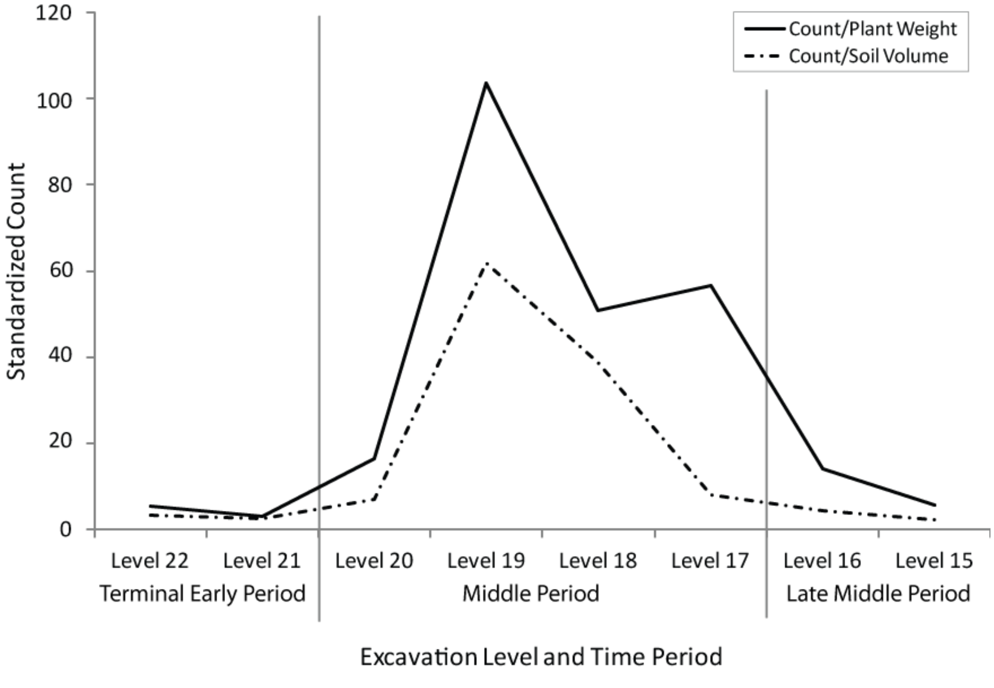

Figure 5.5. Standardized counts of plant remains from the Coastal site. Counts standardized by soil volume scaled to 20% for graphing. Counts standardized by plant weight not scaled.

Figure 5.5 illustrates variation in standardized counts of plant remains at the Coastal site, by level assemblage through time. In order to represent counts standardized by soil volume and counts standardized by plant weight on the same graph I scaled counts standardized by soil volume to 20%. Counts standardized by plant weight are represented at their true value. It is evident that the abundance of plant remains recovered in Middle Period contexts is dramatically higher than in preceding terminal Early Period or succeeding late Middle Period contexts. This pattern is consistent with the previous assessment that plant exploitation overall increased significantly between the terminal Early Period and Middle Period. However, plant exploitation at the Coastal site does not remain consistent throughout the entire Middle Period. There is a sharp decrease moving into the late Middle Period during which plant exploitation appears to return to lower levels, similar to the terminal Early Period.

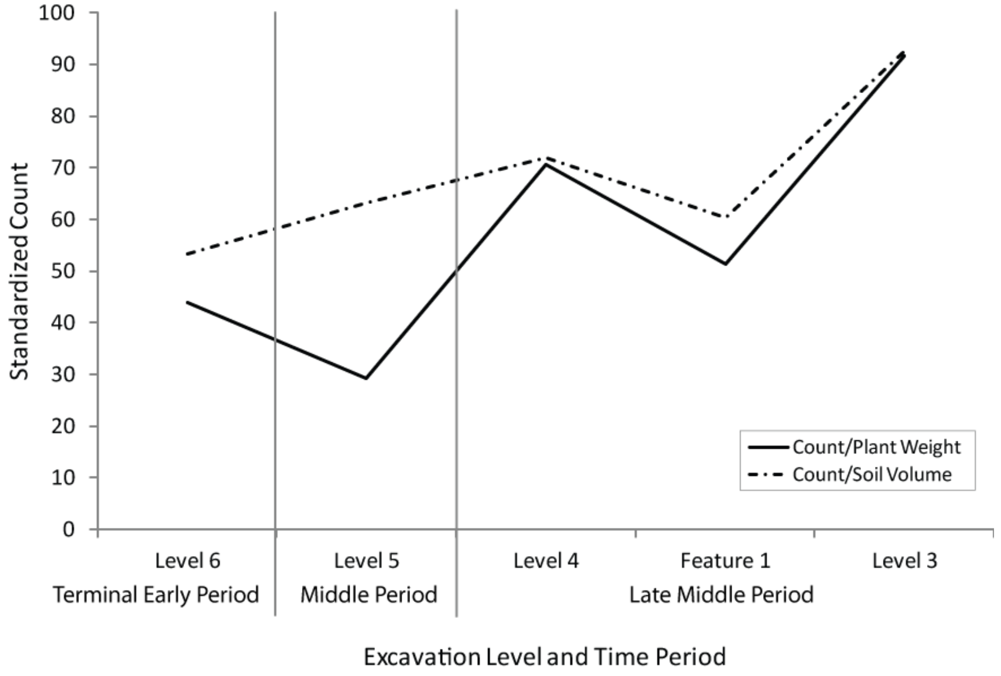

Figure 5.6. Standardized counts of plant remains from the Pericoastal site.

Figure 5.6 illustrates variation in standardized counts of plant remains at the Pericoastal site, by level assemblage through time. This intrasite perspective reveals that terminal Early Period contexts at the Pericoastal site contain a greater abundance of plant remains, by standardized counts, than terminal Early Period contexts at either the Coastal or the Interior site. There is an apparent steady increase in standardized counts through time, with slightly higher values during the subsequent Middle Period and even higher values during the late Middle Period. This suggests that plant exploitation at the Pericoastal site was consistently high throughout all temporal periods without dramatic Middle Period increase or late Middle Period decrease evidenced at the Coastal site.

Although this pattern is in part consistent with the previous assessment that plant exploitation overall increased between the terminal Early Period and Middle Period, this broad generalization obscures important differences between the Coastal and Pericoastal site, which may relate to changes in site function through time. Moreover, high plant abundance in terminal Early Period and late Middle Period contexts at the Pericoastal site indicates that the very low plant abundance during these two temporal periods at the Coastal site is not likely due to environmental regimes that negatively influenced the availability of plant resources. Plant exploitation on Santa Cruz Island did not simply stay the same throughout the entire Middle Period, as suggested by the overall temporal trend, or decrease precipitously, as evidenced at the Coastal site. Rather, the distinct differences evident in the site-based assemblages likely reflect variation in site function and land-use patterns.

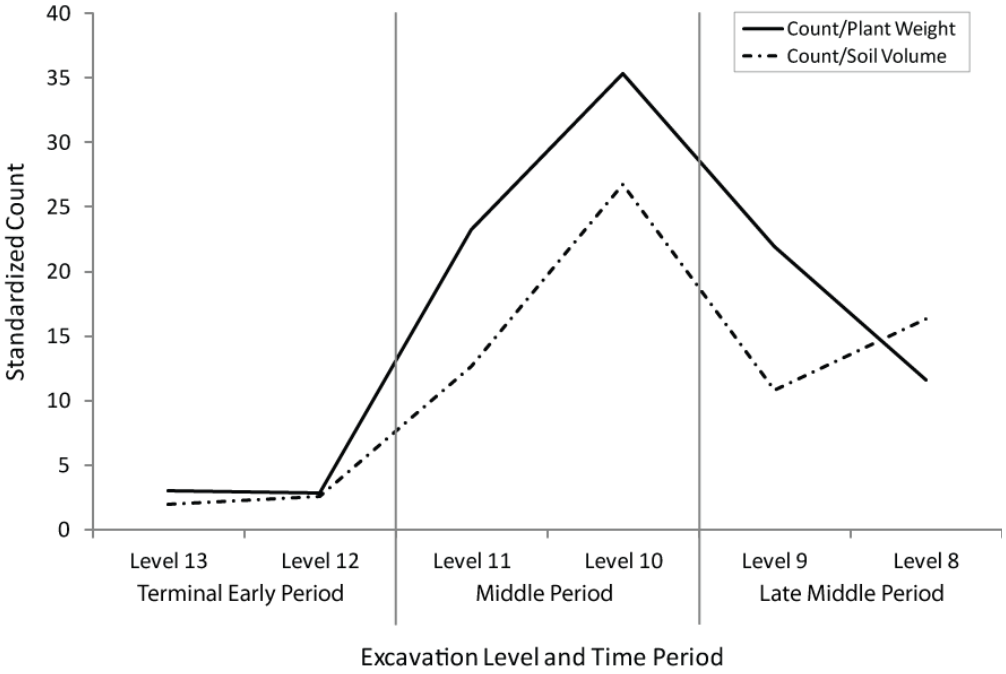

Figure 5.7. Standardized counts of plant remains from the Interior site. Counts standardized by plant weight scaled to 20% for graphing. Counts standardized by soil volume not scaled.

Figure 5.7 illustrates variation in standardized counts of plant remains at the Interior site. In order to represent counts standardized by soil volume and counts standardized by plant weight on the same graph I scaled the counts standardized by plant weight to 20%. Counts standardized by soil volume are graphed at their true value. The relative abundance of plant remains by standardized count at this site appear to follow a similar pattern of dramatic Middle Period increase and late Middle Period decrease as seen at the Coastal site. As seen at the Pericoastal site, the initial abundance of plant remains from terminal Early Period contexts is higher than at the Coastal site; however, the overall temporal pattern is more similar to the Coastal site than to the Pericoastal site. The abundance of plant remains recovered from Middle Period contexts at the Interior site is much higher than the abundance of plant remains from preceding and subsequent temporal periods. This pattern is consistent with the previous assessment that plant exploitation increased significantly between the terminal Early Period and Middle Period. This shift is followed by a subsequent decrease during the late Middle Period. In contrast to the Coastal site, plant abundance does not drop all the way down to terminal Early Period values, nor does it continue to rise as evidenced at the Pericoastal site. The pattern of plant exploitation at the Interior site is distinct. After the Middle Period plant exploitation decreases by half, remaining much higher than plant exploitation at the Coastal site, and similar to plant exploitation at the Pericoastal site.

Summary of Plant Abundance. Charred plant remains from terminal Early Period contexts are most abundant in deposits at the Pericoastal and Interior sites, suggesting that plant exploitation during this temporal period occurred away from the coast. Moving into the Middle Period, plant exploitation increases significantly at all three sites. The incredible abundance of charred plant remains at the Coastal site suggests a shift not only in the intensity of plant exploitation but perhaps also in land use patterns. Evidence of Middle Period plant exploitation at the Coastal site increased dramatically, and is more comparable to plant exploitation at the Pericoastal and Interior site than during the previous temporal period. After the Middle Period, patterns of plant exploitation became more complicated. There is not a consistent decline in the abundance of plant remains after the Middle Period; thus, it is unlikely that decreased plant exploitation, evidenced most dramatically at the Coastal site, and to a lesser degree at the Interior site, is related to the lack of plant availability. It is clear that the prehistoric inhabitants of Santa Cruz Island continued to exploit plants at similar levels throughout the entire Middle Period. However, it appears that they were not exploiting plants in the same way throughout this temporal period. After the

Middle Period, charred plant remains occur primarily in deposits at the Pericoastal and Interior sites suggesting another shift in land use patterns, once again away from the coast.

Diversity of Plant Taxa

Raw counts and abundance measures document the range of taxa and intensity of plant use, but alone they do not offer much interpretative value (VanDerwarker 2006:91). However, raw counts do provide a representation of the diversity of types within a sample and can be used as a basis for measuring species richness and evenness, key components of diet breadth. Measures of assemblage diversity allow for effective evaluation of land use patterns across space as well as specialization or diversification in diet breadth through time. In this analysis I focus specifically on plant *food* taxa, excluding all identified taxa not recorded as edible in the ethnographic or ethnohistoric literature.

DIVERS Computer Simulation. I first consider Kintigh′s (1984, 1989) DIVERS computer simulation to evaluate species diversity and control for potential effects of sample size. Figure 5.8 plots calculated richness by sample size for each site. I include assemblages from all temporal periods. The center solid line in the DIVERS plot represents expected richness and evenness values based on 500 simulated assemblages for each sample size. The dotted lines above and below the centerline represent the 90% confidence interval for expected values. Filled circles, open circles, and x’s represent the actual richness and evenness values of the paleoethnobotanical assemblages from the Coastal, Pericoastal, and Interior sites, respectively. In this analysis, I do not directly compare the diversity of archaeological plant assemblages to each other; rather I compare the archaeological plant assemblage to expected values simulated for the same size assemblage (Kintigh 1984, 1989).

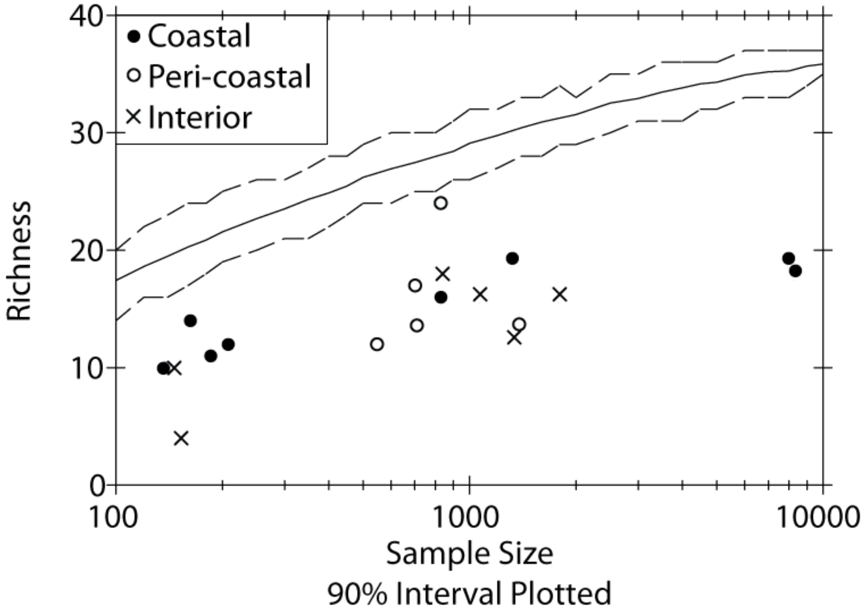

Figure 5.8. DIVERS richness plot of all plant remains from all temporal periods, by site.

I ran multiple DIVERS simulations, grouping samples by site and by temporal period. In each iteration the calculated richness of the archaeological assemblages, which remain constant, fall *below* the line of the 90% confidence interval. Comparison of archaeological plant assemblages to the expected values simulated for the same size assemblage indicates that all archaeological plant assemblages considered in this study are statistically less rich than expected. That is to say that many fewer taxa are present in each assemblage than anticipated based on comparison to the simulated assemblages. This suggests a great deal of selectivity in the plant taxa exploited by the Island Chumash throughout time and across space.

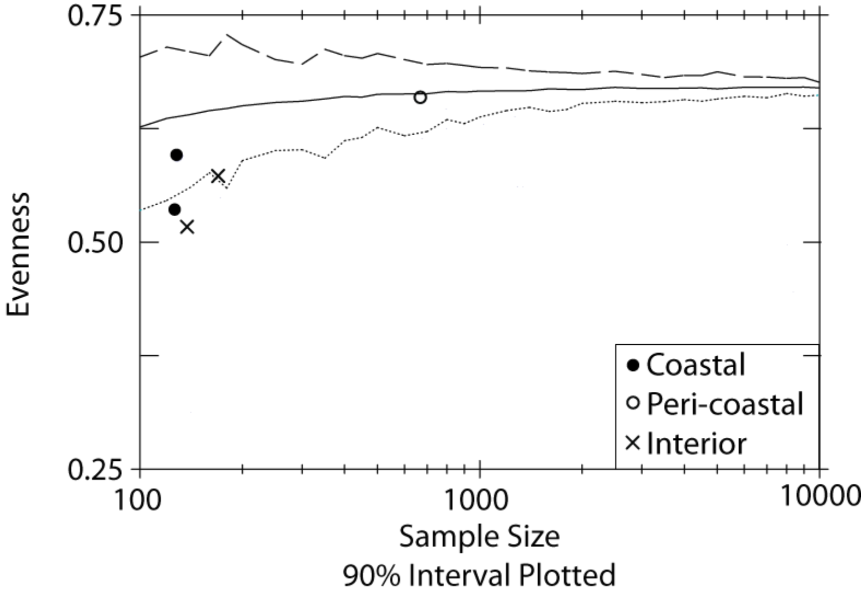

Figure 5.9. DIVERS evenness plot of all plant remains by site from terminal Early Period contexts.

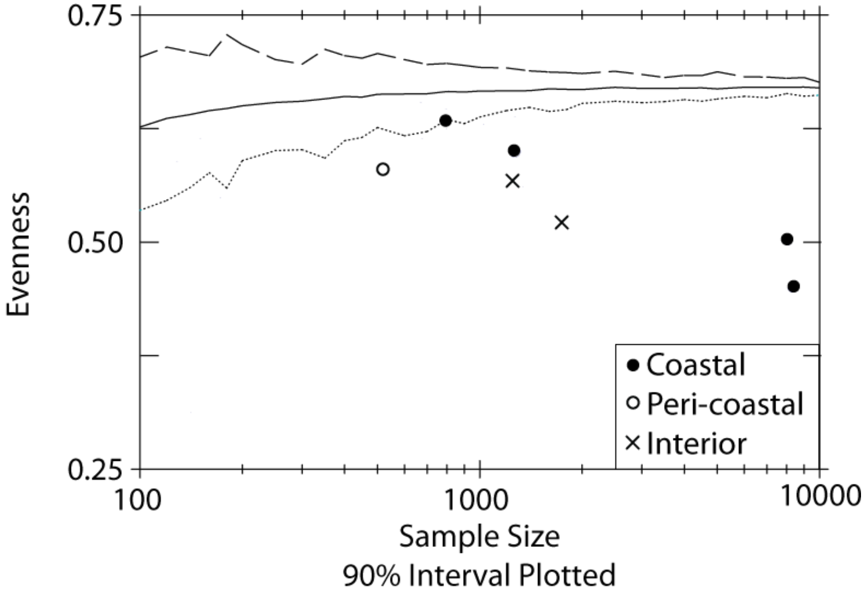

Figure 5.10. DIVERS evenness plot of all plant remains by site from Middle Period contexts.

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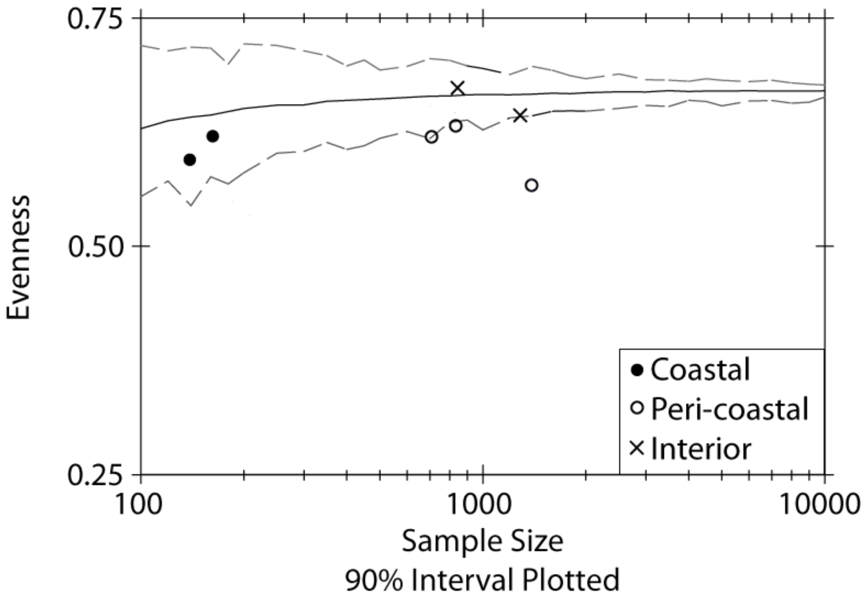


Figure 5.11. DIVERS evenness plot of all plant remains by site from late Middle Period contexts

In terms of evenness, terminal Early Period plant assemblages from the Coastal, Pericoastal, and Interior sites fall *within* the 90% confidence interval for expected range of values (Figure 5.9). In other words, most plant assemblages from the terminal Early Period are as evenly distributed as expected given their respective sample sizes. One plant assemblage from the Coastal site and one plant assemblage from the Interior site fall below the expected range of values. Both of these samples come from the lowermost excavation level at each site. The other two samples from the Coastal and Interior site fall in the lower range of the confidence interval. The single terminal Early Period sample from the Pericoastal site falls directly on the line of expected evenness at its sample size. Thus, the relative evenness of plant taxa exploited at the Pericoastal site appears to be higher than at the Coastal or Interior site.

In terms of evenness, most Middle Period plant assemblages from the Coastal, Pericoastal, and Interior sites fall *below* the 90% confidence interval for expected range of values (Figure 5.10). Plant assemblages from all three sites are significantly less evenly distributed than expected given their respective sample sizes. The only assemblage that falls within the expected range of values pertains to the sample from excavation level 20 at the Coastal site. Overall, DIVERS results suggest that plant exploitation during Middle Period occupation at the Coastal, Pericoastal, and Interior sites skewed towards just a few resources.

Late Middle Period plant assemblages from the Coastal, Pericoastal, and Interior sites appear to be much more evenly distributed than plant assemblages from Middle Period contexts. Assemblages from all three sites fall at or *within* the 90% confidence interval for expected range of values at their sample size (Figure 5.11). Both samples from the Coastal site fall well within the expected range of values. Of the three samples from the Pericoastal site, two fall just at the lower limit of the expected range of values, and one falls below it. One sample from the Interior site falls in the higher range of expected values while the other sample falls at the lower limit of the expected values. Nonetheless, these results indicate that overall plant exploitation appears more equitable at all three sites during the late Middle Period than during previous the previous temporal period.

The results of the DIVERS computer simulation provide a broad overview and assessment of richness and evenness of the plant assemblages considered in this study. It is clear that the number of plant taxa exploited across space and time is significantly lower than expected and that the relative focus on these taxa is variable across space and through time. However, further interpretation is limited, as DIVERS values cannot be used for direct comparison between samples.

Shannon Weaver Index. In order to compare the diversity of archaeological plant assemblages from different contexts and temporal periods I calculated Shannon-Weaver index *H′* and *V′* values for diversity and equitability. Table 5.3 presents all *H′* and *V′* values calculated for level assemblages by site and temporal period. Unlike the DIVERS computer simulation, the Shannon-Weaver index does not control for differences in samples sizes, which may influence diversity and equitability values, as discussed in the Chapter 4. However, I do consider sample size in the discussion of these values. I use box plots to explore variation in diversity and equitability by site and through time. Median values between site or temporal periods are significantly different from each other at the 0.05 level if the notches in the box plots do not overlap.

Table 5.3. Shannon Weaver index values *H′* diversity and *V′* equitability calculated for all samples. L indicates excavation level, F indicates feature.

	TEP		MP				LMP		
Coastal Site	**L22**	**L21**	**L20**	**L19**	**L18**	**L17**	**L16**		**L15**
H′ Diversity	2.260	2.156	2.355	1.815	1.629	2.044	2.240		2.328
V′ Equitability	0.815	0.937	0.850	0.616	0.563	0.635	0.849		0.822
Pericoastal Site	**L6**		**L5**				**L4**	**F1**	**L3**
H′ Diversity	2.377		2.096				2.345	2.240	2.277
V′ Equitability	0.839		0.844				0.696	0.827	0.716
Interior Site	**L13**	**L12**		**L11**	**L10**		**L9**		**L8**
H′ Diversity	1.942	2.006		1.884	2.137		2.430		2.349
V′ Equitability	0.810	0.837		0.679	0.702		0.841		0.771

Broad Spatial Trends. Figures 5.13 and 5.14 indicate no significant difference in the overall diversity and equitability of archaeological plant assemblages from the three sites. The median *H′* diversity value of all plant assemblages from all temporal periods at the Coastal site is 2.198, slightly lower than the median *H′* diversity value of 2.277 from the Pericoastal site, and slightly higher the median *H′* diversity value of 2.072 from the Interior site. The median *V′* equitability values follow a similar pattern. However, differences between site assemblages are not statistically significant.

It is notable that the overall spread, i.e., variability, in diversity values at the Coastal site and Interior site is much greater than variability at the Pericoastal site. The box plots suggest that the relative diversity and equitability of plant taxa exploited at the Coastal site was quite variable through time. The diversity of plant taxa exploited at the Interior site also appears quite variable through time, albeit with lower average diversity and equitability than at the Coastal site. In contrast, there is distinctly less variability in the diversity and equitability values of the plant assemblage from the Pericoastal site. The relative diversity of plant taxa exploited at this site was greater and much more consistent through time than the relative diversity of plant taxa exploited at the Coastal and Interior sites.

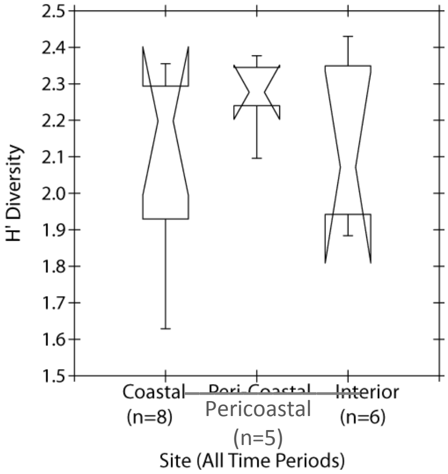


Figure 5.12. Box plots of Shannon Weaver *H′* diversity values for all plant assemblages from all temporal periods by site.

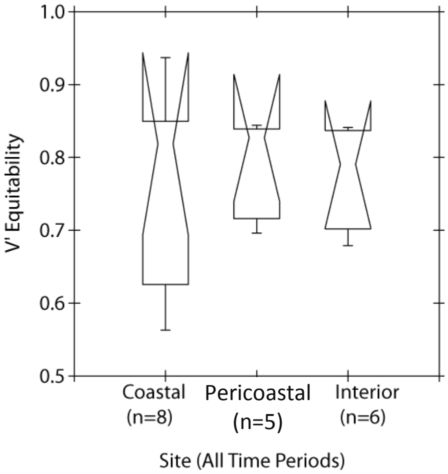


Figure 5.13. Box plots of Shannon Weaver *V′* equitability values for all plant assemblages from all temporal periods by site.

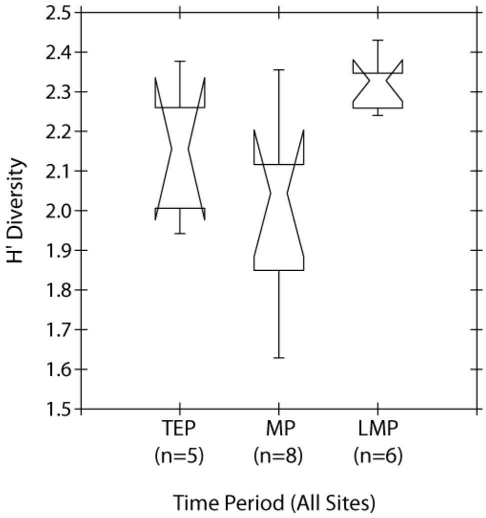


Figure 5.14. Box plots of Shannon Weaver *H′* diversity values for plant assemblages from all sites by temporal period.

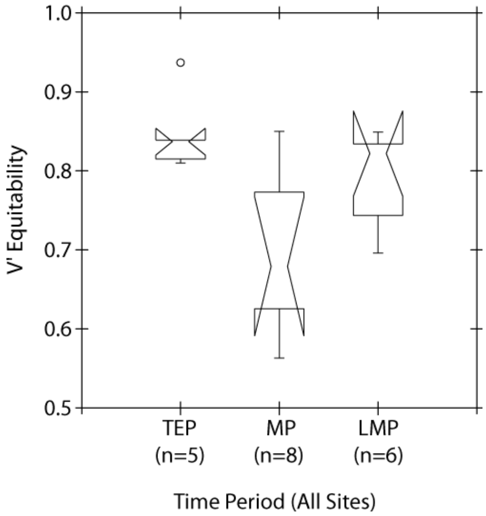


Figure 5.15. Box plots of Shannon Weaver *V′* equitability values for plant assemblages from all sites by temporal period.

Broad Temporal Trends. Figure 5.14 and 5.15 reveal significant differences in the overall diversity and equitability of archaeological plant assemblages from all three sites throughout time. Paleoethnobotanical assemblages from the terminal Early Period contexts contain a slightly higher diversity (*H′*) of plant taxa than assemblages from Middle Period contexts. Although this difference is not statistically significant, it does suggest that there was a decrease in the diversity of plant taxa exploited after the terminal Early Period. This decline in diversity is accompanied by a statistically significant decrease in the equitability (V') of plant taxa exploited after the terminal Early Period. Plant assemblages from late Middle Period contexts contain statistically greater diversity (H') and equitability (V') of plant taxa than assemblages from Middle Period contexts. Median diversity and equitability values for plant assemblages from late Middle Period contexts are the highest of all three temporal periods. This is generally consistent with the results of the DIVERS computer simulations. However, Figure 5.14 reveals no significant difference in the diversity and equitability of plant assemblages from late Middle Period contexts and plant assemblages from terminal Early Period contexts.

Overall, these results indicate that the terminal Early Period inhabitants of Santa Cruz Island exploited a wide diversity of plant food resources quite equitably. However, this pattern shifts abruptly during the Middle Period. Later occupants at each of the three sites during the Middle Period exploited a lower diversity of plant food resources much less equitably. This pattern is reversed during the late Middle Period. The late Middle Period inhabitants once again appear to have diversified the variety of plant food resources exploited, relying on a wide diversity of taxa much more equitably.

The preceding analysis groups H' and V' values from all three site assemblages in order to assess general temporal trends in plant exploitation. This grouping does not allow further exploration of temporal variation within site assemblages. Below I consider how species diversity and equitability varies through time at each site. Due to a low number of samples per temporal period at each site, statistical analysis of the site-based assemblages is not possible. I simply present these data as a series of scatter plots that graph the Shannon

Weaver diversity (*H'*) and equitability (*V'*) values calculated for each excavation level assemblage in stratigraphic order and indicate the temporal period each assemblage pertains.

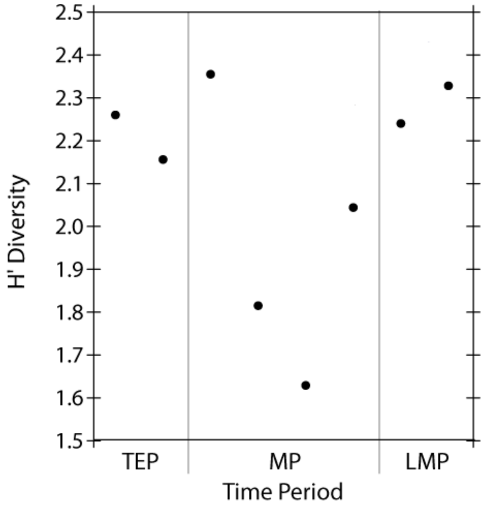


Figure 5.16. Scatter plot of Shannon Weaver *H'* diversity values of all archaeological plant assemblages from the Coastal site by temporal period.

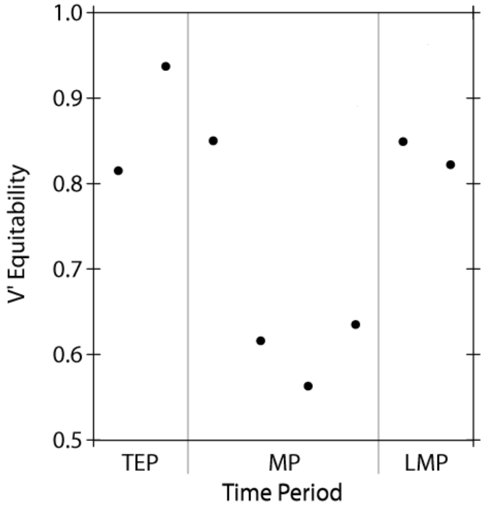


Figure 5.17. Scatter plot of Shannon Weaver *V'* equitability values of all archaeological plant assemblages from the Coastal site by temporal period.

Diachronic Trends at the Coastal Site. Figure 5.16 and 5.17 illustrate variation through time in the diversity and equitability of level assemblages from the Coastal site. At this site, the average diversity and equitability of plant taxa in the two sample assemblages from terminal Early Period contexts and the two samples from late Middle Period contexts are much higher than the average diversity and equitability of the four samples from Middle Period contexts. Thus, variation through time at the Coastal site mirrors the broad temporal patterns discussed above. However, it must be noted that that the plant assemblage recovered from excavation Level 20 is considerably more diverse and even than the three other assemblages that also pertain to the Middle Period. The diversity and equitability values calculated for the plant assemblage from Level 20 are quite similar to the values calculated for plant assemblage from the adjacent Level 21. AMS radiocarbon dates on shell of California mussel (*Mytilus californianus*) indicate that cultural materials derived from Level 20 pertain to the Middle Period, and cultural materials from excavation Level 21 pertain to the terminal Early Period. A much lower sample size from Level 20 relative to the sample size from the three other Middle Period samples may account, in part, for this difference. Regardless, it is evident that the prehistoric inhabitants of the Coastal site exploited a lower diversity of plant food resources, in a less equitable manner, during the Middle Period than they did during preceding and subsequent temporal periods. Samples from this temporal period are the largest recovered from the Coastal site. Thus, it is unlikely that low diversity and evenness are due to the effects of sample size.

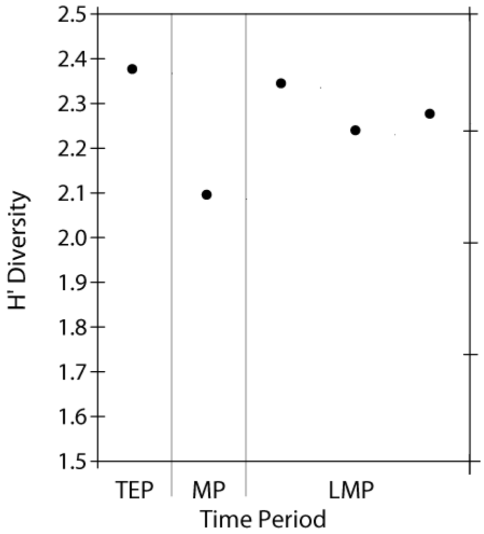


Figure 5.18. Scatter plot of Shannon Weaver *H′* diversity values of all archaeological plant assemblages from the Pericoastal site by temporal period.

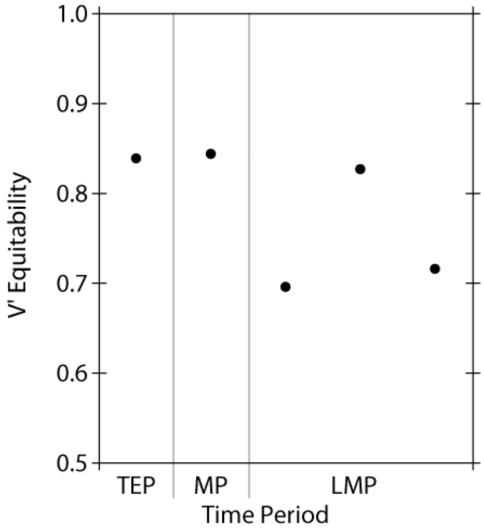


Figure 5.19. Scatter plot of Shannon Weaver *V′* equitability values of all archaeological plant assemblages from the Pericoastal site by temporal period.

Diachronic Trends at the Pericoastal Site. Figure 5.18 and 5.19 illustrate variation through time in the diversity and equitability of level assemblages from the Pericoastal site. At this site, the diversity of plant taxa in the sample assemblage pertaining to the terminal Early Period and the three samples pertaining to the late Middle Period are higher than the diversity of plant taxa in the assemblage pertaining to the Middle Period. Thus, variation through time in the diversity of plants exploited at the Pericoastal site mirrors the Coastal site and broad temporal patterns discussed above. However, this is not true in regards to equitability. At the Pericoastal site, equitability values for plant taxa in assemblages pertaining to the terminal Early Period and the Middle Period are higher than the average equitability value for the three samples pertaining to the late Middle Period. One relatively high equitability value among the late Middle Period assemblages pertains to the sample from Feature 1. As described in Chapter 4, Feature 1 represents a discrete deposit of distinctive faunal remains, quite different from the faunal taxa in all other assemblages at the Pericoastal site. Thus, it is not surprising to encounter increased evenness in the plant assemblage of this unique feature. Nonetheless, the overall pattern is strong. It is evident during the terminal Early Period the prehistoric inhabitants of the Pericoastal site exploited a high diversity of plant food resources in an equitable manner. Although the general diversity of plant food resources exploited decreased during the Middle Period occupation, the relative equitability of taxa exploited remained high. During the late Middle Period the prehistoric inhabitants of the Pericoastal site once again began to exploit a high diversity of plant food resources, but in a much less equitable manner.

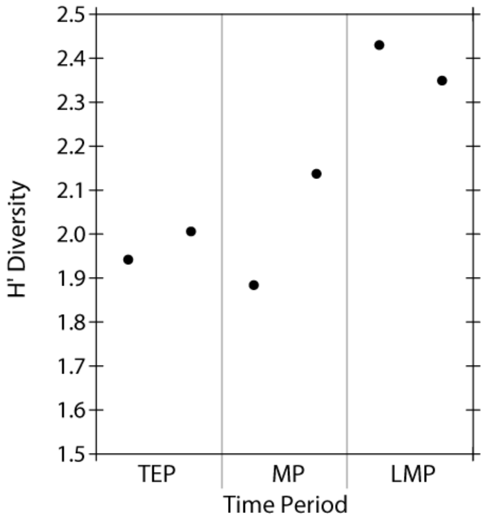


Figure 5.20. Scatter plot of Shannon Weaver *H′* diversity values of all archaeological plant assemblages from the Interior site by temporal period.

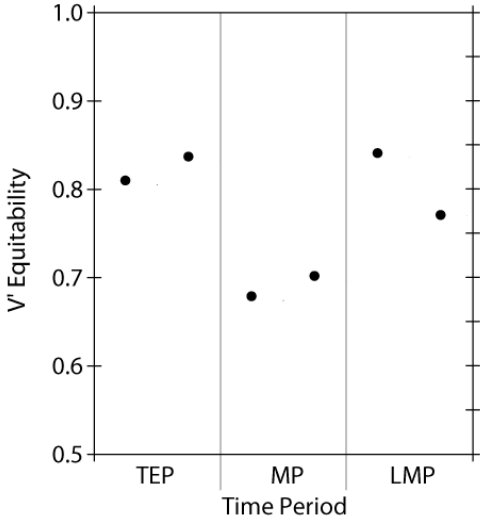


Figure 5.21. Scatter plot of Shannon Weaver *V′* equitability values of all archaeological plant assemblages from the Interior site by temporal period.

Diachronic Trends at the Interior Site. Figure 5.20 and 5.21 illustrate variation through time in the diversity and equitability of level assemblages from the Interior site. The average diversity values calculated for plant assemblages from the Interior site increase through time. Two samples pertaining to terminal Early Period contexts at this site are slightly less diverse than terminal Early Period assemblages from the Coastal and Pericoastal site, though equitability of plant taxa appears to be comparable. Moving into the Middle Period, the average diversity (*H′)* of plant taxa increases, but equitability (*V′*) decreases. This decrease in equitability mirrors the decrease previously noted at the Coastal and Pericoastal sites. The average diversity of plant taxa in the two samples pertaining to the late Middle Period is quite high, indeed slightly higher than in late Middle Period assemblages from the Coastal or Pericoastal site. The relative equitability of plant taxa also increases in these latter assemblages, returning to values similar to those of the terminal Early Period.

It is clear that diachronic variation in diversity and equitability of plant taxa exploited at the Interior site is distinct from the broad temporal patterns noted above. Plant exploitation at the Interior site becomes increasingly diverse through time, beginning relatively low in the terminal Early Period and ending relatively high in the late Middle Period, accompanied by a significant decrease in the equitability of plant taxa during the Middle Period, similar to the decrease in equitability noted at the Coastal and Pericoastal sites.

Summary of Plant Diversity. Analysis of assemblages by temporal period within site contexts reveals that diversity and equitability of plant taxa exploited at each site were broadly shaped by temporal trends. During the terminal Early Period, the diversity and equitability of plant taxa exploited appears quite high at the Coastal and Pericoastal sites, suggesting that plant exploitation during this temporal period included a wide variety of plants that were collected, and presumably consumed, in a relatively equitable manner. Slightly lower diversity of plant taxa exploited at the Interior site during this temporal period may relate to differences in season of occupation or site function. However, great similarity in the relatively high equitability of plant taxa exploited at all three sites indicates a pattern of generalized plant exploitation, without specific focus on any particular taxon or group of taxa.

Moving into the Middle Period there is a clear shift in patterns of plant exploitation. During this temporal period, diversity and equitability of plant taxa exploited decreased at all three sites, although more so at the Coastal and Pericoastal sites than at the Interior site. Thus, some spatial variability appears to exist. Overall, this temporal period is characterized by evidence of more focused plant exploitation of fewer plant taxa across space.

After the Middle Period these patterns of plant exploitation became more complicated. During the late Middle Period occupation at all three sites, there appears to be a significant increase in the diversity of plant species exploited; however, the relative equitability of these taxa is more variable. At the Coastal site, diversity of plant taxa rebounds, returning to levels similar to the terminal Early Period occupation. Equitability of the plant taxa exploited also increases, but remains lower than the level of equitability of plant taxa in terminal Early Period assemblages. This indicates that after the Middle Period, occupants at the Coastal site once again began to collect a wide diversity of plant taxa, but continued to focus exploitation on specific taxa. At the Pericoastal site, diversity of plant taxa also rebounded, but remained below levels evidenced in the terminal Early Period assemblage from this site. In contrast, equitability of the plant taxa exploited at the Pericoastal site actually decreases during the late Middle Period. This indicates that after the Middle Period, occupants at the Pericoastal site once again began to collect a wider diversity of plant taxa, but also increased their focus on the exploitation on specific taxa. Diversity of plant taxa exploited during the late Middle Period increases most dramatically at the Interior site, surpassing both the Coastal and Pericoastal sites, and the previously high diversity noted in terminal Early Period assemblages. Equitability at this site also increases, returning to similar levels evidenced in terminal Early Period assemblages from this site. Overall, plant exploitation during the late Middle Period is characterized by exploitation of a wide diversity of plant taxa, but with continued emphasis on narrower range.

Ubiquity Analysis

Ubiquity analysis is a presence/absence analysis that measures occurrence frequency of a specific taxon in a given number of samples. I calculate ubiquity values by site and temporal period. I also rank the resources in descending order by ubiquity value to get a sense of changes across space and through time.

Primary Plant Food Taxa. In order to identify plant food taxa that appear consistently across space and through time I first consider ubiquity values calculated for all 19 plant samples. This analysis provides a general assessment of primary plant food taxa exploited on Santa Cruz Island from the terminal Early Period throughout the Middle Period. Table 5.4 presents the ranking and ubiquity values of all plant taxa that occur in more than 60% of all plant samples considered in this study. As ubiquity deals with occurrence frequency rather than abundance, the 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 suggests that the prehistoric Island Chumash consistently relied on these plant foods. Small seeds, greens, berries, nuts and geophytes are all represented among the most regularly used plant foods across space and through time on in the lower Cañada Christy watershed.

Table 5.4 Ranking and ubiquity value for primary plant food taxa. Based on occurrence frequency across all sites and all temporal periods (N=19).

Rank	Ubiquity Value	Taxa (Common Name)
1	95%	Canary grass
2	89%	Blue Dicks
		Manzanita
		Red Maids
3	84%	Clover
		Goosefoot
4	79%	Common Tarweed
5	63%	Acorn
		Legume

In the following analyses I consider how ubiquity values of these primary plant food taxa changed through time and across the three sites. I also consider variation in occurrence frequency of bedstraw, mallow, phacelia, saltbush, sunflower, pacific pea, and islay. I include these additional eight plant taxa because they are represented by a greater than 70% ubiquity value in one or more temporal period or site assemblage groupings.

Broad Spatial Trends. Ubiquity analysis of all plant samples grouped by site provides a tentative measure of spatial variation in the occurrence of primary plant taxa. Due to the low number of sample sizes considered, this analysis is subject to sampling error. Thus, I only discuss the most dramatic differences between the site assemblages and regard all results as tentative. Table 5.5 lists ubiquity values for primary plant food taxa of all temporal periods by site. Canary grass, manzanita, clover, legumes, and mallow occur in similar frequencies across in plant assemblages from the Coastal, Pericoastal, and Interior sites. Ubiquity of these species does not appear to be related to site location. Blue dicks, red maids, tarweed, bedstraw, and pacific pea occur in notably higher frequencies at the Pericoastal and Interior site than at the Coastal site. This suggests that these plant food resources were more regularly collected or processed away from the coast. Phacelia, saltbush, and sunflower seeds occur in much higher frequencies at the Coastal site than at the Pericoastal or Interior sites. This suggests that these three plant food resources were more regularly collected at the Coastal site. Acorn and islay occur in much higher frequencies at the Coastal and Interior site, with very little representation of either species at the Pericoastal site. This suggests that people collected, processed, or consumed acorn and islay regularly at both sites; although acorn is most common at the Interior site, and islay is most common at the Coastal site.

Table 5.5. Ubiquity values for primary plant food resources by site.

	Coastal site	Pericoastal site	Interior site
Samples (N)	*8*	*5*	*6*
Canary grass	100%	100%	83%
Blue Dicks	75%	100%	100%
Manzanita	88%	100%	83%
Red maids	75%	100%	100%
Clover	88%	80%	83%
Goosefoot	100%	100%	50%
Tarweed	63%	100%	83%
Acorn	63%	20%	83%
Legume	63%	60%	67%
Bedstraw	25%	100%	67%
Mallow	63%	60%	50%
Phacelia	88%	40%	17%
Saltbush	88%	40%	33%
Sunflower	75%	40%	33%
Pacific Pea	0%	60%	83%
Islay	50%	0%	33%

Rank-order comparisons of ubiquity values by site (Table 5.6) provide another method for evaluating the relative importance of the primary plant food taxa across space. Notably red maids and blue dicks are among the most highly ranked plant food resources at the Pericoastal and Interior site; however, these two taxa are ranked lower at the Coastal site. Indeed in modern times blue dicks are not as abundant in grasslands near the coast as they are just a few kilometers inland (Glassow 2013, personal communication). Tarweed, acorn, and pacific pea are also higher ranked at the Interior site, suggesting 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; however, these two taxa are ranked lower at the Interior site. 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 relative importance at the Coastal site.

Table 5.6. 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
4	Common Tarweed Legume Checker mallow Acorn		

Broad Temporal Trends. Ubiquity analysis of the plant samples by temporal period provides a tentative measure of temporal variation in the occurrence of primary plant taxa. As discussed previously, due to the low number of sample sizes considered, this analysis is subject to sampling error. As with the site assemblages, I discuss only the most dramatic differences between the temporal components. Table 5.7 lists ubiquity values for the primary plant food taxa from all sites by temporal period. Canary grass, red maids, clover, manzanita, saltbush, and pacific pea are equally ubiquitous throughout all temporal periods, from the terminal Early Period to the late Middle Period. Ubiquity of these plant taxa does not appear to be related to temporal period. Acorns occur in similar frequencies in plant samples from terminal Early Period and Middle Period contexts. The ubiquity value for acorns is much lower in late Middle Period plant samples. This pattern suggests that acorns were collected or processed less frequently during this later temporal period.

Table 5.7. Ubiquity values for primary plant food resources by temporal period.

	TEP	MP	LMP
Samples (N)	*5*	*7*	*7*
Canary grass	80%	100%	100%
Blue Dicks	60%	100%	100%
Manzanita	80%	100%	86%
Red maids	80%	100%	86%
Clover	80%	100%	86%
Goosefoot	60%	100%	86%
Tarweed	40%	86%	100%
Acorn	80%	86%	29%
Legume	40%	71%	71%
Bedstraw	40%	43%	71%
Mallow	20%	57%	86%
Phacelia	40%	71%	57%
Saltbush	60%	57%	57%
Sunflower	20%	57%	71%
Pacific Pea	40%	43%	43%
Islay	0%	86%	0%

The occurrence frequency of blue dicks, goosefoot, tarweed, legumes, mallow, phacelia, sunflower, and islay increases substantially in plant samples from Middle Period contexts. This pattern indicates that these primary plant food taxa were collected more regularly during this temporal period. Blue dicks, goosefoot, tarweed, legumes, mallow, and sunflowers continue to occur at similar or higher frequency in plant samples from the late Middle Period. This consistency suggests that these plant taxa continued to be collected or processed regularly from the Middle Period into the late Middle Period. Lower ubiquity values for phacelia and islay during the late Middle Period implies that these taxa were collected less regularly than they were during the Middle Period.

Table 5.8. Ranking by ubiquity value of primary plant food resources for each temporal period.

Rank	TEP	MP	LMP
1	Canary grass Manzanita Red maids Clover Acorn	Canary grass Blue Dicks Manzanita Red maids Clover Goosefoot	Canary grass Blue Dicks Common Tarweed
2	Blue Dicks Goosefoot Bedstraw Saltbush	Common Tarweed Acorn Islay	Manzanita Red maids Goosefoot Mallow
3	Common Tarweed Legume Phacelia Pacific Pea	Legume Phacelia	Clover Legume Bedstraw Sunflower
4	Mallow Sunflower	Mallow Saltbush Sunflower	Phacelia Saltbush
5		Bedstraw Pacific Pea	Pacific Pea Acorn

Rank-order comparisons of ubiquity values by temporal period (Table 5.8) provide another method for evaluating the relative importance of the primary plant food taxa through time. Notably manzanita, red maids, and clover are among the most ubiquitous plant food resources during the terminal Early Period and Middle Period; however, these three taxa are less ubiquitous during the late Middle Period. Acorn is also much more ubiquitous during these two earlier temporal periods. These four primary plant resources were of greater relative importance during terminal Early Period and Middle Period. Bedstraw, saltbush, phacelia, and pacific pea are also higher ranked in plant samples from terminal Early Period contexts than in samples from later temporal periods. This increase suggests that these taxa were of greater relative importance during the terminal Early Period. Blue dicks and goosefoot are among the most highly ranked plant food resources in samples from Middle Period contexts. Common tarweed and islay are also more highly ranked during the Middle Period than in the preceding terminal Early Period, indicating that these four plant taxa were of greater relative importance during the Middle Period. Blue dicks remains among the most highly ranked plant food resources in plant samples from late Middle Period contexts. However, manzanita, red maids, goosefoot, clover, islay, and acorns slip in ranking after the Middle Period, implying that these primary plant food resources were of less relative importance during the late Middle Period.

Summary of Species Ubiquity. Ubiquity analysis indicates changes across space and through time in the exploitation of plant food taxa. Canary grass, blue dicks, manzanita, red maids, clover, goosefoot, common tarweed, acorn and legumes occur more frequently in all samples relative to other plant food resources. However, the relative importance of these resources, and the others considered in this analysis, vary substantially by site and temporal period.

Independent Assessment of Plant Taxa and Groups: Standardizing by Plant Weight

The rankings employed above provide a useful starting point for assessing variation between the different plant resources used across space and through time. However, interpretation of the placement of any one resource depends on the placement of the others. Here I consider the contributions of the eight most ubiquitous plant resources (canary grass, manzanita, red maids, clover, goosefoot, common tarweed, acorn and legumes), as well as broad plant groups (seeds, greens, fruits, nuts, and geophytes) independently through the use of ratios. The only geophyte taxon identified in the study samples is blue dicks; thus I simply refer to the analysis of blue dicks discussed above. Analysis of the broader plant groups considers all edible plant taxa identified in the study samples.

Ratios are useful quantitative tools that overcome the problems of absolute counts and offer greater insight than ubiquity measures alone. I standardize by plant weight (taxon or plant groups counts/plant weight per sample) and present these values as distributions in the form of box plotss, with sample sizes noted at the bottom of each graph. Sample size in box plotss refers to the number of samples in which I identified the taxon or plant groups. Only the eight most ubiquitous plant taxa occurred in enough samples when grouped by spatial or temporal context to provide sufficiently large distributions and meaningful results. As discussed previously, the medians of two sample distributions are significantly different from each other at the 0.05 level if the notches of the box plotss do not overlap.

Broad Spatial Trends: Individual Taxa. Figure 5.22 illustrates the distributions of canary grass, blue dicks, manzanita, red maids, goosefoot, tarweed, acorn, and legume plant remains recovered from each site throughout all temporal periods. This analysis reveals statistically significant differences in the use of key plant resources between the Coastal, Pericoastal, and Interior sites. Specifically, the contribution of blue dick, manzanita, and clover remains relative to the overall plant assemblage is significantly higher at the Interior site than at the Coastal site (Figure 5.22). It appears that a greater amount of collection, processing, or consumption activities related to these four taxa occurred away from the coast than at the coast. Standardized counts for canary grass, tarweed, red maids, goosefoot and acorn remains are also higher at the Interior site than at the Coastal site, but these differences are not statistically significant (Figure 5.22). Nonetheless, this pattern may also reflect activities related to these taxa occurred more frequently or more intensively at the Interior site rather than at the Coastal site.

The distribution of standardized counts of canary grass, blue dicks, manzanita, and goosefoot remains recovered at the Pericoastal consistently fall in the middle between the lower values from the Coastal site and the higher values from the Interior site. There is no significant difference in the distribution of canary grass, manzanita, or goosefoot between the Pericoastal and Coastal site although the distribution of these specific plant groups does appear to increase with distance from the coast. Blue dicks remains are significantly lower at the Pericoastal site than at the Interior site (Figure 5.22), but there is no significant difference in the distribution of canary grass, manzanita, or goosefoot remains at between the Pericoastal and Interior sites. There are also no significant differences in the standardized counts of red maids, clover, tarweed, acorn or legume remains recovered at the Pericoastal site relative to the Coastal or the Interior sites. As the location of the Pericoastal site is between the Coastal site and the Interior site, these patterns suggests that exploitation, processing, or consumption of canary grass, blue dicks, manzanita, clover, and goosefoot increased with distance from the coast, moving up the watershed, towards the interior of the island.

The box plots presenting distributions of acorn remains also suggest greater exploitation or processing of acorns at the Interior site. Figure 5.22 reveals higher distribution of acorn remains at the Interior site, in comparison to the Coastal and Pericoastal sites. It also appears that acorn-related activities may have also been slightly greater at the Coastal site relative to the Pericoastal site. However, neither of these patterns are statistically significant. Nonetheless the results are not surprising considering that acorns were most likely acquired from the upper reaches of the watershed, in proximity to the Interior site, or via trade with the mainland, hence in greater proximity to the Coastal site. It is likely that Island Chumash had greater access to acorns from the Interior or Coastal site than the Pericoastal site.

These distributions include samples from all temporal periods. Thus, the general spatial patterns noted in this section appear constant throughout all temporal periods considered. Generally, the prehistoric island Chumash appear to have processed and/or consumed greater amounts of these key plant taxa at the Interior site than at either the Pericoastal or Coastal site. This pattern of plant exploitation appears to have been maintained throughout the temporal periods considered in this analysis.

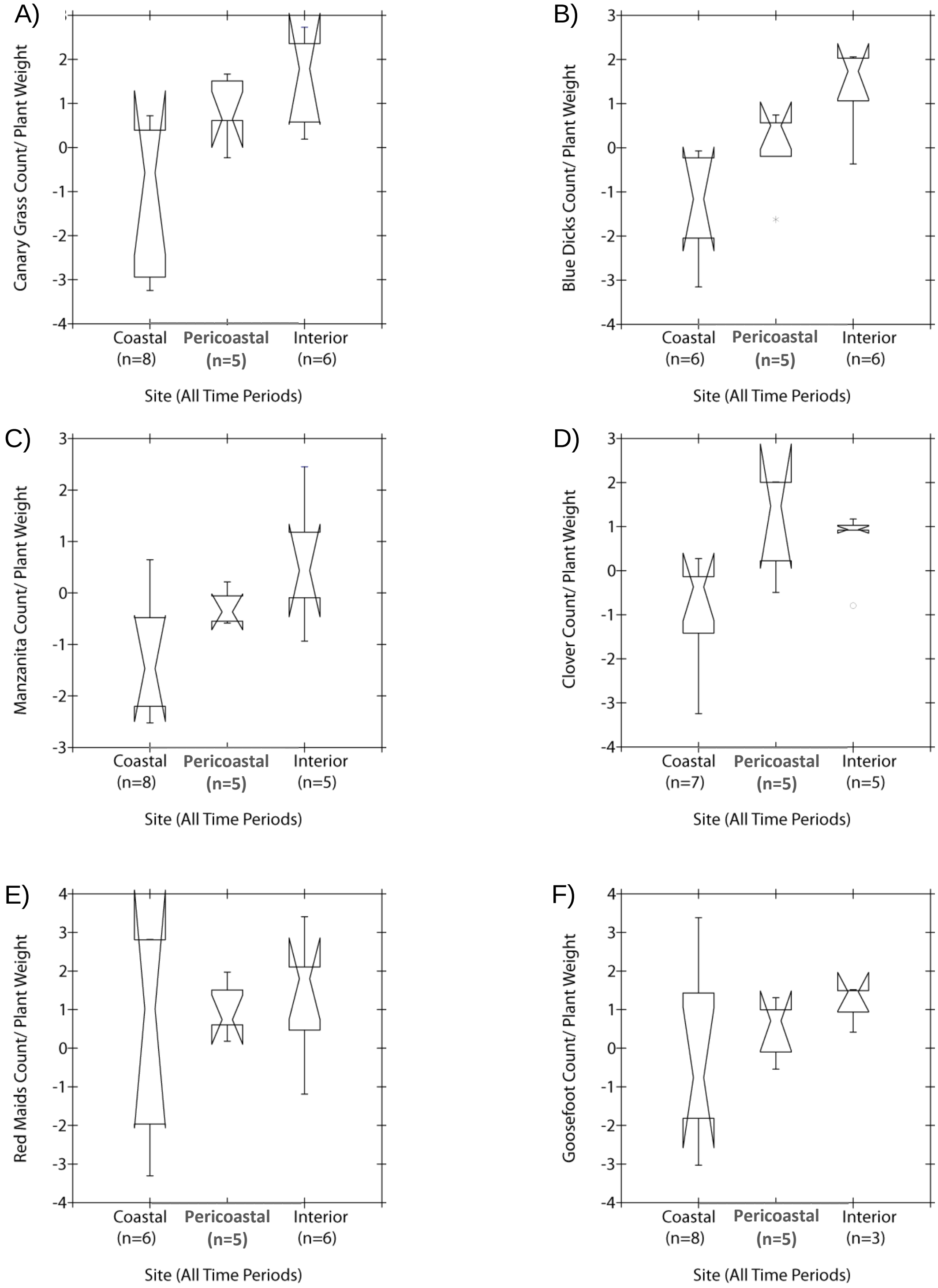


Figure 5.22. Box plots of standardized counts for each of the most ubiquitous plant resources from all temporal periods by site. A) canary grass, B) blue dicks, C) manzanita, D) clover, E) red maids, F) goosefoot, G) tarweed, H) acorn, and I) legume. Values on Y-axis are log transformed.

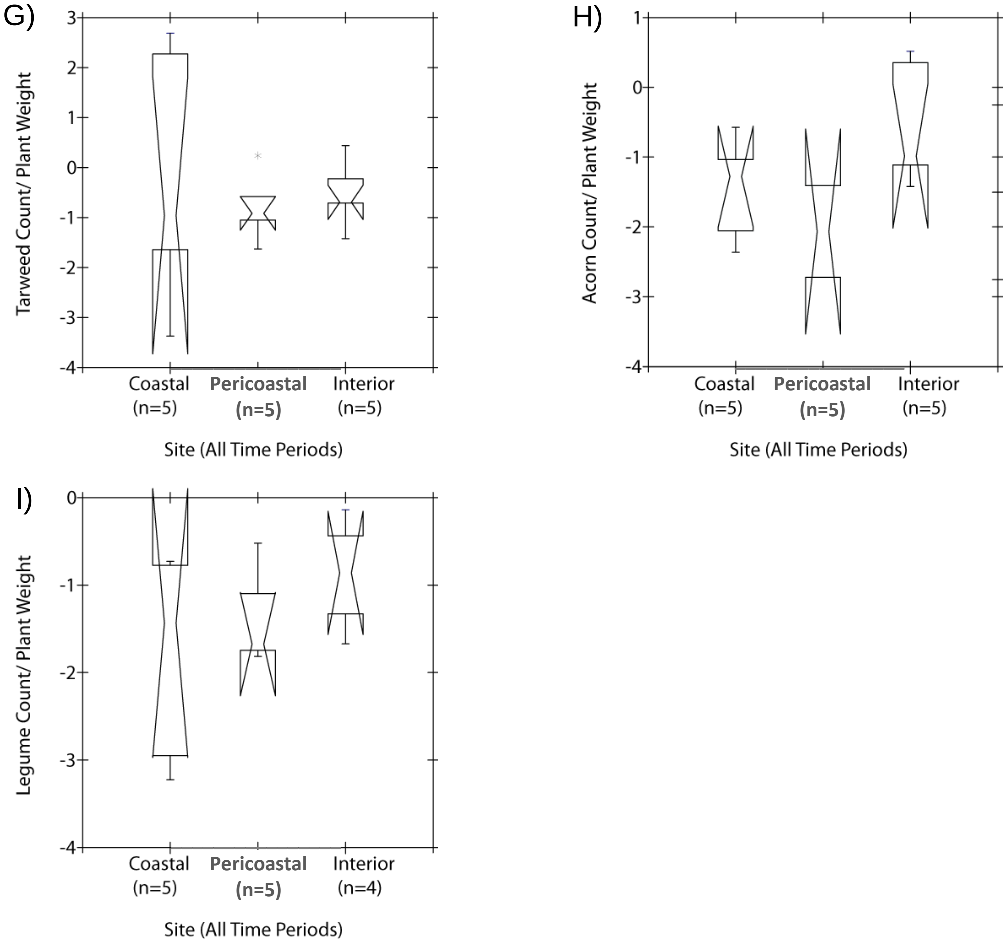


Figure 5.22 continued. Box plots of standardized counts for each of the most ubiquitous plant resources from all temporal periods by site. A) canary grass, B) blue dicks, C) manzanita, D) clover, E) red maids, F) goosefoot, G) tarweed, H) acorn, and I) legume. Values on Y-axis are log transformed.

Broad Temporal Trends: Individual Taxa. Figure 5.23 illustrates the distribution of canary grass, blue dicks, manzanita, red maids, goosefoot, tarweed, and acorn plant remains recovered from all sites, represented by temporal period. This analysis reveals statistically significant differences in the use of key plant resources from terminal Early Period, Middle Period, and late Middle Period contexts. Specifically, the relative contribution of goosefoot, a small starchy seed, relative to the overall plant assemblage is significantly higher during the Middle Period occupation at all three sites than during the terminal Early Period occupation

(Figure 5.23). This suggests a significantly increased contribution of taxa to the Middle Period plant diet. The distributions of canary grass, clover, red maids, tarweed, and legume plant remains are also higher in Middle Period components than the terminal Early Period components, but this difference is not statistically significant.

The distributions of aforementioned taxa (canary grass, clover, red maids, tarweed, and legume) remain high during the subsequent late Middle Period. There is no statistical difference in the distributions of canary grass, red maids, goosefoot, or acorn plant remains between the Middle Period and subsequent late Middle Period. This lack of difference indicates that there was no significant change in the exploitation of these taxa between the two temporal periods. There is a statistically significant increase in the distributions of clover and legume between the Middle Period and subsequent late Middle Period components, indicating a potential increased emphasis in the exploitation of these taxa. Figure 5.23 illustrates that the contribution of blue dicks, manzanita, and acorns relative to the overall plant assemblage remained relatively constant through time. There is no significant difference in the distributions of these three taxa among the three temporal periods. Tarweed is the only taxon for which a slight decline is noted during the late Middle Period, represented by a lower distribution during this temporal period relative to the preceding Middle Period. However, this difference is not statistically significant. Overall, it appears that the prehistoric inhabitants of Santa Cruz Island exploited greater quantities of canary grass, clover, red maids, goosefoot, and legumes during the Middle Period than they did during the terminal Early Period; yet, they continued to process and consume comparable amounts of manzanita, blue dicks, and acorns throughout all periods of occupation.

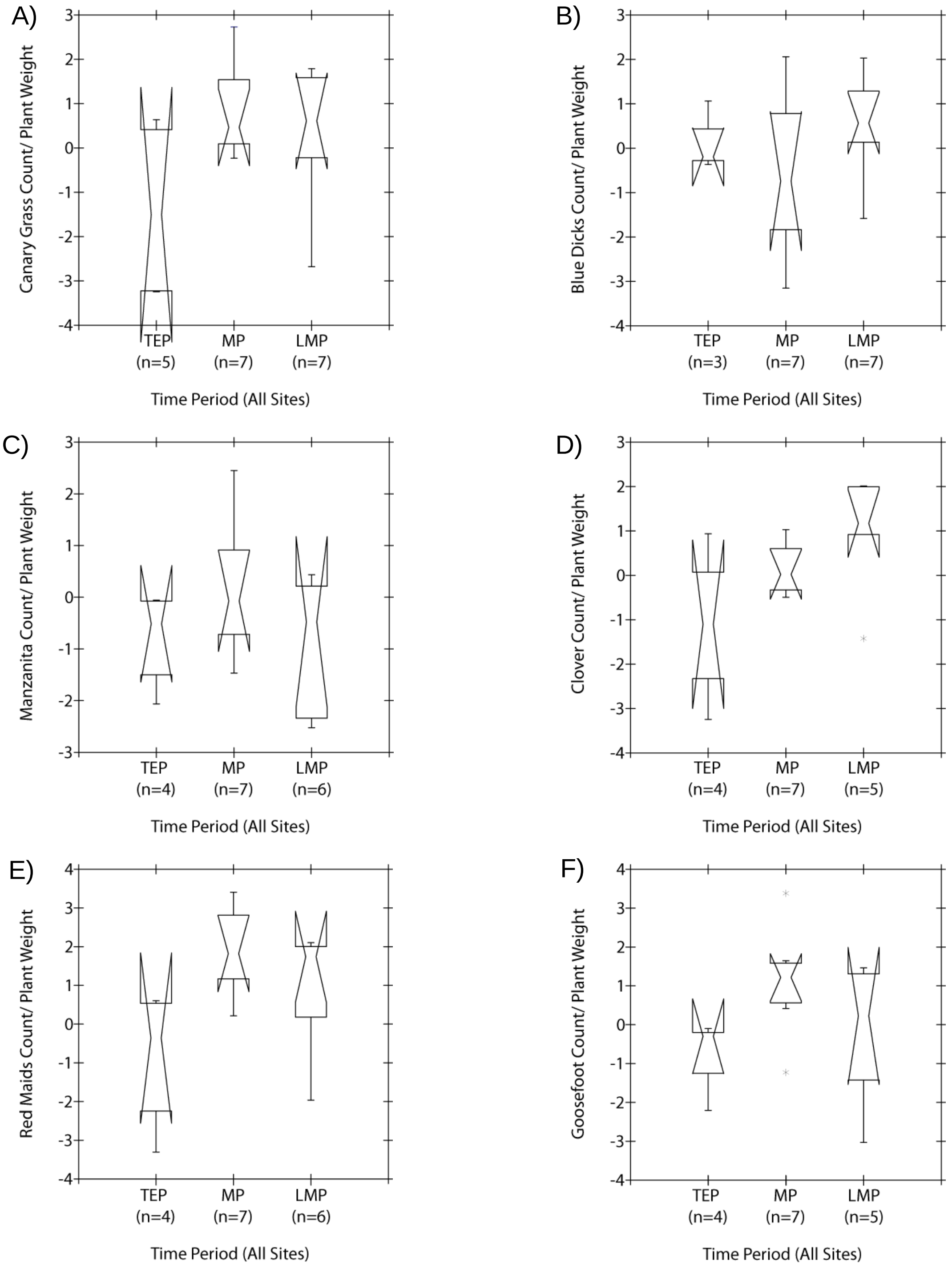


Figure 5.23. Box plots of standardized counts for each of the most ubiquitous plant resources from all sites by temporal period. A) canary grass, B) blue dicks, C) manzanita, D) clover, E) red maids, F) goosefoot, G) tarweed, H) acorn, and I) legume. Values on Y-axis are log transformed.

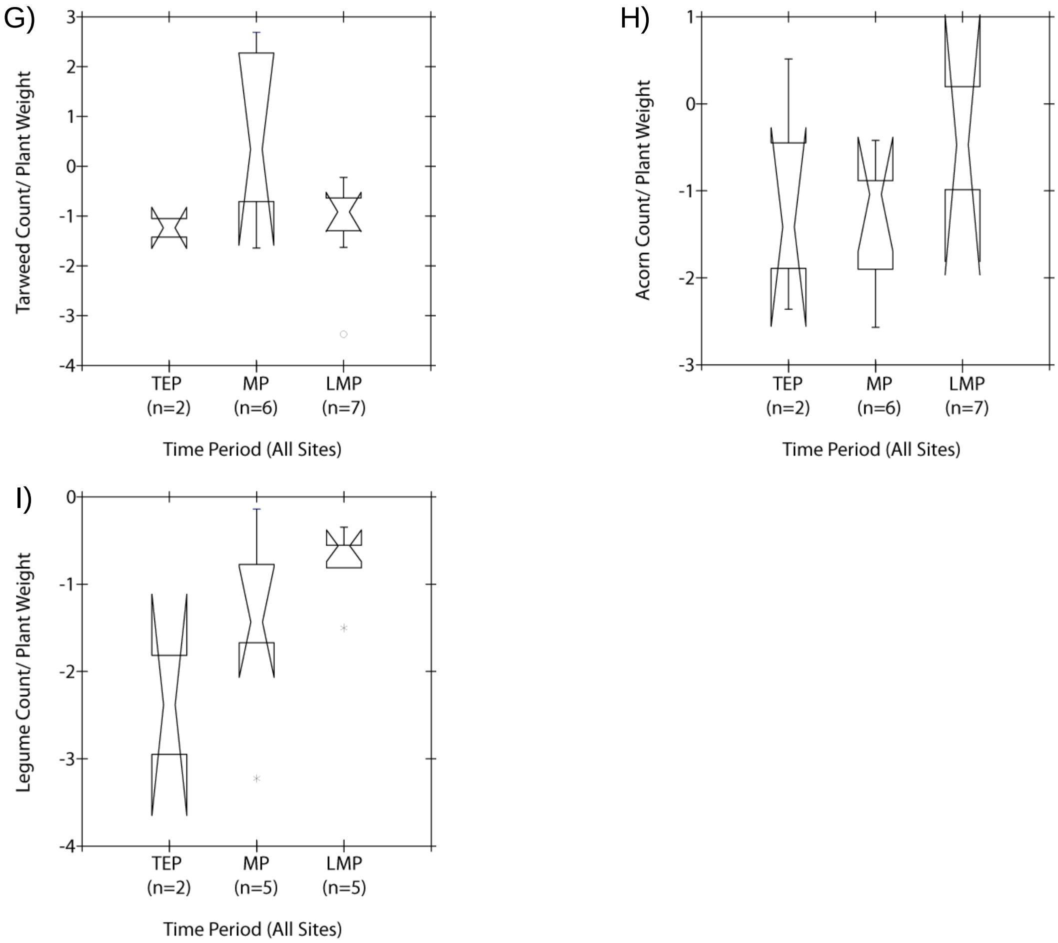


Figure 5.23 continued. Box plots of standardized counts for each of the most ubiquitous plant resources from all sites by temporal period. A) canary grass, B) blue dicks, C) manzanita, D) clover, E) red maids, F) goosefoot, G) tarweed, H) acorn, and I) legume. Values on Y-axis are log transformed.

Broad Spatial Trends: Plant Groups. This section steps away from the consideration of specific plant taxa to consider broader variation in the plant groups exploited at each of the different sites. This analysis incorporates all edible plant taxa identified in the archaeological study assemblages. Figure 5.24 illustrates the distribution plant remains of seeds, greens, fruits, and nuts recovered from each site throughout all temporal periods. Geophytes are only represented by one plant taxon, blue dicks. Analysis of this taxon is presented above, but included in discussion here. Standardized counts of taxa commonly collected for seeds, greens, fruits, nuts (Figure 5.24), and geophytes (Figure 5.23B) are generally higher at the

Interior site than at the Coastal or Pericoastal site. This pattern of higher distributions at the Interior site mirrors the pattern previously noted for several of the most ubiquitous plant taxa. However, this apparent increased contribution to the overall plant assemblage at the Interior site is only statistically significant for greens and geophytes. Notably, the distribution of plant remains from greens is higher at the Pericoastal site than at the Coastal site (Figure 5.24B). This analysis may indicate that the collection, processing, and/or consumption of all plant taxa, particularly greens and geophytes, occurred more frequently or more intensively at the Interior site than at the Coastal site. There are no significant differences between the standardized counts of any plant taxa between the Coastal and Pericoastal sites, and there is only a significant difference in the standardized counts of geophytes between the Pericoastal and Interior sites. This demonstrates a clear and persistent spatial gradient in the exploitation of important plant food resources.

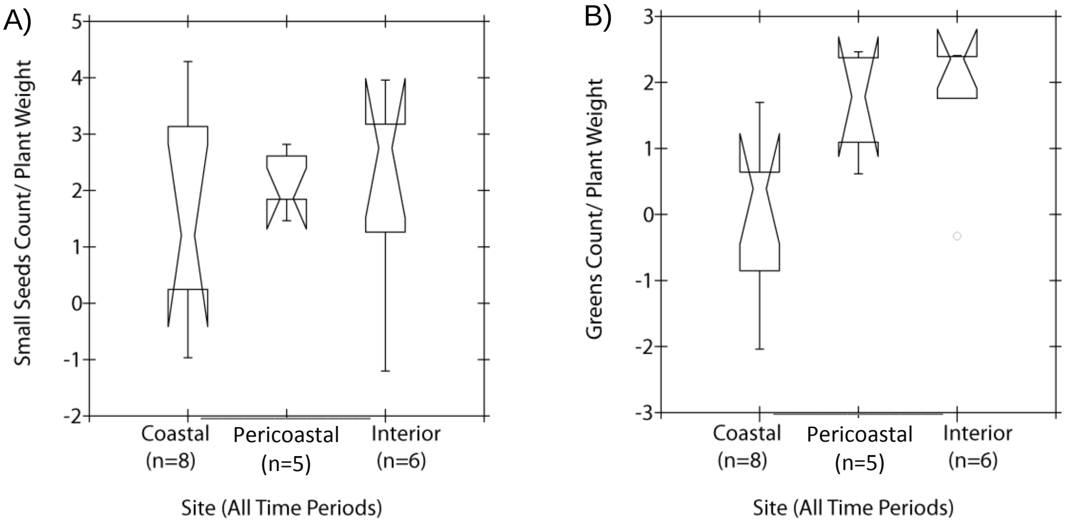


Figure 5.24. Box plots of standardized counts for each of primary plant groups from all temporal periods by site. A) seeds, B) greens, C) fruits, and D) nuts. Values on Y-axis are log transformed.

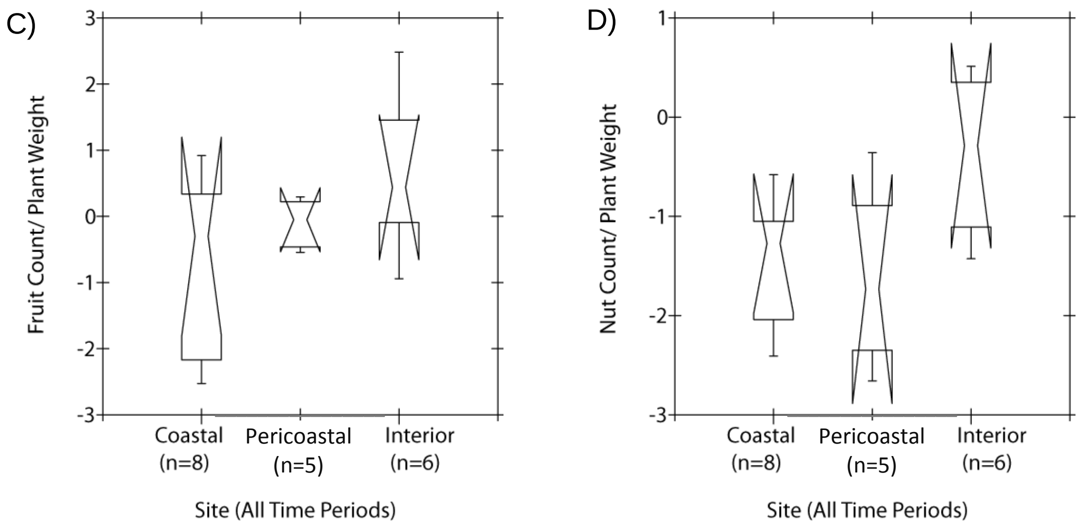


Figure 5.24 continued. Box plots of standardized counts for each of primary plant groups from all temporal periods by site. A) seeds, B) greens, C) fruits, and D) nuts. Values graphed on Y-axis are log transformed.

Broad Temporal Trends: Plant Groups. Figure 5.25 illustrates the distribution plant remains from the four of the primary plant groups identified in the study assemblages: seeds, greens, fruits, and nuts. In this section I consider variation through time, combining plant assemblages recovered from all three sites. The analysis of blue dicks is presented above (Figure 5.23 B) and included in discussion here.

Standardized counts of taxa commonly collected for seeds, greens, and fruits (Figure 5.25) are higher during the Middle Period than during the terminal Early Period; however, this increase is only significant for small seeds is statistically significant. Box plots of standardized values for nuts (Figure 5.25) and blue dicks (Figure 5.23 B) reveal no statistical differences through time. The distribution of standardized counts for seeds and fruits are slightly lower moving into the subsequent late Middle Period, which may indicate a slight decline in the contribution of these plant groups. However, the difference is not statistically significant. Indeed, Figure 5.25 and Figure 5.23 B reveal no statistically significant differences in the distributions of plant remains from seeds, greens, fruits, nuts or geophyte plant groups between the Middle Period and late Middle Period.

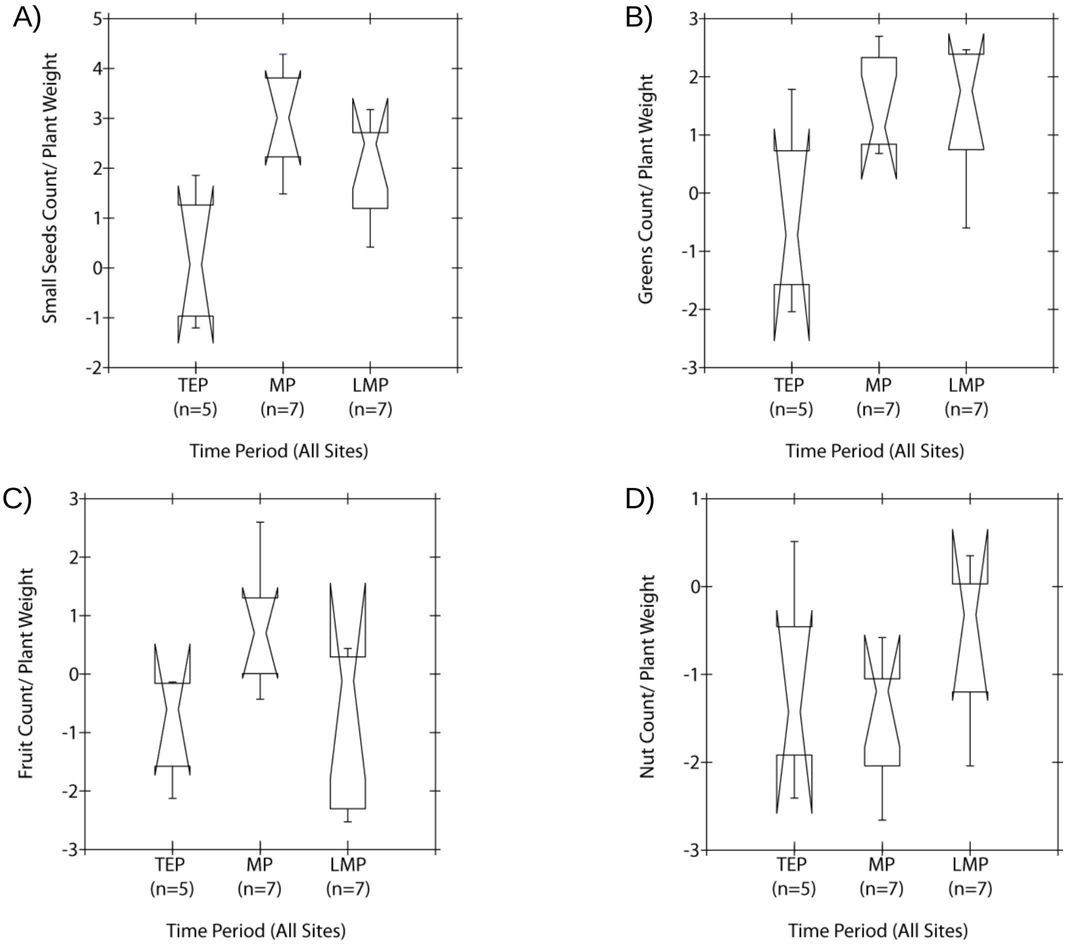


Figure 5.25. Box plots of standardized counts for each of primary plant groups from all sites by temporal period. A) seeds, B) greens, C) fruits, and D) nuts. Values graphed on Y-axis are log transformed.

Summary of Independent Taxa/Group Assessment. These data indicate a possible emphasis on the collection, processing, or consumption of all plant taxa, including the most ubiquitous plant taxa that were analyzed individually, at the Interior, and to a lesser degree, Pericoastal sites. Moreover, the preceding analyses suggest that this broad spatial pattern in the exploitation of primary plant resources is relatively consistent throughout all temporal periods. This analysis also highlights diachronic variation in the exploitation of specific plant groups and of the most ubiquitous plant taxa. There is a significant increase in the contribution of small seeds in the Middle Period diet, accompanied by an apparent increase in greens and fruits as well, which is not statistically significant. Prominent dietary mainstays, manzanita, blue dicks, and acorns remain important throughout all temporal periods with no significant variation in exploitation through time.

Reconstructing Plant Use across Space and through Time

Careful consideration of broad spatial patterns in the specific taxa selected, as well as the abundance, diversity, ubiquity, and relative importance of these taxa facilitates understanding of how the Island Chumash inhabiting Canada Christy during the Late Holocene organized their exploitation of plant food resources across the landscape. The archaeobotanical data presented and analyzed illustrate consistent variation in patterns of plant exploitation 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.

The archaeobotanical assemblages indicate that the array of plants collected, processed, and/or consumed at each location broadly correlates with taxa readily available in adjacent vegetation communities. That is to say, the Island Chumash consistently collected plant food resources within the immediate proximity of where they were living. Manzanita and acorns are the only taxa that defy this broad generalization. There is considerable consistency in the ubiquity and rank-order of manzanita and acorns at all three of the sites; however, both were collected and processed in significantly greater quantities at the Interior site. Indeed the overall abundance of plant food resources, particularly greens and blue dicks, and including most of the primary plant food taxa, is significantly higher in archaeobotanical assemblages (from all temporal periods) at the Interior and, to a lesser degree, Pericoastal site. Although this pattern is reversed briefly during the Middle Period, the data indicate that in general the Island Chumash exploited a much greater amount of plant food resources when living away from the coast. Surprisingly the greater abundance of plant food remains at the Interior site does not translate to increased diversity. There are no statistical differences in the overall diversity or evenness of plant taxa in the archaeobotanical assemblages from each site. Variation in species diversity and evenness appear driven by temporal patterns rather than site location, or proximity to distinct vegetation communities.

The archaeobotanical data presented and analyzed in this chapter pertain to three distinct temporal periods: terminal Early Period, Middle Period, and late Middle Period. Broad spatial patterns provide foundational understanding of how the Island Chumash organized their exploitation of plant food resources across the landscape; however, plant exploitation was far from consistent through time. Comparison of broad temporal patterns in the specific taxa selected, as well as the abundance, diversity, ubiquity, and relative importance of these taxa, facilitates understanding of how the Chumash people who inhabited Santa Cruz Island adjusted exploitation of plant food resources in response to environmental, social, technological, and demographic developments.

The archaeobotanical assemblages indicate substantial continuity in the exploitation of important plant food resources such as manzanita, blue dicks, and acorns, which Island Chumash exploited in similar quantities throughout all temporal periods. During the terminal Early Period, the inhabitants of Santa Cruz Island supplemented these dietary staples with a wide diversity of plant food resources, including small seeds, greens, and fruits, exploited equitably but in relatively low quantities. Greater abundance of charred plant remains at the Pericoastal and Interior sites suggests primary plant exploitation during this temporal period occurred away from the coast, perhaps as the Island Chumash moved towards the interior of the island to access a greater range of vegetation communities. Overall, these patterns indicate a pattern of generalized plant exploitation that entailed collecting plants within immediate proximity without specific focus on any particular taxon or group of taxa.

This pattern shifts abruptly during the Middle Period. Later occupants at each of the three sites exploited a much greater quantity of plant foods than their predecessors did. Although blue dick corms and acorns remain important during the Middle Period, greens, fruits, and—most dramatically—small seeds become significantly more abundant in archaeobotanical assemblages of this temporal period. Greater similarity in the abundance of plant food remains recovered from the Coastal, Pericoastal, and Interior sites suggests that land use patterns also shifted. This is supported by the appearance of several additional taxa, particularly fruits and nuts that do not occur in the nearby vegetation communities, to the Coastal site during the Middle Period. Despite the appearance of novel taxa, the significant increase in the abundance of plant food remains and increased similarity in plant exploitation across space is accompanied by a significant decrease in the diversity and equitability of plant food resources. That is to say, during the Middle Period the Island Chumash dramatically increased exploitation of fewer specific plant food resources, with an intense focus on the acquisition of small oily seeds, and began to transport other important food resources over greaer distances.

The pattern of plant exploitation becomes considerably more complicated during the late Middle Period. There are no significant differences in exploitation of seeds, greens, fruits, nuts, or geophyte plant groups between the Middle Period and late Middle Period. Plant taxa introduced during the Middle Period continue to be important, even as novel resources, such as black walnut traded from the mainland, also appear in the archaeobotanical assemblage. Although the Island Chumash continued to exploit a similar array and quantity of plant food resources during this temporal period, the manner in which they exploited these taxa once again appears to shift quite dramatically. Collection, processing, and consumption of plant food taxa once again shift away from the coast. The abundance of plant food remains plummets at the coast site, even as the abundance of plant food remains continues to increase at the Pericoastal site and remains quite high at the Interior site. The late Middle Period inhabitants of Santa Cruz Island once again diversified the variety of plant food resources exploited, relying on a wide diversity of taxa much more equitably.

CHAPTER 6

EXPLOITING THE MARINE ENVIRONMENT: ANALYSIS OF THE FAUNAL DATA

Variation in the abundance and distribution of both terrestrial and marine resources on Santa Cruz Island shaped prehistoric Chumash foraging behaviors (Kennett 2005:58). 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 groups of 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 dietary contributions of these different 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—in each site assemblage. In the previous chapter, I discussed the ways in which the Island Chumash moved across the landscape to exploit the terrestrial environment. Evidence of significant changes in exploitation of plant food resources must be considered in the broader context of subsistence and mobility, including variation in the exploitation of animal food resources through time, the relationship of site locations to faunal and terrestrial resource patches, as well as the technology required for animal exploitation and primary habitats exploited. This chapter examines these issues through a quantitative analysis of the zooarchaeological data and reconstructs broad spatial and temporal patterns of animal use from the terminal Early Period through the Middle Period.

The Zooarchaeological Remains in Ecological and Cultural Perspective

In addition to terrestrial plants and animals, the rich and diverse marine environment surrounding Santa Cruz Island provided abundant animal food resources to the prehistoric Chumash. I identified a variety of animal taxa, including terrestrial mammals, marine mammals, birds, fishes, and shellfish, in the faunal assemblages from the Coastal site, Pericoastal site, and Interior site. The suite of taxa represented in the zooarchaeological assemblages informs us about the exploitation of animal foods through time, the relationship of site locations to faunal resource patches, as well as the technology required for animal exploitation and primary habitats exploited. To examine these issues, I review the ecological and cultural context of the animal taxa identified in these study assemblages. This section reconstructs the accessibility, character, and nutritional gains of diverse animal food resources, given the available technology that shaped foraging decisions.

Ecological Context

Of the 63 unique animal taxa identified in the study assemblages, all but one, Mule deer (*Odocoileus hemionus*), are native species commonly found on Santa Cruz Island or in the surrounding waters. Indeed marine fauna derived from intertidal, nearshore, and pelagic habitats comprise the overwhelming majority of animal food resources exploited. This diversity and intensity of use was made possible by the environment. Unlike most of the California coast, which trends north-south and is exposed to prevailing winds and heavy surf, the Santa Barbara Channel is relatively sheltered, containing stretches of protected shore line that trend east-west. The Northern Channel Islands and surrounding waters contain an incredibly diverse assemblage of marine species (Murray and Littler 1981). This diversity is largely attributable to exposure to varying oceanographic conditions, high productivity resulting from upwelling of cold nutrient-rich water, and the diversity of habitat types (Blanchette et al. 2008:162). Oceanographic conditions mediate the structure of nearshore biological communities via delivery of nutrients and larvae and influences on growth, productivity, and reproduction (Blanchette et al. 2008:162). The Santa Barbara Channel is influenced by two major current systems, the southward flowing California Current, and the westward flowing, nearshore southern California Countercurrent (Hickey et al. 2003). Santa Cruz Island lies within this highly diverse oceanographic region, experiencing variable mixing between the cold, low-salinity waters of the California Current and the warm, saline waters of the southern California Countercurrent (Hickey et al. 2003). Temperature differences in air masses over land and water drive seasonal upwelling that augments local ocean productivity (Hickey et al. 2003; Schoenherr et al. 1999:72; Winant et al. 2003). Prevalent north and northwesterly winds, most persistent from April through about September, lead to offshore transport of warm coastal surface waters and replacement by cold, saline, nutrient rich waters drawn from depths to about 100m (Hickey et al. 2003). The influence of the cold California Current, coupled with seasonal upwelling, provides the foundation for high marine productivity and the rich nearshore fishery in the region (Kennett 2005:55).

On Santa Cruz Island the spatial distribution and productivity of marine life is very similar to that of the mainland, with an abundance of rocky intertidal reefs, nearshore sandy beaches, kelp forests, and pelagic waters (Schoenherr et al. 1999:72). The specific composition and productivity of these marine habitats varies greatly with the geologic composition, size, slope, and exposure of substrates (see Engle 1994). Local coastline configuration and bottom topography directly affect the distribution and composition of algae, kelp beds, benthic biota, shellfish, fish, and sea mammals available around Santa Cruz Island (Blanchette et al. 2006; Engle 1993, 1994; Murray and Littler 1981). Patches of rocky reef substrates provide favored three-dimensional habitats for a wide range of ecologically and economically important fishes and invertebrates (Graham 2004:341-342; Kinlan et al. 2005:132). Nearshore reefs in shallow water support giant kelp (*Macrocystis pyrifera*), understory macroalgae, seagrasses, and at least 750 species of fish and invertebrates (Schoenherr et al. 1999:104). Rocky intertidal habitats and associated tidepools support a diversity of macrophytes and hundreds invertebrate species (Blanchette et al. 2006:693). Discrete stretches of sandy substrates, covering 14 percent of the Santa Cruz Island coastline, provide dynamic habitats to abundant macrofauna (Dugan 1999:339). Nearshore sandy bottoms and surfzones are favored by a diversity of rays and cartilaginous fishes among others (Schoenherr et al. 1999:119-121). Sandy intertidal habitats support dozens of invertebrate macrofauna that attract vertebrate predators such as shorebirds, seabirds, marine mammals, and fishes (Dugan 1999:339). Each of these nearshore habitats occurs within proximity to the Cañada Christy watershed on Santa Cruz Island. The prehistoric Chumash easily accessed marine fauna from kelp forests, rocky intertidal reefs, sandy bottoms, as well as habitats offshore from this location (summarized in Table 6.1).

Table 6.1 Summary of preferred habitat(s) of all animal taxa identified in the study assemblages. Table is based on data from Love 2011 and Schoenherr et al. 1999.

TAXONOMIC NAME	COMMON NAME	PREFERRED HABITAT					
BIRDS		Offshore Waters		Nearshore Waters		Bay/ Harbor	
Pelecanus sp.	Pelican						
Phalacrocorax sp.	Cormorant	X		X		X	
Larax sp.	Gull	X		X		X	
Melanitta sp.	Scoter						
LAND MAMMALS			Terrestrial Mainland			Terrestrial Island	
Odocoileus hemionus	Mule Deer		X				
Urocyon littoralis	Island Fox					X	
Spilogale gracilis amphiala	Island Spotted Skunk					X	
MARINE MAMMALS			Marine Resident			Marine Migratory	
Cetacea (sml)	Small Whale/Dolphin		X			X	
Enhydra lutris	Sea Otter		X				
Pinnipedia	Seal/Sea Lion Order		X			X	
Zalophus californianus	California Sea Lion					X	
Phoca vitulina	Harbor Seal		X				
CARTILIGENOUS FISH		Pelagic	Migratory	Kelp Forest	Rocky Nearshore	Sandy Bottoms	Surfzone
Isurus oxyrinchus	Shortfin Mako	Primary	Primary				
Prionace glauca	Blue Shark	Primary	Primary				
Myliobatis californica	California Bat Ray		Primary	Seasonal	Seasonal	Seasonal	
Galeorhinus galeus	Soupfin Shark			Secondary	Secondary	Primary	
Triakis semifasciata	Leopard Shark			Secondary	Secondary	Primary	
Rhinobatis californica	Shovelnose Guitarfish				Secondary	Primary	Secondary
Platyrhinoidis triseriata	California Thornback					Primary	Secondary
Urobatis halleri	Round Stingray					Primary	Secondary
Squalus suckleyi	Spiny Dogfish					Primary	
Squatina californica	Pacific Angel Shark					Primary	
BONY FISH		Pelagic	Migratory	Kelp Forest	Rocky Nearshore	Sandy Nearshore	Surfzone
Xiphias gladius	Swordfish	Primary					
Seiola lalansi	Yellowtail	Primary	Primary				
Clupea pallasii	Pacific Herring		Primary	Seasonal	Seasonal	Seasonal	Seasonal
Sardinops sagax	Pacific Sardine		Primary	Seasonal	Seasonal	Seasonal	Seasonal
Scomber japonicus	Pacific Mackerel		Primary	Seasonal	Seasonal		
Trachurus symmetricus	Jack Mackerel		Primary	Seasonal	Seasonal		
Merluccius productus	Pacific Hake		Primary			Secondary	
Sphyraena argentea	Pacific Barracuda		Primary			Seasonal	Seasonal
Medialuna californiensis	Halfmoon			Primary			
Haliochoeres semicinctus	Rock Wrasse			Primary			
Paralabrax clathratus cf.	Kelp Bass			Primary			
Hexagrammos decagrammus	Kelp Greenling			Primary			
Oxyjulis californica	Senorita			Primary	Primary		
Girella nigricans	Opaleye			Primary	Primary		
Rhacochilus vacca	Pile Perch			Primary	Primary		
Heterostichus rostatus	Giant Kelpfish			Primary	Secondary		
Ophioden elongates	Lingcod			Secondary	Primary		
Scorpaenichthys marmoratus	Cabezon			Secondary	Primary		
Semicossyphus pulcher	California Sheephead			Secondary	Primary		
Sebastes spp.	Rockfish			Secondary	Primary	Secondary	
Porichthys ssp.	Midshipman				Primary		
Cheilotrema saturnum	Black Croaker				Primary		
Cottidae (sml)	Sculpin				Primary		
Gymnothorax mordax	California Moray				Primary		
Genyonemus lineatus	White Croaker					Primary	
Roncador stearnsii	Spotfin Croaker					Primary	Primary
Embiotocidae	Surf Perch			Secondary	Secondary	Secondary	Primary
SHELLFISH		Rocky Intertidal	Rocky Subtidal	Sandy Intertidal	Sandy Subtidal	Estuarine	
Balanus spp.	Sessile Barnacle	X					
Mytilus californianus	California Mussel	X					
Pollicipes polymerus	Leaf Barnacle	X					
Septifer bifurcatus	Platform Mussel	X					
Tegula spp.	Turban Snail	X					
Acmaeidae	Limpet	X	X				
Decapoda	Crab	X	X				
Haliotis cracherodii	Black Abalone	X	X				
Polinices spp.	Moon Snail	X	X				
Polyplacophora	Chiton	X	X				
Strongylocentrotus spp.	Sea Urchin	X	X				
Haliotis rufescens	Red Abalone		X				
Megastraea undosa	Wavy Top		X				
Tivela stultorum	Pismo Clam			X	X		
Chione spp.	Venus Clam					X	

Terrestrial Mammals. A relatively small number of specimens from terrestrial mammals occur in the faunal assemblages considered in this study. This is not surprising as the largest land mammal available on Santa Cruz Island, currently and prehistorically, is a diminutive species of fox (*Urocyon littoralis*). Researchers posit that the Chumash introduced the Island fox and the Island spotted skunk (*Spilogale gracilis amphialus*) onto the Northern Channel Islands during the Holocene (Collins 1991a; Floyd et al. 2011; Rick et al. 2009b; Rick et al. 2011; Vellanoweth 1998). Island foxes played an important role in the spiritual lives of native Island Chumash (Collins 1991b; Rick et al. 2009b:94), evidenced by deliberate burials and internment with humans. Ethnohistoric accounts and archaeological evidence suggests that skunks and foxes provided a very occasional source of meat (Collins 1991b: 213-215), and most importantly, fur and skins (Collins 1991b:215-16; Hudson and Blackburn 1986:43-44; Landberg 1965; Rick et al. 2009b:94). These small mammals may have been caught using snares or small traps (Landberg 1965). The occurrence of Mule deer (*Odocoileus hemionus*) metapodial fragments in the study assemblages provides a clear indication of interaction across the Santa Barbara Channel. Mule deer are not native to Santa Cruz Island; they do, however, occur throughout Santa Barbara County on the mainland. Ethnohistoric accounts indicate that deer not only formed an important part of the mainland Chumash diet, but they also contributed hides, bones, and antler that could be manufactured into useful personal and household items (Landberg 1965). Previous archaeological research suggests that the presence of deer long bones in midden assemblages on Santa Cruz Island largely represents tool manufacture rather than subsistence related activities (Colten 1995:96). Overall, it appears unlikely that the limited occurrence of specimens from terrestrial mammals pertains to subsistence activities.

Marine Mammals. A minimum of three marine mammal species are represented in the zooarchaeological assemblages considered in this study: sea otters (*Enhydra lutris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*). The cold productive waters of the California Current and topographically varied coastline of the Northern Channel Islands support large numbers of these marine mammals. The importance of marine mammal hunting and the relative contribution of these animals to Chumash subsistence is hotly debated (Braje and Rick 2011; Colten 2002; Colten and Arnold 1998; Hildebrandt and Jones 1992; Jones et al. 2004a, 2004b; Jones and Hildebrandt 1995; Porcasi et al. 2000, 2004). Based simply on body size, in combination with secondary benefits, the profitability of marine mammals appears exceedingly high; however, return rates are inconsistant, contingent on highly variable pursuit time and handling costs associated with capturing, killing, and butchering each of these species (Kennett 2005:26).

Of the marine mammals represented in the study assemblages, sea otters are the smallest and most elusive. Permanent residents of the subtidal kelp beds that fringe Santa Cruz Island, sea otters stay near shore throughout the year (Schoenherr et al. 1999:122). Ethnohistoric accounts indicate that the Chumash valued robes and blankets made from the pelts of these small sea mammals (Greenwood 1978:523; Hudson and Blackburn 1985:43-45, 52-54; King 1990:52). Although sea otters provide very little fat and represent much lower potential food value, relative to other marine mammals, archaeologists generally assume that the Chumash consumed the meat of sea otters after removing their valuable fur (Jones et al. 2011:245). Since these elusive, aquatic breeders rarely venture onto land (Kenyon 1969) it is not known exactly how the Chumash hunted them. One Chumash informant indicated that the Chumash hunted otters much like other California hunter-gatherer groups did, by catching baby otters and using them as bait to attract adults (Landberg 1965:59-60). Ethnographic reports indicate that Native Californians captured sea otters using nets, snares, and clubs (Jones et al. 2011:245). Recent archaeological data from the late prehistoric site CA-LAN-2616 confirms the use of stone-tipped projectiles and/or harpoons to hunt otters just south of the Chumash region (Langenwalter II et al. 2001). These data support ethnographic accounts that the Island Chumash hunted sea otters using stone-tipped spears, harpoons, and arrows (Hudson and Blackburn 1982:190). Regardless of the specific hunting methods chosen, sea otters must have been acquired with the aid of watercraft (see Hudson and Blackburn 1982:190), and were thus more difficult and costly to pursue than marine mammals that haul out on beaches (Colten 2002:13).

Harbor seals (*Phoca vitulina*) inhabit the Santa Barbara Channel region throughout the year, feeding in nearshore kelp forests and hauling out on rocks, reefs, beaches, and coves (Delong and Melin 2000:402; Schoenherr et al. 1999:124). Thick subcutaneous blubber insulates harbor seals from the cold water and offers human hunters a rich source of fat and calories (Erlandson 2001:298). Ethnohistoric accounts indicate that Chumash hunters attacked seals basking along the shore, chasing them inland where other hunters dispatched them with clubs or spears (Bleitz 1993; Glassow and Wilcoxon 1988; Hudson and Blackburn 1982; Landberg 1965). However, harbor seals typically occur in smaller numbers and spend less time on land with their young than do other sea mammals. Readily alarmed and equipped with keen vision, harbor seals quickly abandon haulouts at the least sign of disturbance (Peterson and Bartholomew 1967:16; Schoenherr et al. 1999:124). Success of simple shore-based hunting methods would likely increase during late May and June when molting harbor seals aggregate at preferred rookeries on nearby islands (Bartholomew and Boolootian

1960:370; Bartholomew 1965:239; Yochem et al. 1987:324). Although it is considerably more costly and difficult to pursue and capture harbor seals in the ocean, this would have been possible with the aid of watercraft and harpoons (Colten 2002:13).

Migratory California sea lions (*Zalophus californianus*) begin to aggregate in dense rookeries on the Northern Channel Islands in May (Schoenherr et al. 1999:130). These large sea mammals breed, give birth, and nurse their pups on land until mid-August (Schoenherr et al. 1999:130). During breeding season, sea lions appear reluctant to leave the rookery or retreat to the sea when threatened, rather, males and females often respond aggressively in defense of their young (Peterson and Bartholomew 1967:17). Nonetheless, due to sea lions' poor aerial vision, human hunters easily sneak up on terrestrial breeding colonies. Ethnographic documents indicate that Chumash hunters relied on simple shore-based hunting tactics—as described above for harbor seals—snares, clubs, and spears to exploit this animal food resource (Hudson and Blackburn 1982; Landberg 1965). Although California sea lions are not as well insulated as sea otters or harbor seals, having neither thick fur nor a particularly thick layer of blubber to offer (Schoenherr et al. 1999:130), their large body size provides a valuable source of meat and animal protein (Kennett 2005:26). Archaeological and ethnographic research indicates that California sea lions contributed to the Chumash diet, particularly on the Channel Islands (Glassow and Wilcoxon 1988; Landberg 1965).

Birds. A minimum of four avian species is represented in the zooarchaeological assemblages considered in this study: pelican (*Pelecanus* spp.*)*, cormorant *(Phalacrocorax* spp.*)*, gull *(Larax* spp.*)*, and scoter *(Melanitta* spp.*)*. In many hunter-gatherer societies, birds are no more than a supplementary or rare food resource, if important at all (Serjeantson 2009:257). However, large sea birds and waterfowl may be of greater relative importance on islands and along coastlines (Serjeantson 2009:257). The incredible biomass of macrozooplankton, small schooling fish, and large kelp forest fish in the cold productive waters surrounding the Northern Channel Islands supports an abundance of sea birds and waterfowl (Sydeman et al. 2001:312). Ethnographic and ethnohistoric records indicate that in addition to food, the Chumash captured avifauna for tool manufacture, clothing, and ceremonial purposes (Hudson and Blackburn 1986; Landberg 1965).

A single bone specimen indicates exploitation of *Melanitta* sp., most likely the surf scoter. This large, stocky, diving sea duck winters on the Northern Channel Islands, first appearing in November and leaving by March (Briggs et al. 1987). During this time, thousands of migrating scoters feed in shallow, sandy nearshore areas of the open coast, bays, and estuaries around Santa Cruz Island (Briggs et al. 1987). The three most common avian taxa represented in the study assemblages, pelicans (*Pelecanus* sp.*),* cormorants *(Phalacrocorax* sp.*),* and gulls *(Larax* sp.*),* inhabit Santa Cruz Island throughout the year, nesting in colonies along the rocky shoreline (Hunt 1978). Although marine, fish-eating birds are not known for their palatability (Guthrie 1980:696), these large sea birds provided a potential source of meat and fat for the Island Chumash. Juvenile pelicans are notoriously fatty, maintaining a layer of fat underneath the skin even as adults (Serjeantson 2009:233). Ethnographic and archaeological records suggest that prehistoric inhabitants of the Northern Channel Islands consumed cormorants, at least occasionally (Guthrie 1980:696; Guthrie 1993:165). Eggs of these species also provided a valuable seasonal source of fat and protein, but tend to be archaeologically invisible. Perhaps most importantly, these densely feathered sea birds provided skins and feathers used for blankets and coverings. Ethnographic and ethnohistoric accounts discuss dresses, capes, and other garments made from cormorant, gull, or pelican skin (Hudson and Blackburn 1982:38-39, 43-47). Unfortunately, bird bones provide almost no information about hunting techniques (Guthrie 1993:165). Ethnographic accounts indicate that the Chumash hunted birds by bow and arrow or with tule-constructed traps (Hudson and Blackburn 1982:63, 110; Landberg 1965). Large diving sea birds, like cormorants and pelicans, may have also been taken at their roosting sites or with baited fishhooks (Guthrie 1993:163).

Fishes. Fish can be an incredibly productive and predictable resource, easily taken with simple technologies (Erlandson 2001: 295-296; Rick et al. 2001). From a nutritional standpoint, fish flesh is highly digestible, metabolized more efficiently by the human body than the meat of land mammals (Erlandson 2001: 295-296). Although specific nutritional value—particularly fat and calorie content—of fish species varies considerably (see Table 6.2), fish tend to be low in carbohydrates but high in protein, vitamins, and minerals (Erlandson 2001: 295-296; Silva and Chamul 2000:34; Sidwell et al. 1974:26, 30). Fish eggs seasonally harvested in large quantities also offer a significant source of protein and calories. Along coastal California, fishers took dozens of different fish species from a variety of habitats, using a wide array of gear (Pletka 2011:150). Dip nets or small tidal weirs facilitated the mass harvest of small schooling fish in truly impressive yields (Erlandson 2001: 295-296). In some cases—especially those requiring large nets, sophisticated boats, or elaborate weir structures—mass harvest required considerable investment in materials, labor, and maintenance, as well as coordination of activities (Bertrando and McKenzie 2011:184; Erlandson 2001: 296). Nonetheless, even when more sophisticated technologies are required to capture fish, these need not be especially elaborate or expensive to produce (Erlandson 2001:296). Hook/gorge and line or spear fishing cannot effectively capture smaller species

(Pletka 2011:151); however, these are effective means of capture for large-bodied and more solitary fishes (Bertrando and McKenzie 2011:184). Thus, the cost and return rates for fishing is dependent on the overall productivity and character of the targeted fish species and the technology available at the time of harvest or capture (Kennett 2005:23).

Nearshore reefs in shallow water support giant kelp (*Macrocystis pyrifera*), understory macroalgae, seagrasses, and at least 150 different fish species (Schoenherr et al. 1999:107). Most of the species that inhabit rocky nearshore reefs and subtidal kelp beds are year-round residents, available throughout most of the year, with prehistoric exploitation impeded, perhaps, only by the worst winter storms (Kennett 2005:58). A diverse array of rockfishes (*Sebastes* spp.), kelp greenlings (*Hexagrammus* spp.), cabezon (*Scorpaenichthys marmoratus*), California sheephead (*Semicossyphus pulchrum*), lingcod (*Ophiodon elongatus*), midshipman (*Porichtys* spp.), black croaker (*Cheilotrema saturnum*), and sculpins (*Cottidae*) inhabit rocky nearshore habitats. Voracious predators of intertidal invertebrates, cabezon and California sheephead move from subtidal kelp beds into the rocky intertidal zone, migrating in and out with the tides (Schoenherr et al. 1999:110, 113). Ethnohistoric accounts indicate that the Chumash often used a long pole with a hook fastened on one end to capture cabezon and other fishes hiding in crevices and holes in tide pools or shallow rocky reefs (Hudson and Blackburn 1982:185-186). Among these shallow rocky reef fishes, rockfish, cabezon, lingcod, and black croaker are large-mouth, aggressive predators effectively captured using hook/gorge and line thrown from the shoreline (Bertrando and McKenzie 2011:170).

Common large-bodied kelp forest fish, such as the opaleye (*Girella nigracans*), halfmoon (*Medialuna californiensis*), kelp bass (*Paralabrax clathratus*), and giant kelp fish

(*Heterostichus rostratus*) primarily feed on kelp, but will take bait (Schoenherr et al. 1999:111-115). Gregarious pile perch (*Rhacochilus vacca*) and smaller solitary wrasses, such as senorita (*Oxyjulis californica*) and rock wrasse (*Halichores semicinctus*) prefer to feed on small invertebrates and zooplankton, but will also take the proper bait from small hooks (Love 2011:428-429, 436-438). Thus, hook/gorge and line technology used in the subtidal kelp forest, perhaps from watercraft, is an effective means of capturing these species throughout the year.

Nearshore sandy bottoms and surfzones provide favorable habitat for a diversity of rays and cartilaginous fishes among others (Schoenherr et al. 1999:119-121). During the spring and summer Pacific angel sharks (*Squatina californiaca*), hound sharks (Trikiadidae), shovelnose guitarfish (*Rhinobatos productus*), California thornbacks (*Platyrhinoidis triseriata*), round stingrays (*Urobatis halleri*), and the California bat ray (*Myliobatis californica*) aggregate in shallow protected bays, embayments, and estuaries, venturing into the intertidal and surf zone to feed (Love 2011; Schoenherr et al. 1999:119-121). Modern shore anglers and pier fisherman manage to catch a fair number of these cartilaginous fish using hook and line technology (Love 2011:22, 27, 49, 67, 68, 79). However, experimental archaeological studies suggest that the mouth structure of sharks limits the effectiveness of hook and line fishing and thus, sharks are most effectively captured using simple spear technology (Bertrando and McKenzie 2011:172) described in ethnographic accounts (Hudson and Blackburn 1982:193-194). Spear fishing is most effective when large targets are available in close proximity to the fisher or in an enclosed setting (Bertrando and McKenzie 2011:174).

Schools of surfperch (Embiotocidae) and white croakers (*Genyonemus lineatus*), as well as less gregarious starry flounders (*Platichthys sellatus*), and other flatfish (Plueronectidae) inhabit open sandy beaches throughout the year (Love 2011). Hook/gorge and line technology is an effective means of capture for surfperch, white croakers, flounders, and other flatfish; however nets, seines, and weirs are extremely productive when employed to capture small- to medium-sized schooling fish such as surfperch (Bertrando and McKenzie 2011:173). Ethnohistoric and archaeological data indicate prehistoric use of a wide variety of fishing nets sometimes deployed from shore, but more frequently from watercraft, to capture great quantities of schooling fish (Hudson and Blackburn 1982:153-164).

Impressive schools of inshore/offshore migratory fish species, such as Pacific herring and Pacific sardine (Clupeidae), Pacific mackerel (*Scomber japonicus*), Pacific hake (*Merluccius productus*), and Pacific barracuda (*Sphyraena argentea*) appear in the Santa Barbara Channel region seasonally. This pulse was of great importance to prehistoric Chumash (Landberg 1965). Pacific herrings and Pacific sardines are highly migratory, moving inshore to kelp forests, rocky intertidal, and nearshore sandy bottoms to spawn. Pacific herrings offer a rich source of protein and fat (Silva and Chamul 2000:34, see also Table 6.2). One of the primary sardine spawning grounds in California occurs just west of the Northern Channel Islands (Landberg 1965:71). Spawning occurs nearshore from February to August (Love 2011:106). During this season sardines form massive schools, often containing Pacific mackerel, in and around kelp beds and bays (Love 2011:105). The flesh of Pacific mackerel is also high in both protein and fat, relative to other fish species available in the Santa Barbara Channel (Silva and Chamul 2000:34, see also Table 6.2). Off the coast of California the peak spawning season for Pacific mackerel occurs from April to August (Love

2011:521). Ethnographic accounts indicate that the Chumash used seines and nets to harvest great quantities of these small fatty fish (Hudson and Blackburn 1982:153), which would be dried or smoked and stored for later consumption (Hudson and Blackburn 1983:170, 215). Traveling in immense schools, Pacific hakes migrate into the Santa Barbara Channel to feed in rich upwelling areas from April through September (Best 1963:51). During this season they are available throughout the nearshore environment, wherever upwelling is close to the coast, attracting many larger species to the region. Schools of California barracuda move northward into the Santa Barbara Channel region in the spring and summer, spawning in nearshore waters from April to October before returning south in the fall (Love 2011:509). Ethnographic accounts indicate that the Island Chumash captured barracuda by spear or harpoon thrown from watercraft (Hudson and Blackburn 1982:194, 206-211).

The presence of swordfish (*Xiphias gladius*), Shortfin mako (*Isurus oxyrinchus*), and Blue shark (*Prionaca glauca*) in the zooarchaeological assemblages considered in this study hints that the Island Chumash may have also exploited dedicated pelagic fishes, but the evidence is far from conclusive. Shortfin mako and Blue shark are each represented by a single tooth, possibly collected from a carcasses washed up onto shore. The lack of other skeletal elements limits further interpretation. Swordfish plays a prominent role in Chumash oral narratives (Blackburn 1975) and ritual life. However, they also offered a rich source of protein and more fat than most nearshore fish species (Sidwell et al. 1974:31, see also Table 6.2). Swordfish generally keep offshore (Love 2011:538); thus capturing this large bodied, solitary pelagic fish would have required stable, ocean-going watercraft. Ethnographic accounts indicate that the Chumash captured swordfish by harpoon, similarly to Pacific Barracuda (Davenport et al. 1993:265-266; Hudson and Blackburn 1982: 206-211).

Archaeologists often regard occurrence of this taxon in archaeological assemblages as a clear indication of pelagic fishing (Bernard 2001:26).

Table 6.2 Nutritional content of fish and shellfish taxa. Values provided indicate grams of protein, fat, and carbohydrates per 100 grams of edible flesh of specified taxon.

	Protein	Fat	Carbohydrates	Reference
FISH (Common Name)				
Rockfish	18.80	1.20		Silva and Chamul 2000:34
Lingcod	17.66	1.06		Sidwell et al. 1974:26
Black Croaker	19.00	1.90		Sidwell et al. 1974:30
Sharks and rays	20.0 - 22.0	0.2 - 0.5		Sidwell et al. 1974:31
Guitarfish	16.40	6.40		Erlandson 1988:104
Flatfish	18.84	1.19		Silva and Chamul 2000:34
Pacific herring	16.39	13.88		Silva and Chamul 2000:34
Pacific mackerel	20.07	7.89		Silva and Chamul 2000:34
Pacific hake	16.30	1.20		Sidwell et al. 1974:26
California barracuda	22.20	1.00		Silva and Chamul 2000:34
Swordfish	19.50	4.10		Sidwell et al. 1974:31
SHELLFISH (Common Name)				
Crabs	15.80	3.10		Sidwell 1981:26
Abalone	18.70	2.20	3.3	Erlandson 1988:104
Wavy top	19.00	2.00	4	Perry and Hoppa 2011:72
Pismo clam	11.20	1.40	4	Erlandson 1988:104
California mussel	14.40	2.20	3.3	Erlandson 1988:104
Oyster	9.60	2.50	5.4	Erlandson 1988:104

Collecting Shellfish. The general category of shellfish includes a variety of marine invertebrates, dominated by molluscs (bivalves and univalves), but also including crabs, sea urchins, barnacles, and other relatively common organisms (Erlandson 2001:293; Kennett 2005:21). A minimum of 18 shellfish taxa were identified in the study assemblages; 13 of which, discussed below, likely represent subsistence taxa. The remaining five taxa, including small gastropods and barnacles, are more likely incidental inclusions arriving at the site attached to the shells of target food resources. Despite their relatively small size, shellfish resources tend to be highly productive, predictable, and accessible (Erlandson 2001:293). Densely packed, sessile aggregations of shellfish occur close to shore or easily accessible in the intertidal zone (Erlandson 2001:293; Kennett 2005:21). Moreover, shellfish provide nutritious sources of complete animal proteins, albeit low in fat, carbohydrates, and calories (Sidwell 1981; Erlandson 1988; Perry and Hoppa 2011; see also Table 6.2) and are available throughout most of the year. Return rates calculated for most shellfish are comparable to medium-sized game or small game/plants (Kennett 2005:21; Jones and Richman 1995; Meehan 1977; Bird and Bliege Bird 2000). Although ethnohistoric records poorly document Chumash shellfish collection techniques (Landberg 1965:75), ethnoarchaeological studies of other coastal foragers indicate that virtually all members of society participate in shellfish collection (men, women, children, and the elderly) without the use of sophisticated technology (Bird and Bliege Bird 2000). Indeed ethhnohistoric documents indicate that Chumash shellfish harvesting tools included just a simple short whale bone or hardwood stick with a beveled end to dislodge shellfish from the rocks (Hudson and Blackburn 1982:253). Overall, exploitation of shellfish beds in the highly productive littoral environment that surrounds Santa Cruz Island would have been an energy efficient way to access dietary protein (Kennett 2005:21), limited only by inclement weather, seasonal tidal patterns, and red tide events (Erlandson 2001:293; Kennett 2005:21).

Rocky shores at the interface of the land and the ocean support an incredible diversity of shellfish species in both intertidal and subtidal habitats. The succession of rocky intertidal habitats (upper, middle, lower) and associated tide pools offer easy access to a broad range of economically valuable taxa (Kennett et al. 2009:303). Various crabs (Decapoda), limpets (Acmaeidae), chitons (Polyplacophora), acorn barnacles (*Balanus* sp.), and turban snails (*Tegula* spp.), as well as many other marine snails (Gastropoda) graze on algae in the upper intertidal zone, covered during most high tides but left exposed during low tides (Schoenherr et al. 1999:85). Filter-feeders such as California mussels (*Mytilus californianus*), platform mussels (*Septifer bifurcatus*), and leaf barnacles (*Pollicipes polymerus*) do not occur above the middle intertidal zone, and as a consequence they are covered by every high tide and uncovered by many but not all low tides (Schoenherr et al. 1999:87). Of these taxa, California mussels are among the most common and abundant shellfish taxa represented study assemblages. These bivalves grow rapidly in dense aggregations of up to 1000 individuals per square meter, and can be harvested en masse (via plucking or stripping) during low tide (see Jones and Richman 1995:46).

Filter feeders are considerably less common in the lower intertidal zone; however, moon snails (*Polinices* spp.), sea urchins (*Strongylocentrotus* spp.), black abalone (*Haliotis cracherodii*), and red abalone (*Haliotis rufescens*) thrive on kelp and are well adapted to living underwater in this portion of the intertidal zone, which is only exposed by the lowest spring tides (Schoenherr et al. 1999:92). At modern sea surface temperatures, sea urchins, and red abalones occur in even greater quantities below the influence of tides, in the subtidal zone, accompanied by wavy tops (*Megastraea undosa*) and a variety of large marine snails (Schoenherr et al. 1999:106). Red abalone and wavy top are among the largest shellfish available on Santa Cruz Island (Perry and Hoppa 2011:65). Researchers suggest that procurement of these profitable subtidal species required at least shallow diving throughout most of prehistory (Erlandson et al. 2008:2145; Perry and Hoppa 2011:71; Sharp 2000). However, recent research provides evidence of increased red abalone exploitation during a brief interval of relatively low sea surface temperatures, which may have encouraged this species to migrate into the low intertidal zone (Glassow et al. 2012).

The sandy intertidal zone is one of the least populated invertebrate habitats, with many fewer species and lower diversity than rocky intertidal and subtidal habitats (Schoenherr et al. 1999:79). Of the shellfish taxa identified in the study assemblages, only Pismo clam (Tivela *stultorum*) was collected from sandy intertidal habitat. When available these large clams can easily be harvested en masse during low tide, with simple technology (see Thakar 2011). Ethnohistoric accounts indicate that the Chumash used no special technology for clam collection. They would simply "get Pismo clams with their feet during low tide" (Hudson and Blackburn 1982:253). Although there are no longer any true estuarine habitats on Santa Cruz Island (Schoenherr et al. 1999:79), there may have been in the past. The presence of two estuarine invertebrate taxa (*Chione undatella* and *Ostrea lurida*) in the studied assemblage sugests that the prehistoric Chumash on Santa Cruz Island had access to this highly productive littoral habitat, directly or through trade. Ethnohistoric records indicate that the Chumash used ironwood sticks to dig for clams that they could not reach with their fingers (Hudson and Blackburn 1982:254).

Quantitative Analysis of the Vertebrate Assemblages

I explore subsistence patterns as related to animal food resources at each site and through time using the quantitative methods described in Chapter 3. This analysis builds on trends noted in the basic results, presented in Appendix C along with all of the relevant data. Although I initially consider all identified taxa in analysis of faunal abundance, I focus on likely food taxa in the subsequent diversity, ubiquity, and taxon specific analyses. I present each analysis and results by site—Coastal (CST), Pericoastal (PER), and Interior (INT)—and by temporal period—terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP). Analysis of all assemblages within a single site reveals broad diachronic patterns in dietary contribution and land use. Analysis of all assemblages from a specific temporal period reveals broad spatial and seasonal patterns in dietary contribution and land use. Consideration of changes in land and resource through time and across space facilitate identification of site function, foraging distance, and prey selection.

Abundance (Density) of Vertebrate Remains

In order to evaluate patterns in faunal abundance across space and through time, as well as correct for comparison between large and small samples, I standardized bone NISP and bone weight recovered from each sample by the original soil volume of the sample. I rely on box plots to explore broad patterns in the bone NISP density and bone weight density condensed by site and temporal period. Sample sizes (the number of samples from each site or pertaining to each period) are noted at the bottom of each sample grouping. The median density values between sites or temporal periods are significantly different from each other at the 0.05 level if the notches in the box plots do not overlap (see Chapter 3 for further discussion of this method). However, I supplement interpretation of the broad trends with reference to bar charts that represent individual samples within each site and spatial variation within each temporal period. Qualitative assessment based on the bar charts contributes a more nuanced perspective of broad temporal or spatial trends.

Broad Temporal Trends in Vertebrate Abundance. In Figure 6.1 the box plots reveal significant temporal variation in the overall abundance of vertebrate remains relative to soil volume when calculated by NISP but not by weight. The faunal assemblages from all terminal Early Period contexts contain a significantly lower density of vertebrate remains than do assemblages from Middle Period contexts. Bone density decreases significantly in all late Middle Period samples. Although there is no statistical difference in the density of vertebrate remains in samples from terminal Early Period and late Middle Period contexts, qualitative assessment of the intrasite sequences (Figures 6.2-6.4) suggests that the lowest bone densities at each site were recovered from late Middle Period assemblages. This broad trend toward increased abundance of vertebrate remains during the Middle Period and decreased abundance during the late Middle Period is evident at all three sites and suggests that vertebrate animal food resources were acquired, processed, and consumed in much greater quantities during the Middle Period than during the preceding or following periods of site occupation. This pattern also suggests that site occupation may have been relatively more intensive during the Middle Period.

Figure 6.1 Box plots of standardized bone density by temporal period. Bone NISP density is represented on the left and bone weight (WT) density is represented on the right). Values on Y-axis are log transformed. Temporal periods represented include terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP).

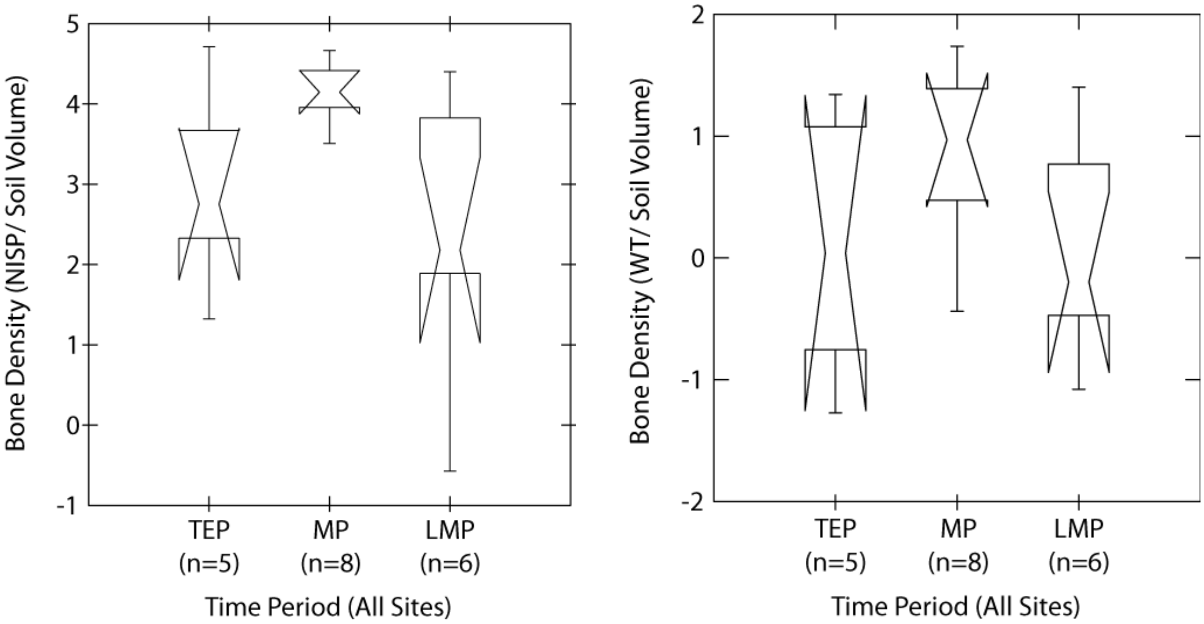


Figure 6.2 Bar chart of bone weight (WT) density (grams/liter) recovered from floated samples at the Coastal site. Temporal periods represented include terminal Early Period (TEP) n=2, Middle Period (MP) n=4, and late Middle Period (LMP) n=2.

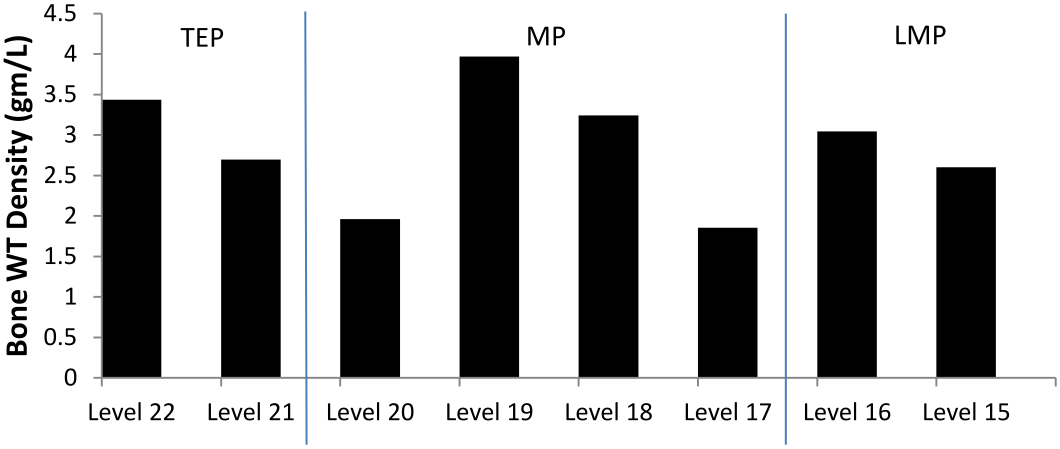


Figure 6.3 Bar chart of bone weight (WT) density (grams/liter) recovered from floated samples at the Pericoastal site. Temporal periods represented include terminal Early Period (TEP) n=1, Middle Period (MP) n=1, and late Middle Period (LMP) n=3.

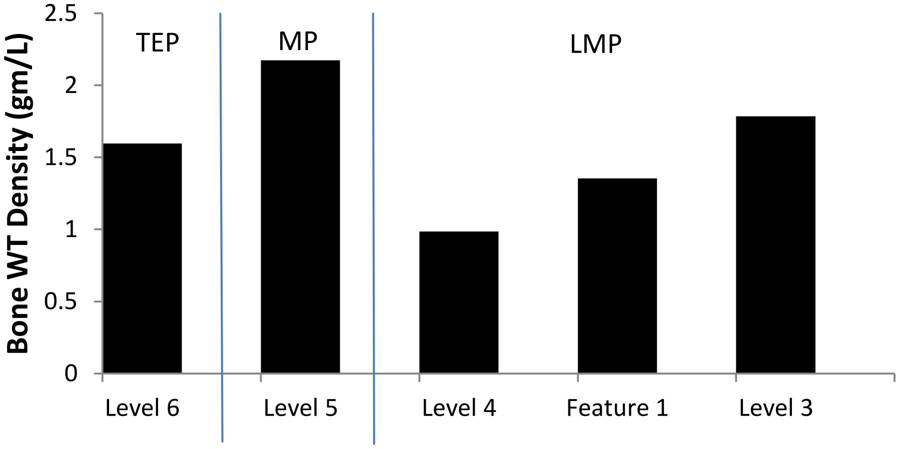
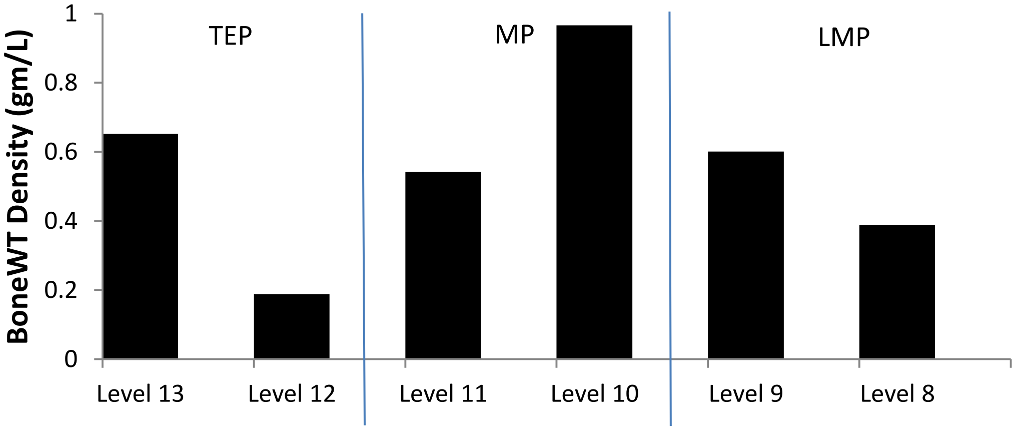


Figure 6.4 Bar chart of bone weight (WT) density (grams/liter) recovered from floated samples at the Interior site. Temporal periods represented include terminal Early Period (TEP) n=2, Middle Period (MP) n=2, and late Middle Period (LMP) n=2.



Broad Spatial Trends in Vertebrate Abundance. All faunal assemblages recovered from the Coastal site contain a significantly higher density of vertebrate remains (by both NISP and weight) than assemblages from the Pericoastal and Interior sites (Figure 6.5). Although there is no statistical difference in the NISP-based density of vertebrate remains from the Pericoastal and Interior sites, when we consider the bone weight density, it is clear that the abundance of vertebrate remains recovered at the Interior site is significantly lower than at the Pericoastal site. Statistically significant decreases in the density of vertebrate faunal remains with relative distance from the coast confirms qualitative assessment based on the bar charts in Figures 6.6-6.8 that vertebrate animal food resources were consistently acquired, processed, and consumed in much greater quantities at the Coastal site than at either the Pericoastal or Interior sites throughout all temporal periods. This broad trend reflects systematic and persistent spatial variation in the exploitation of vertebrate animal food resources and suggests that site function, specifically for the Coastal site may have been defined by the specific vertebrate animal food resources accessed from this location.

Figure 6.5 Box plots of standardized bone density by site. Bone NISP Density is represented on the left and Bone WT (weight) Density is represented on the right). Values on Y-axis are log transformed.

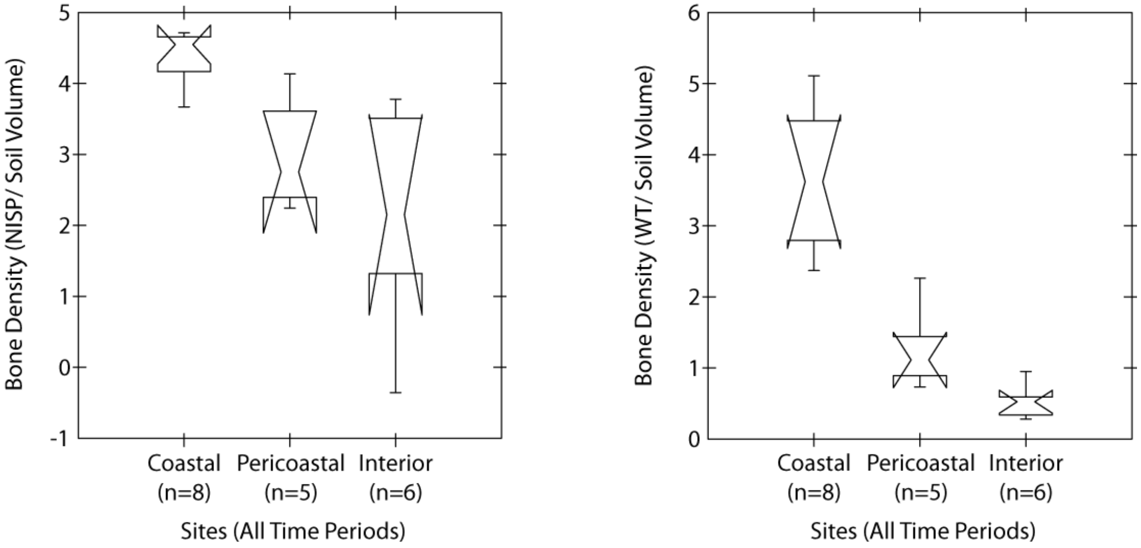


Figure 6.6 Bar chart of bone weight (WT) density (grams/liter) recovered in floated samples from terminal Early Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.

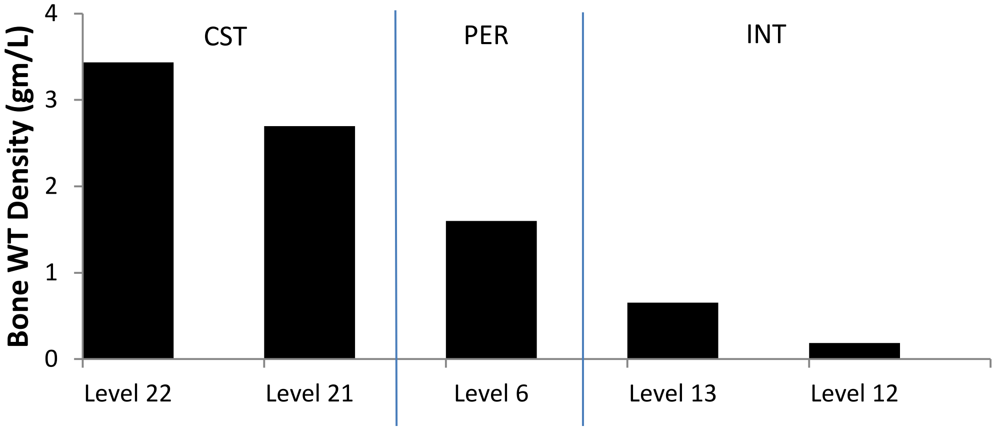


Figure 6.7 Bar chart of bone weight (WT) density (grams/liter) recovered in floated samples from Middle Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.

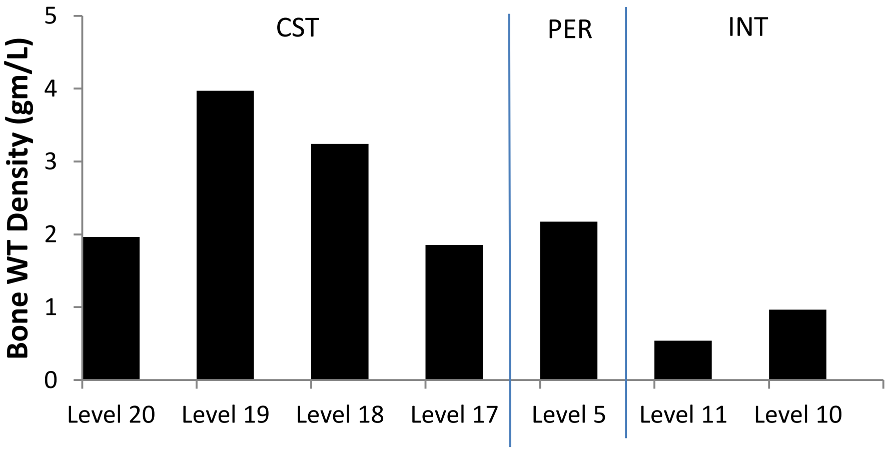
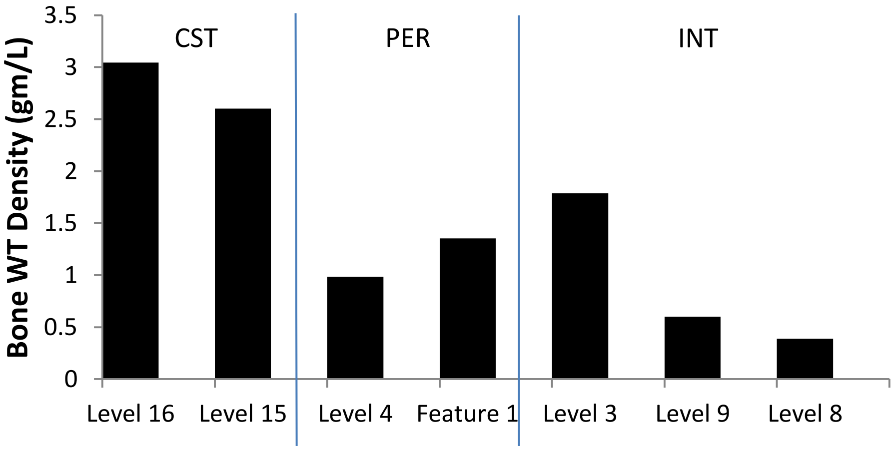


Figure 6.8 Bar chart of bone weight (WT) density (grams/liter) recovered in floated samples from late Middle Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.



Class-based Comparisons

The preceding analysis effectively demonstrates significant temporal and spatial variation that characterized the exploitation of vertebrate and invertebrate animal food resources on Santa Cruz Island from the terminal Early Period to the late Middle Period. Two of the most notable trends are the increased emphasis on vertebrate animal food resources at all sites during the Middle Period and the consistent coastal focus on vertebrate animal food resources. In order to explore how these broad trends reflect variation in the exploitation of specific vertebrate animal food resources through time, I begin with consideration of taxonomic classes—birds, land mammals, marine mammals, cartilaginous fish (including sharks, ray, and skates), and bony fish. The class-based percentages are grouped by site (presented in Figures 6.9- 6.11) to explore intrasite diachronic patterns and then by temporal period (presented in Figures 6.12-6.14) to explore persistent spatial patterns. I do not consider the species composition of the invertebrate assemblage in this section, as this dataset is not directly comparable to quantitative measures used for the vertebrate assemblage.

Diachronic Trends at the Coastal Site. Bony fish dominate the vertebrate faunal assemblage at the Coastal site throughout all temporal periods, followed by marine mammals, then birds, and lastly by cartilaginous fish (Figure 6.9). However, the relative contribution of each class is not static. There is a clear increase in the abundance of marine mammals and cartilaginous fish in the Middle Period that is sustained through the late Middle Period. The contribution of birds is less consistent, but also reflects Middle Period increase. The relative contribution of bony fish is lowest in samples from the Middle Period when the relative contributions of sea mammals and cartilaginous fish peak. Together, these trends suggest an increasing focus on a wider variety of vertebrate animal food resources beginning in the Middle Period and continuing through the late Middle Period. It is worth noting that the bone weight density and bone NISP density of bony fish recovered from Middle Period contexts also decreases during the Middle Period, relative to the comparable values from terminal Early Period contexts. Therefore, the decreased relative contribution of bony fish reflects a decreased exploitation of this class as well as an increased exploitation marine mammals, cartilaginous fish, and birds.

Figure 6.9 Bar charts of percent NISP, percent weight (WT), and percent MNI of the total vertebrate assemblage recovered from each floated sample at the Coastal site are represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) are separated by a vertical blue line.

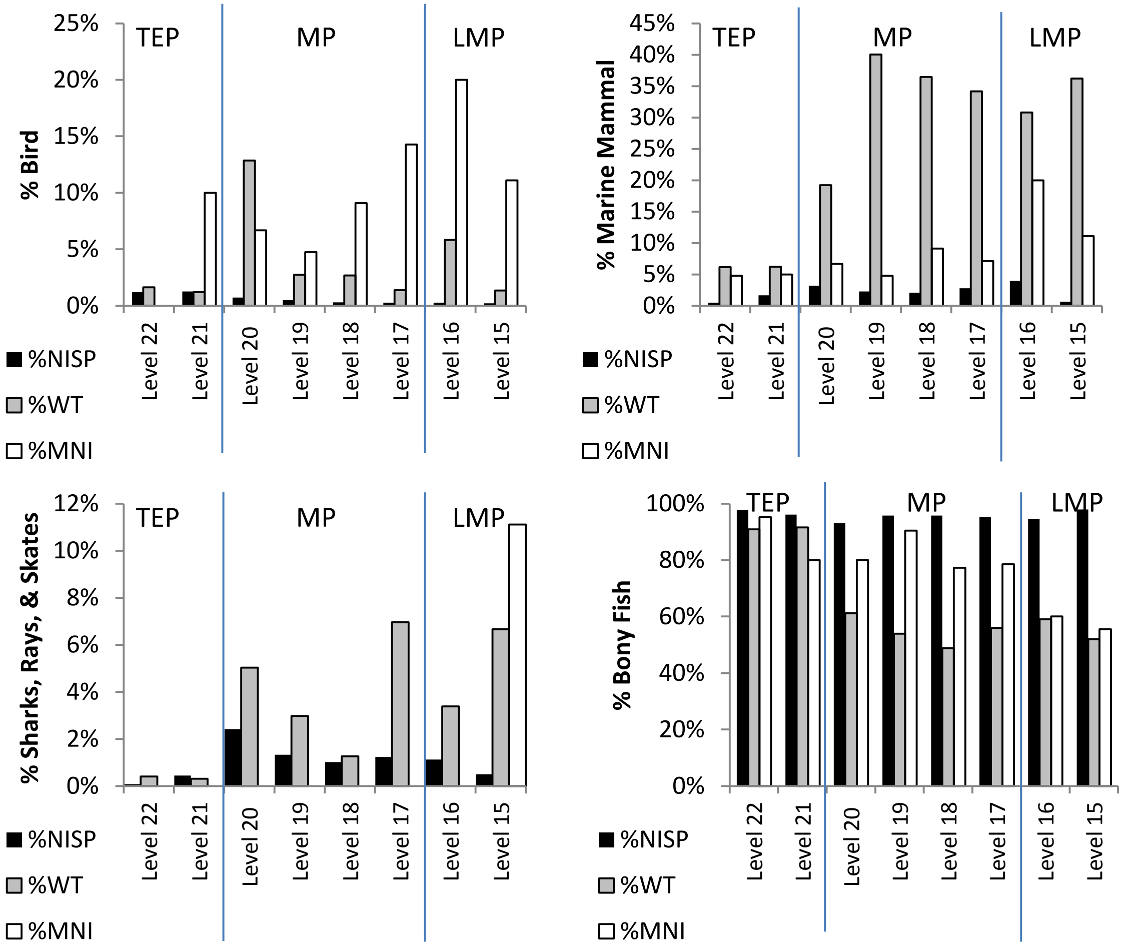
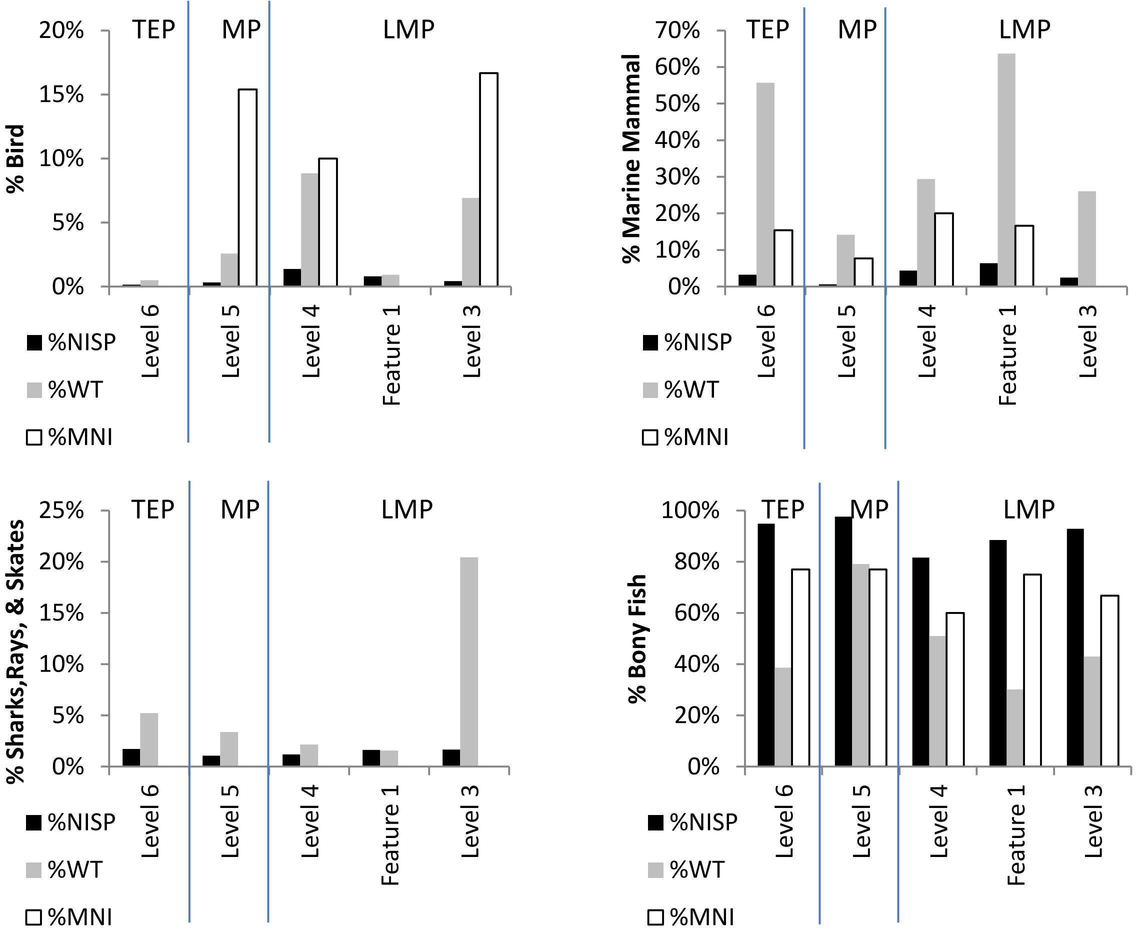


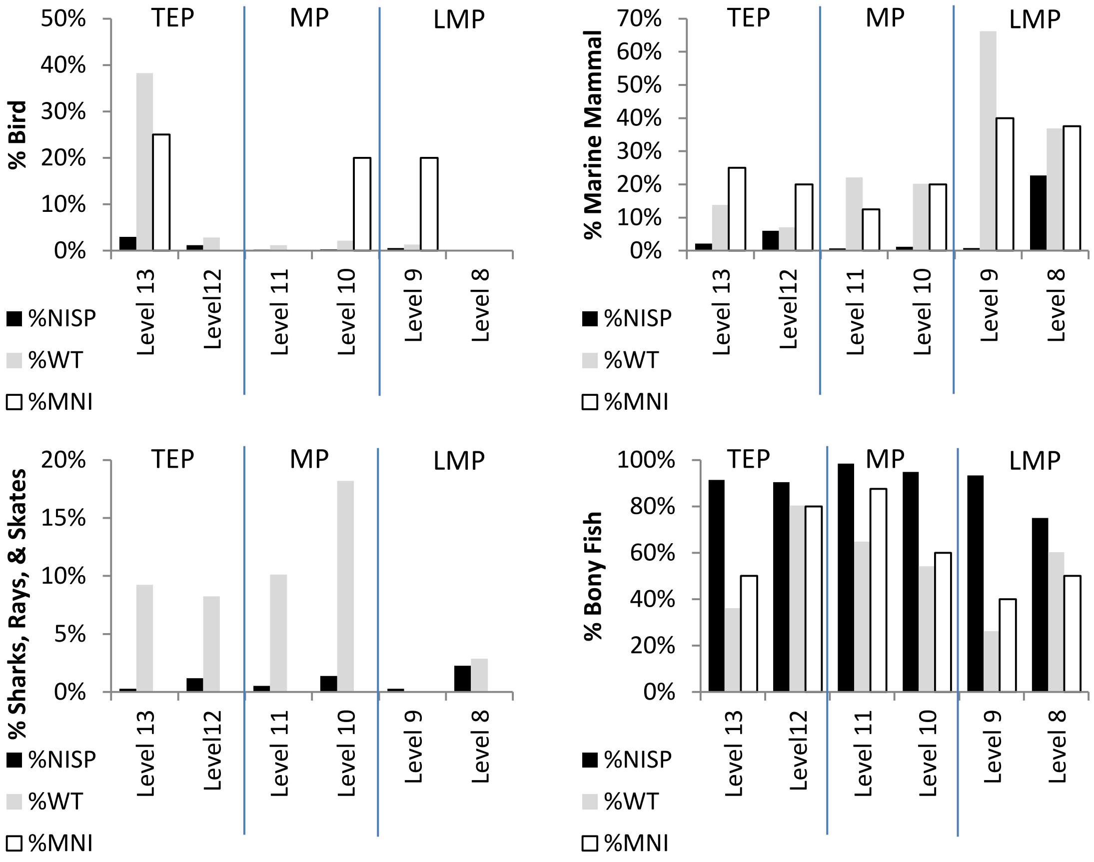
Figure 6.10 Bar charts of percent NISP, percent weight (WT), and percent MNI of the total vertebrate assemblage recovered from each floated sample at the Pericoastal site are represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) are separated by a vertical blue line.



Diachronic Trends at the Pericoastal Site. Bony fish also comprise the single most important vertebrate class by NISP in all samples from the Pericoastal site (Figure 6.10). However, marine mammals appear relatively more important in the earliest sample from terminal Early Period contexts, but decline during the Middle Period before rebounding during the late Middle Period. There is a distinct increase through time in the relative contribution of birds and little change through time in the relative contribution of cartilaginous fish, with the exception of a sharp increase in one of the three late Middle

Period samples (Level 3). These diachronic trends reveal a relatively greater emphasis on marine mammals throughout time that declines sharply during the Middle Period even as the overall density of vertebrate remains in the Middle Period sample increases. This decline in the relative importance of sea mammal is matched by an increase in the relative contribution of bony fish and birds. Decreased density of vertebrate remains in the late Middle Period samples reflects (1) substantial decline in the relative contribution of bony fish, (2) rebound in the relative importance of marine mammals, and (3) continued increase in the importance of birds.

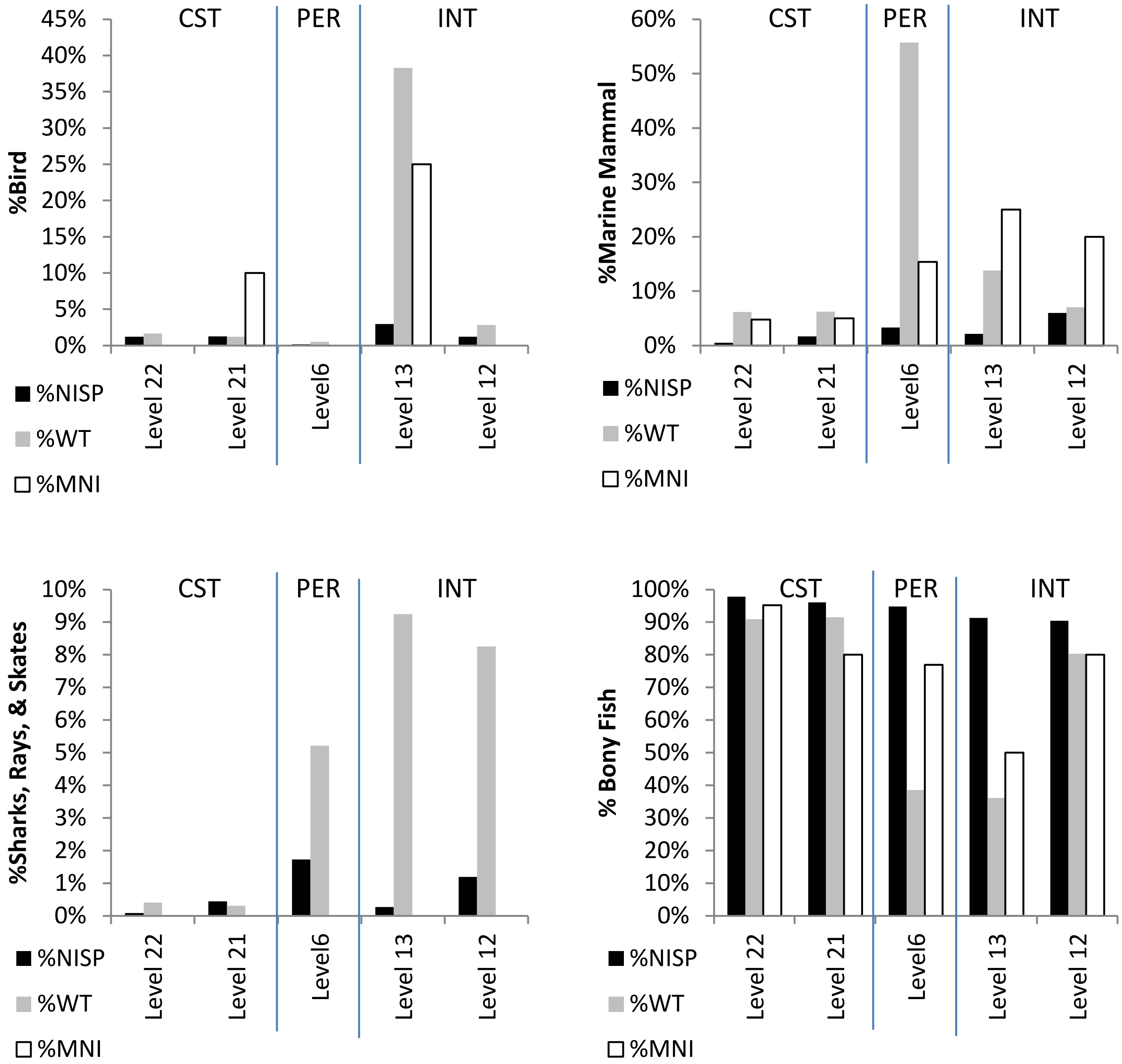
Figure 6.11 Bar charts of percent NISP, percent weight (WT), and percent MNI of the total vertebrate assemblage recovered from each floated sample at the Interior site are represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP) are separated by a vertical blue line.



Diachronic Trends at the Interior Site. Throughout all temporal periods the density of vertebrate remains is significantly lower in samples from the Interior site than in samples from the Coastal or Pericoastal site. Despite this difference, bony fish do comprise the single most important vertebrate class by NISP and MNI in all samples from the Interior site, just as it does at the Coastal and Pericoastal sites (Figure 6.11). Marine mammals and cartilaginous fish appear important during the terminal Early Period and Middle Period assemblages. Birds also contribute most in samples from terminal Early Period contexts, suggesting that people relied on a wider array of fauna during this earliest occupation. Although the total density of vertebrate remains increases in samples from the Middle Period, the contribution of birds decreases substantially. The very low density of vertebrate remains in late Middle Period assemblages reflects a decrease in the relative contribution of bony fish and cartilaginous fish, as the importance of sea mammals and birds appears to increase.

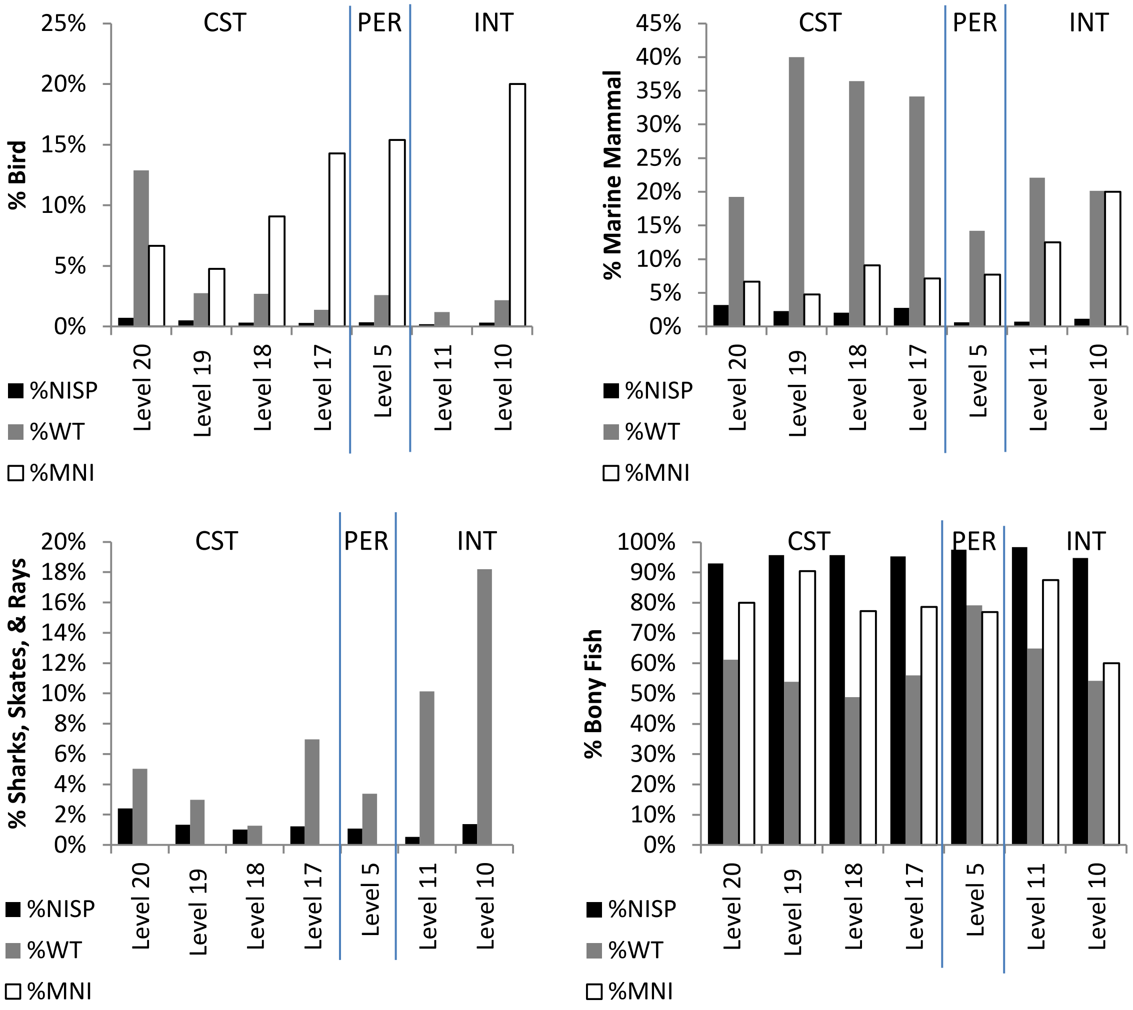
Spatial Trends during the Terminal Early Period. During the terminal Early Period, NISP of bony fish dominate the vertebrate faunal assemblage at all three sites, but the relative contribution of bony fish decreases by all measures with distance from the coast (Figure 6.12). In contrast, the relative importance of marine mammals increases, by all measures, with distance from the coast. The percentage of cartilaginous fish also increases markedly away from the coast in assemblages from the Pericoastal and Interior sites. Birds appear to be fairly unimportant in terminal Early Period assemblages, with the exception of a single sample from the Interior site. These patterns suggest a greater relative importance of bony fish in samples from the Coastal site and a relatively greater focus on marine mammals, cartilaginous fish, and perhaps birds away from the coast at the Pericoastal and Interior sites. Increasing exploitation of these distinct faunal classes accompanies a significant decrease in the overall density of vertebrate remains moving away from the Coastal site (Figure 6.1).

Figure 6.12 Bar charts of percent NISP, percent weight WT, and percent MNI of the total vertebrate assemblage recovered in each floated sample derived from terminal Early Period context are represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a vertical blue line.



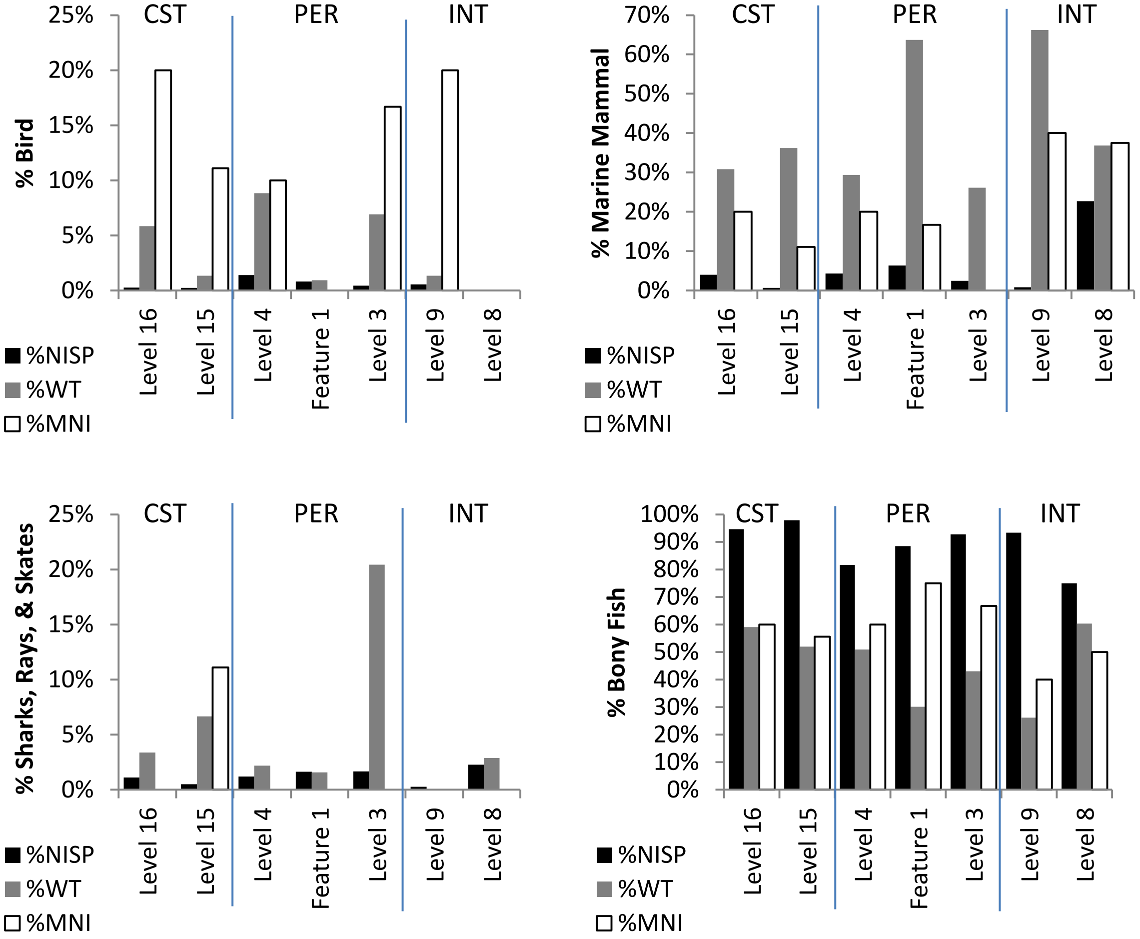
Spatial Trends during the Middle Period. Bony fish dominate the vertebrate faunal assemblage at all three sites with respect to all measures, but they contribute less, by NISP and weight, in samples from the Coastal site than in samples from the Pericoastal site (Figure 6.13). In contrast to the terminal Early Period, the relative importance of marine mammals is greater at the Coastal site than at either the Pericoastal or Interior site. Birds appear to contribute a similar percentage in all Middle Period samples with the exception of one Coastal sample (Level 20). The contribution of cartilaginous fish increases dramatically by weight in Middle Period samples from the Interior site. These spatial trends in the relative importance of vertebrate classes during the Middle Period contrast with the spatial trends identified during the terminal Early Period. The greater relative abundance of marine mammals and birds in coastal assemblages co-occurs with a greater overall density of vertebrate remains in these assemblages in comparison to the Pericoastal or Interior site. A lower overall abundance of vertebrate remains at the Pericoastal site parallels a higher relative contribution of bony fish than at the Coastal and Interior sites. Spatial patterns in the relative contribution of each vertebrate class are more complicated during the Middle Period than during the preceding terminal Early Period. The most noteworthy trend is the increased emphasis on a wider range of taxa at the Coastal site during this period.

Figure 6.13 Bar charts of percent NISP, percent weight (WT), and percent MNI of the total vertebrate assemblage recovered in each floated sample derived from Middle Period contexts is represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a vertical blue line.



Spatial Trends during the Late Middle Period. Bony fish dominate the faunal assemblage at all three sites, although the relative importance measured by NISP and weight appears greater at the Coastal site (Figure 6.14). This suggests a renewed coastal focus on the exploitation of bony fish. Marine mammals once again appear to be of relatively greater importance away from the coast, particularly at the Interior site, even as the overall density of vertebrate remains at this site decreases. The relative contribution of birds and cartilaginous fish are variable across space, but birds may have been of greater relative importance at the Coastal and Pericoastal sites.

Figure 6.14 Bar charts of percent NISP, percent weight (WT), and percent MNI of the total vertebrate assemblage recovered in each floated sample derived from late Middle Period contexts are represented by birds (upper left), marine mammals (upper right), cartilaginous fish (lower left), and bony fish (lower right). Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a vertical blue line.



Broad Trends in Vertebrate Class Representation. It is clear that bony fish dominate the vertebrate faunal assemblage through time and across space, followed by marine mammals. However, the relative importance of these primary vertebrate classes does shift along with the relative contribution of cartilaginous fish and birds.

During the terminal Early Period the relative contribution of vertebrate animal food resources is significantly lower than during subsequent Middle Period occupation (Figure 6.1). Although bony fish dominate the vertebrate faunal assemblage at all three sites, the relative contribution of bony fish decreases by all measures with distance from the coast. In contrast the percentage of cartilaginous fish increases markedly away from the coast in terminal Early Period assemblages from the Pericoastal and Interior sites. Marine mammals also appear to be of greater seasonal importance away from the coast at the Pericoastal site. Birds contribute minimally to terminal Early Period assemblages with the exception of a single sample from the Interior site. These patterns suggest a greater relative importance of bony fish in samples from the Coastal site and a relatively greater focus on marine mammals, cartilaginous fish, and (perhaps) birds away from the coast at the Pericoastal and Interior sites. Increasing exploitation of these distinct faunal classes accompanies a significant decrease in the overall density of vertebrate remains moving away from the Coastal site (Figure 6.9). It is clear that exploitation of vertebrate faunal during the terminal Early Period was most important at the Coastal site, where people focused on the acquisition of bony fish, and less important at the Pericoastal and Interior sites, where people relied on low quantities of bony fish, marine mammals, cartilaginous fish, and (perhaps) birds.

A significantly higher density of vertebrate remains characterize Middle Period faunal assemblages, relative to the preceding and following temporal periods (Figure 6.1). Although bony fish dominate the vertebrate faunal assemblage at all three sites, they are relatively less important at the Coastal and Interior sites, with respect to NISP and weight, than at the Pericoastal site. This represents a marked decrease in the relative importance of bony fish at the Coastal and Interior site during the Middle Period, in comparison to the terminal Early

Period. Also in contrast to the terminal Early Period, the relative importance of marine mammals is greater at the Coastal site than at either the Pericoastal or Interior site, suggesting a coastal focus on the exploitation of marine mammals. Indeed, increased relative importance of marine mammals at the Coastal site accompanies a substantial decline in the relative importance of marine mammals at the Pericoastal site. Birds appear to contribute a similar percentage across all three sites with the exception of one Coastal sample (Level 20). The contribution of cartilaginous fish weight increases dramatically in Middle Period samples from the Interior site and slightly at the Coastal site. These spatial trends in the relative importance of vertebrate classes during the Middle Period contrast with the spatial trends identified during the terminal Early Period. The greater relative abundance of marine mammals and birds in the Coastal site assemblages co-occurs with a greater overall density of vertebrate remains in these assemblages in comparison to those from the Pericoastal or Interior sites. A lower overall abundance of vertebrate remains at the Pericoastal site parallels a higher relative contribution of bony fish in comparison to the Coastal or Interior sites. The very lowest density of vertebrate remains from Middle Period assemblages at the Interior site correlates with a higher relative contribution of cartilaginous fish than evident in samples from the Coastal or Pericoastal site, but a lower relative contribution of bony fish in comparison to the Pericoastal site. Spatial patterns in the relative contribution of each vertebrate class are more complicated in the Middle Period than in the preceding terminal Early Period. The most noteworthy temporal trend is the greater emphasis on animal food resources from all vertebrate classes, which accompanies an increase in the overall abundance of vertebrate remains, evident at the Coastal site during this period.

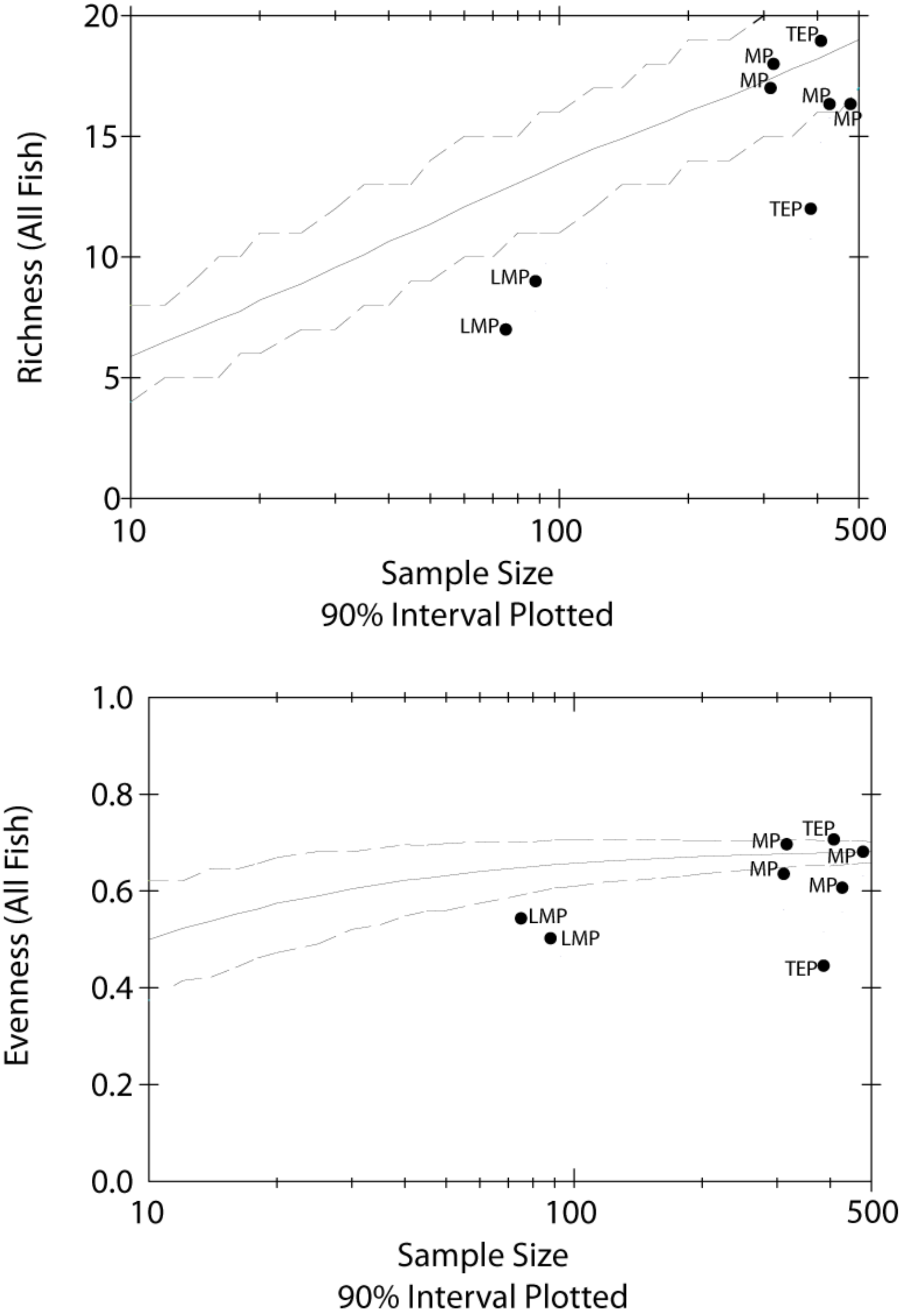
Late Middle Period samples are broadly characterized by significantly lower density of vertebrate remains than samples from the preceding temporal period (Figure 6.1). Although bony fish continue to dominate the vertebrate assemblage at all three sites, the relative contribution of this class decreases, by all measures, relative to the preceding temporal period. Furthermore, substantial decline in the exploitation and relative importance of bony fish contrasts with an overall increased importance of marine mammals (particularly at the Interior site, away from the coast) and cartilaginous fish (at the Pericoastal and Coastal sites, near the coast). This pattern suggests that the significant decrease in the density of vertebrate remains in late Middle Period contexts, relative to the preceeding Middle Period, is a result of a decrease in the importance of bony fish at all three sites.

Diversity of Cartilaginous and Bony Fish Taxa

The class-based patterns indicate that the density of fish taxa dominate the vertebrate assemblages in all samples of all temporal periods, driving patterns in the overall abundance of vertebrate remains and influencing the relative importance of all other taxonomic classes. The sheer quantity of fish remains also defines patterns in the diversity of vertebrate faunal assemblage. Raw abundance (bone NISP or bone weight) measures document the range of fish taxa and relative intensity of use, but alone they do not offer much interpretative value (VanDerwarker 2006:91). However, bone NISP does provide a representation of the diversity of types within a sample and can be used as a basis for measuring species richness and evenness, key components of diet breadth. Measures of assemblage diversity allow for effective evaluation of land use patterns across space as well as specialization or diversification in diet breadth through time. In this analysis I focus specifically on *food* taxa, excluding all identified taxa unlikely to represent food resources. The goal of this analysis is to identify how the composition of fish species exploited through time and across space changes in relationship to the broad trends identified in the two preceding sections.

DIVERS Computer Simulation. Here I consider Kintigh′s (1984, 1989) DIVERS computer simulation to evaluate fish species diversity and control for potential effects of sample size. In multiple iterations of this analysis, I verified that the broad patterns of diversity, represented by richness and evenness, for the entire vertebrate faunal assemblage of each sample was influenced heavily by diversity of the fish assemblage in the sample. Therefore, in the analysis that I present and discuss below I focus on DIVERS results for just the fish assemblages. Figures 6.16-6.18 plot calculated richness and evenness by sample size. I measure species diversity for all temporal periods and for all sites. In this analysis, I do not directly compare the diversity of archaeological fish bone assemblages to each other; rather I compare the archaeological fish bone assemblages to expected values simulated for the same size assemblage (Kintigh 1984, 1989).

Figure 6.15 DIVERS richness (top) and evenness (bottom) plots of all identified fish taxa (based on bone NISP) at the Coastal site. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP. The solid center line in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dashed lines above and below the center-line represent the 90% confidence interval for expected values.



Evaluation of Individual Samples at the Coastal Site. The two terminal Early Period fish assemblages from the Coastal site are quite different from each other. The sample recovered from Level 22 falls well below the range of richness and evenness values expected given its sample size (Figure 6.15). The assemblage from Level 22 is biased towards the exploitation of nearshore rockfish and to a lesser degree rock wrasse. In contrast, the sample recovered from Level 21 falls well within the upper limits of expected richness and evenness values, given its sample size. This indicates a significant increase in the both the number of fish taxa exploited and the relative equitability with which the taxa are exploited by at the end of the terminal Early Period. This substantial increase in diversity is accompanied by a decrease in the total density of fish bone, calculated by NISP and weight, and a slight decrease in the relative importance of fish. Richness values remain high in all four Middle Period fish assemblages recovered from the Coastal site. Each assemblage falls well within the expected range of richness values. Two of the four samples (Level 19 and Level 18) also fall within the expected range of evenness; the other two fall just below the 90% confidence interval, indicating that the abundances of each taxa in these samples are less evenly distributed than expected. The assemblages from both Level 20 and Level 17 are both biased towards the exploitation of migratory clupeids, a taxon that first appears at the Coastal site in the assemblage from Level 21. Both late Middle Period fish assemblages from the Coastal site fall well below the 90% confidence interval, indicating that these assemblages are significantly less rich and less evenly distributed than expected. The assemblage from Level 16 is biased towards the exploitation of clupeids and rockfish, whereas the assemblage from Level 15 is biased primarily towards rockfish and nearshore surfperch.

Overall, the diversity of fish taxa exploited at the Coastal site varies significantly through time, and even with individual temporal periods. There is a striking increase in diversity at the end of the terminal Early Period occupation that persists through the Middle Period before decreasing significantly during the late Middle Period. Although absolute quantities of fish bone remain similar, evidence of increased diversity during the Middle Period corresponds with significant decrease in fish bone density and a slight decrease in the relative importance of fish. Thus, it is clear that during the Middle Period occupation at the Coastal site, people were exploiting a lower quantity of a more diverse array of fish taxa than during the preceding period of occupation. These results also suggest that during the late Middle Period occupation at the Coastal site, as the relative importance of bony fish continued to decrease, people exploited a relatively narrow range of fish taxa, much less equitably than during the preceding temporal periods.

Evaluation of Individual Samples at the Pericoastal Site. The terminal Early Period and Middle Period fish assemblages from the Pericoastal site fall well below the range of richness and evenness values expected for their respective sample sizes (Figure 6.16). This suggests that during both the terminal Early Period and Middle Period occupation people exploited a relatively narrow range of fish taxa, favoring just a few specific fish species. Indeed, the fish assemblage from the terminal Early Period sample is biased heavily towards the exploitation of nearshore surfperch and rockfish. Similarly, the Middle Period fish assemblage is heavily biased towards rockfish. All three late Middle Period fish assemblages from the Pericoastal site fall within the 90% confidence interval for their expected range of richness values. Only one late Middle Period assemblage falls below the expected range of evenness values. The fish assemblage from Feature 1 appears biased towards surfperch and rockfish. This deposit represents a unique feature, distinctive from the general midden deposits represented by level assemblages; thus it is expected to differ to some extent from the other contemporaneous deposits. Notably, richness values are high even in the Feature 1 assemblage. This suggests that throughout the late Middle Period occupation at the Pericoastal site, people exploited a wider variety of fish species than during previous temporal periods. Evenness values from both of the non-feature midden samples from late Middle Period contexts suggest that people were also exploiting a wide range of fish taxa quite similarly.

Overall, DIVERS results suggest substantial diachronic variation in the diversity of fish species exploited at the Pericoastal site. People living at this site during the terminal Early Period exploited a narrow range of fish, with a pronounced emphasis on surfperch and rockfish. This low diversity corresponds with a low density of fish bone. This suggests that the small quantity of fish brought to the Pericoastal site favored these medium sized nearshore fishes, easily captured from shore. This pattern shifts somewhat during the Middle Period. Although, it appears that people continued to transport a relatively low diversity of fish species, they do so in much greater quantities. The density of fish bone in Middle Period samples almost triples, suggesting that the Middle Period inhabitants at the Pericoastal site maintained a focused exploitation on just a few specific taxa in much greater quantities than during the terminal Early Period. The relative abundance of fish remains drops substantially during the late Middle Period, even as diversity increases. It appears that during this period of occupation people living at the Pericoastal site began to transport a much wider range of fish taxa relatively equally distributed among the taxa, but in lower quantities.

Figure 6.16 DIVERS richness (top) and evenness (bottom) plots of all identified fish taxa (based on bone NISP) at the Pericoastal site. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP. The solid center line in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dashed lines above and below the center-line represent the 90% confidence interval for expected values.

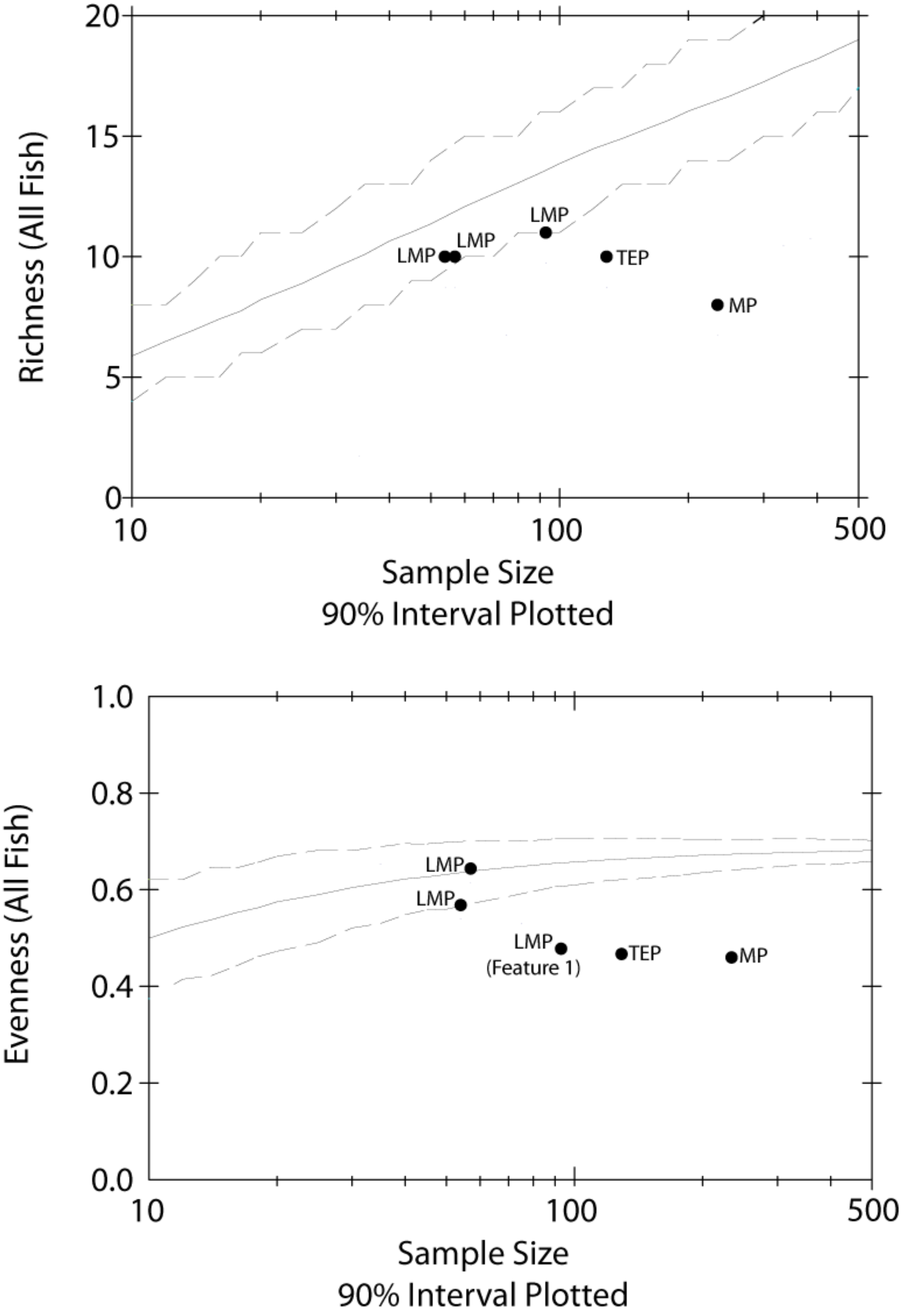
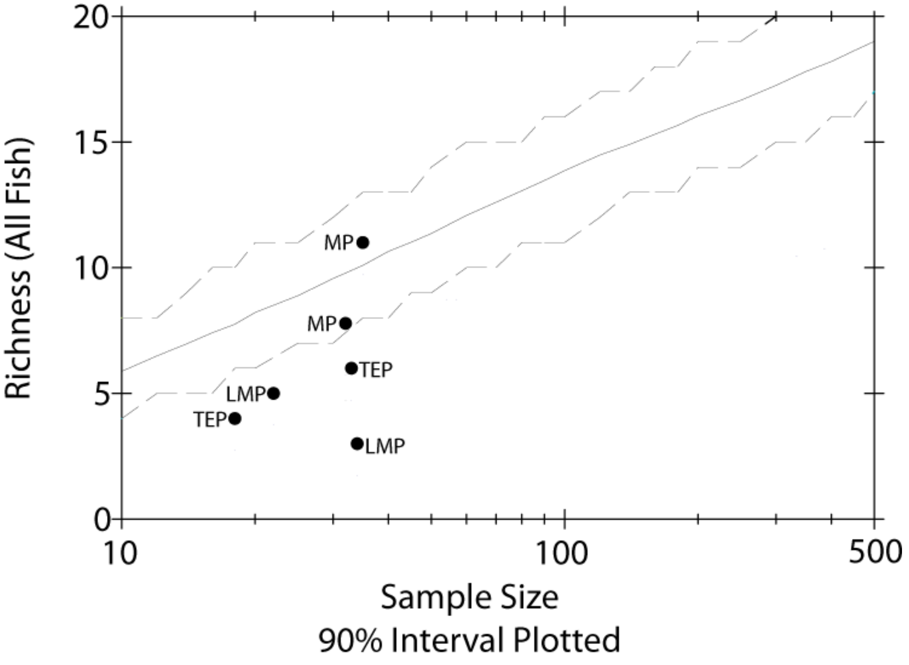
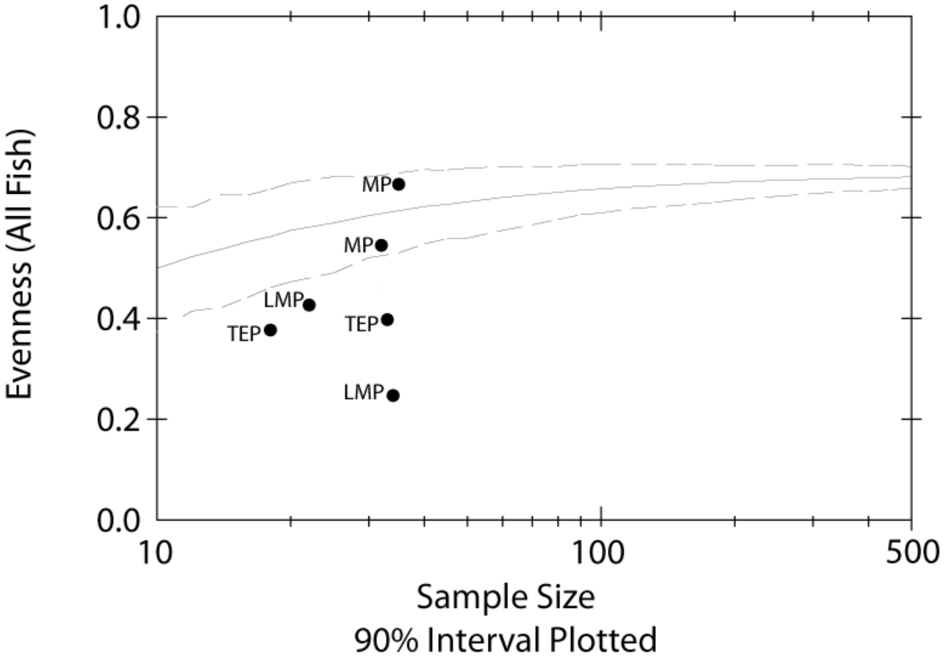


Figure 6.17 DIVERS richness (right) and evenness (left) plots of all identified fish taxa (based on bone NISP) at the Interior site. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP. The solid center line in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dashed lines above and below the center-line represent the 90% confidence interval for expected values.





Evaluation of Individual Samples at the Interior Site. The two terminal Early Period fish assemblages from the Interior site both fall well below the richness and evenness values expected for these samples given their respective sample sizes (Figure 6.17). This suggests that terminal Early Period inhabitants at the Interior site transported a narrow range of fish species and focused heavily on just a few taxa. The fish assemblage from Level 13 is biased heavily towards the exploitation of nearshore surfperch and California sheephead; whereas the fish assemblage from Level 12 is biased heavily towards the exploitation of migratory clupeids and surfperch. This pattern is reversed in fish assemblages recovered from Middle Period samples at the Interior site. Both Middle Period fish assemblages fall well within the 90% confidence interval for richness and evenness, indicating that these samples are as rich and as evenly distributed among taxa as expected given their respective sample sizes. This result indicates that people who occupied the Interior site during the Middle Period transported (and presumably consumed) a statistically greater diversity of fish species than their predecessors; albeit in similar overall quantities. In contrast, late Middle Period fish assemblages from the Interior site fall well below the 90% confidence intervals, indicating that these assemblages are significantly less rich and less evenly distributed among taxa than expected. This suggests that similar to patterns documented in the terminal Early Period assemblage, during the late Middle Period occupation, people once again began to transport a statistically lower diversity of fish species three kilometers up the watershed to the Interior site than expected based on sample size.

This analysis documents clear diachronic variation in the diversity of fish species transported to and consumed at the Interior site. People living at the Interior site during the terminal Early Period exploited a narrow range of fish, with emphasis on just a few specific species. This low diversity corresponds with a particularly low density of fish bone. This suggests that very few fish species were transported in low quantities during this early occupation. This pattern shifts substantially during the Middle Period. Not only is the richness and equitability of fish species significantly higher during the Middle Period than during the Early Period, so is the density of fish bone. The density of fish bone in Middle Period samples more than triples, suggesting that Middle Period inhabitants at the Interior site transported and consumed greater quantities of a wider range of fish species that were relatively evenly distributed among the taxa represented. This pattern is quickly reversed. The density of fish bone plummets during the late Middle Period, as does the overall diversity of fish species transported to the Interior site. It appears that during this period people living at the Interior site began to transport a significantly reduced range of fish, focused on just a few specific species in substantially lower quantities. As at the Coastal site, both late Middle Period fish assemblages are biased towards representation of nearshore surfperch and rockfish.

Broad Trends in Fish Diversity. There are broad parallels in the diversity of bony and cartilaginous fish exploited through time at the Coastal and Interior site. At both of these sites there is a clear trend of significantly lower richness and equitability during the terminal Early Period, followed by significantly higher richness and equitability during the Middle Period, and a reversal during the late Middle Period when richness and equitability decrease significantly. However, this pattern does not hold at the Pericoastal site. The diversity of fish taxa transported to the Pericoastal site remains significantly lower than expected until the late Middle Period. It is clear that broad patterns in the diversity of fish species exploited are best characterized by diachronic trends at the Coastal and Interior sites, whereas the quantity of fish exploited are heavily influenced by variation across space (i.e. distance from the coast) as well as through time. The overall diversity of fish assemblages from the Pericoastal site does not correlate with the diachronic trends noted at the Coastal and Interior sites; although the quantity of fish exploited does. This may reflect diachronic variation in site function at the Pericoastal site relative to broader land use patterns.

Fish Size and Method of Capture

Given the incredible focus on fish throughout all temporal periods and clear variation in the abundance and diversity of fish exploited across space and through time, it is necessary to consider how these changes relate to technological changes. Ethnohistoric and archaeological evidence reviewed previously in this chapter indicate that the prehistoric fishers of Santa Cruz Island and the Santa Barbara Channel Region relied on a variety of fishing implements, including spears, harpoons, bone gorges, shell fish hooks, various types of nets, such as dip nets and drag nets, tule reed rafts, and plank canoes (Hudson and Blackburn 1982). In this analysis I focus specifically on discernment of the actual fishing gear required to capture fish taxa identified in this assemblage, rather than watercraft technology. The use of these various technologies varied through time, as new techniques were adopted (Pletka 2011:151). Ethnographic studies indicate that manufacture and maintenance of nets requires substantial investment (Pletka 2011:151), but may also provide exceptionally efficient and effective returns (Bertrando and McKenzie 2011:172). Thus, I consider the likely technology used to form the archaeological assemblages of fish remains as an indication of the labor involved in procurement.

Large versus Small Fish Taxa. In order to identify the gear used to capture the fish assemblages identified, I first consider physical characteristics of the fish assemblage. Gear types differ in the sizes of fish captures (Wheeler and Jones 1989:168; Pletka 2011:151). Nets capture a wider range of fish sizes than other gear, such as hook and line or spear. Furthermore, hook-and-line or spears cannot effectively capture smaller species. Assemblages formed from fish caught primarily from nets should have a larger proportion of small fish than assemblages formed from fish primarily caught by hook and line or spear.

Previous studies of a number of fish species demonstrate a strong positive relationship between vertebra size and fish size (Bertrando and McKenzie 2011; Casteel 1976; Granadeiro and Silva 2000; Pletka 2011; Reitz and Wing 2008). A preliminary analysis from southern California demonstrates a strong, positive relationship between vertebra size and fish size exists among many species of bony fish (Pletka 2011:153). Thus vertebra height provides a reliable predictor of live weight in bony taxa (Pletka 2011:153). However, the vertebral centra of sharks, rays, and skates seem to vary to a much greater extent within individuals (Pletka 2011:153). For this reason subsequent analysis will focus on bony fish.

Vertebrae are generally the most well represented skeletal element among all fish species likely to occur in these midden assemblages and indeed produce more than adequate sample sizes for further analysis. Excavation and recovery techniques were designed specifically to ensure the recovery of very small fish remains, and these are constant among all assemblages. Therefore, the proportion of small fish should reflect behaviors of interest rather than taphonomic factors or recovery techniques. In order to evaluate variation in the size of fish exploited, for each sample I begin with identification of the distribution of fish size that should reflect the use of different fishing gear. The following statistical analysis is based on height measurements of 2,606 vertebral centra recovered from terminal Early Period, Middle Period, and late Middle Period contexts at all three sites.

Figure 6.18 Box plots of vertebral height (proxy for fish size) by sample from the Coastal site. Temporal period attribution is indicated at the top and separated by a vertical blue line. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.

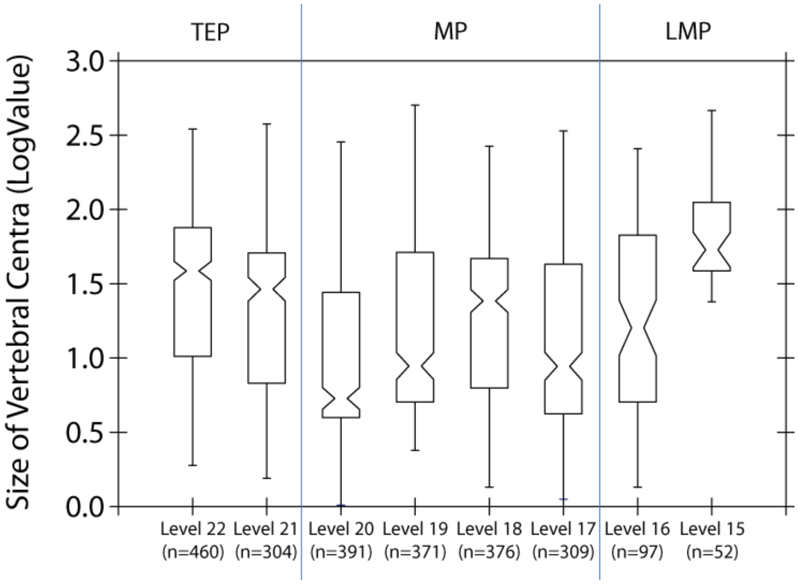


Figure 6.19 Box plots of vertebral height (proxy for fish size) by sample from the Pericoastal site. Temporal period attribution is indicated at the top and separated by a vertical blue line. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.

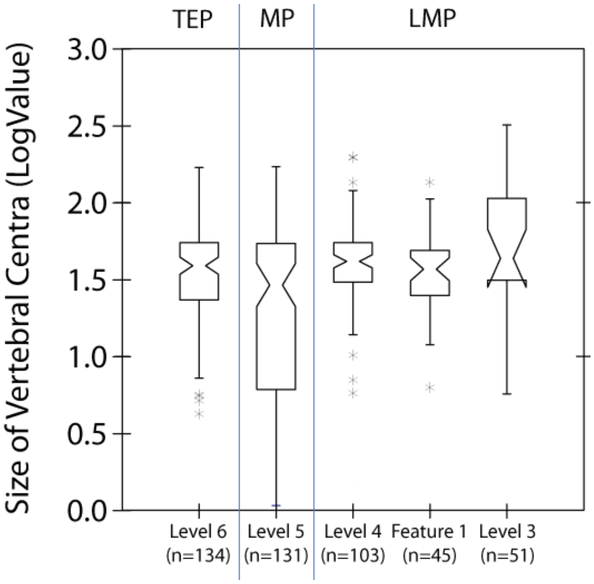
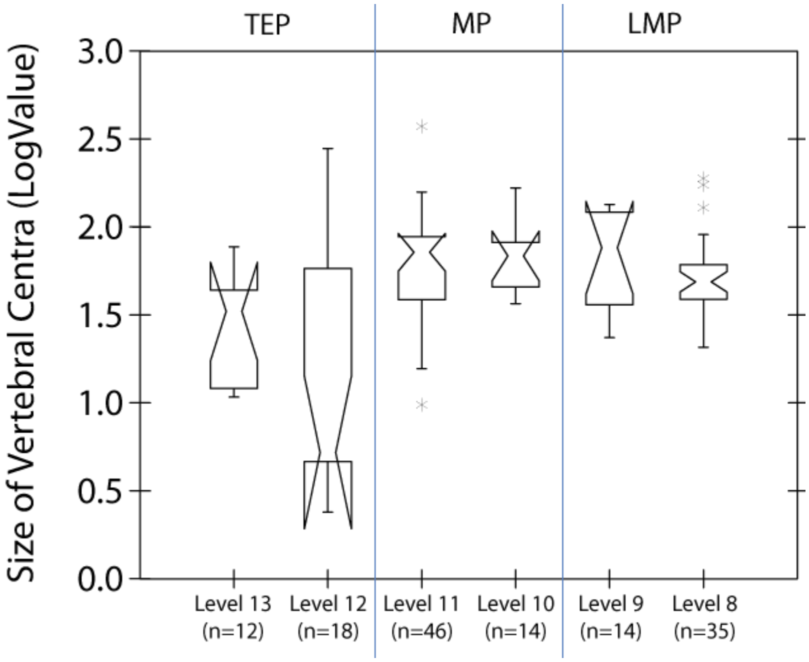


Figure 6.20 Box plots of vertebral height (proxy for fish size) by sample from the Interior site. Temporal period attribution is indicated at the top and separated by a vertical blue line. Samples from terminal Early Period contexts are denoted by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.



Box plots in figures 6.18-6.20 illustrate the distributions of vertebral size measurements for each sample assemblage at the Coastal site, at the Pericoastal site, and at the Interior site. These box plots reveal statistically significant variation (at the 0.05 level) through time at the Coastal site, Pericoastal site, and Interior site. A one-way ANOVA was used to evaluate whether differences between assemblages (from all three sites) attributed to each temporal period are statistically significant. The size of fish vertebrae recovered from terminal Early Period, Middle Period, and late Middle Period contexts (samples from all three sites are represented in each period grouping) differed significantly (*F*=101.684, *d.f.*=2, *p*=0.000). Tukey post-hoc comparisons of the three temporal periods indicate that mean size of bony fish vertebrae in terminal Early Period assemblages is significantly larger than the mean size of bony fish vertebrae in Middle Period assemblages (*p*=0.000). Comparisons between Middle Period assemblages and late Middle Period assemblages indicate that mean size of bony fish vertebrae in Middle Period assemblages are significantly smaller than that mean size of bony fish vertebrae in late Middle Period assemblages (*p*=0.000). Final comparisons between the terminal Early Period assemblages and late Middle Period assemblages indicate that the mean size of bony fish vertebrae in late Middle Period assemblages is also significantly larger than the mean size of bony fish vertebrae in terminal Early Period assemblages (*p*=0.007).

These results document consistent diachronic variation in the size of fish exploited during the terminal Early Period, Middle Period, and late Middle Period occupations at all three sites. There is a marked decrease the size of fish captured during the Middle Period. This trend appears to begin at the end of terminal Early Period occupation at both the Coastal site and the Interior site. The mean size of bony fish vertebrae in the assemblage from Level 21 at the Coastal site and Level 12 at the Interior site are both significantly smaller than the in the preceding assemblages from Level 22 and level 13, respectively (Figure 6.19 and Figure 6.20). This suggests an increase in net-fishing during the Middle Period. However this pattern is reversed during the late Middle Period, with a substantial increase in the size of fish exploited. The mean size of fish during the late Middle Period greatly exceeds the mean size exploited in the terminal Early Period. This suggests a shift in fishing strategies, including the importance of sophisticated watercraft, and/or environmental factors that influenced the size of fish captured. This broad temporal trend is evident at the Coastal and Pericoastal sites, but contrasted at the Interior site. There is a statistically significant increase in the mean size of bony fish vertebrae recovered from Middle Period contexts at the Interior site. This indicates that despite a highly significant temporal trend towards smaller fish during the Middle Period, a fair amount of spatial variability is evident as well.

Figure 6.21 Box plots of vertebral height (proxy for fish size) from terminal Early Period samples. Site attribution is indicated at the top and separated by a vertical blue line.

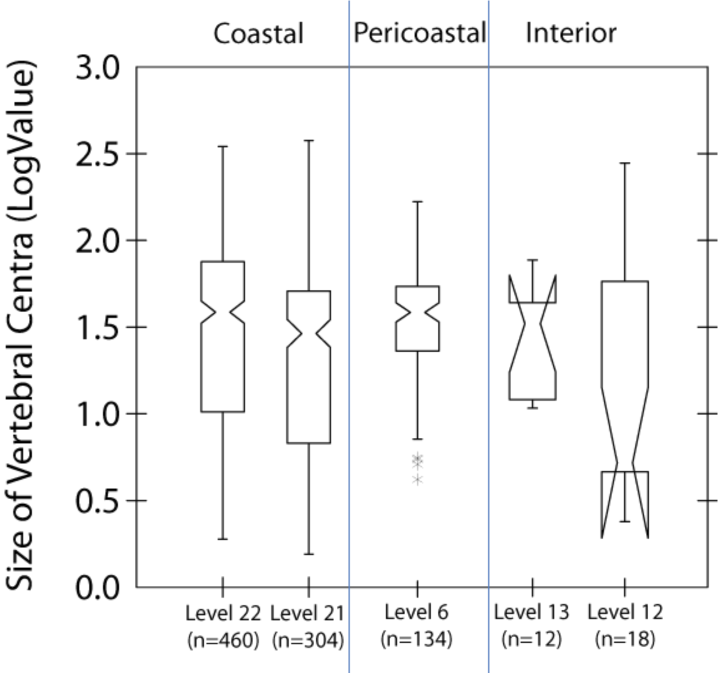


Figure 6.22 Box plots of vertebral height (proxy for fish size) in Middle Period samples. Site attribution is indicated at the top and separated by a vertical blue line.

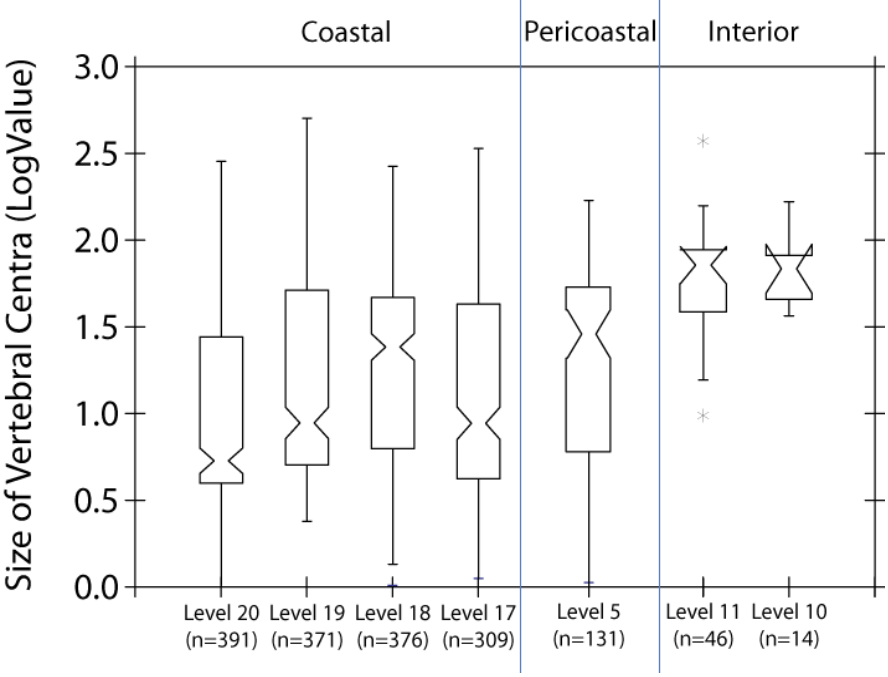
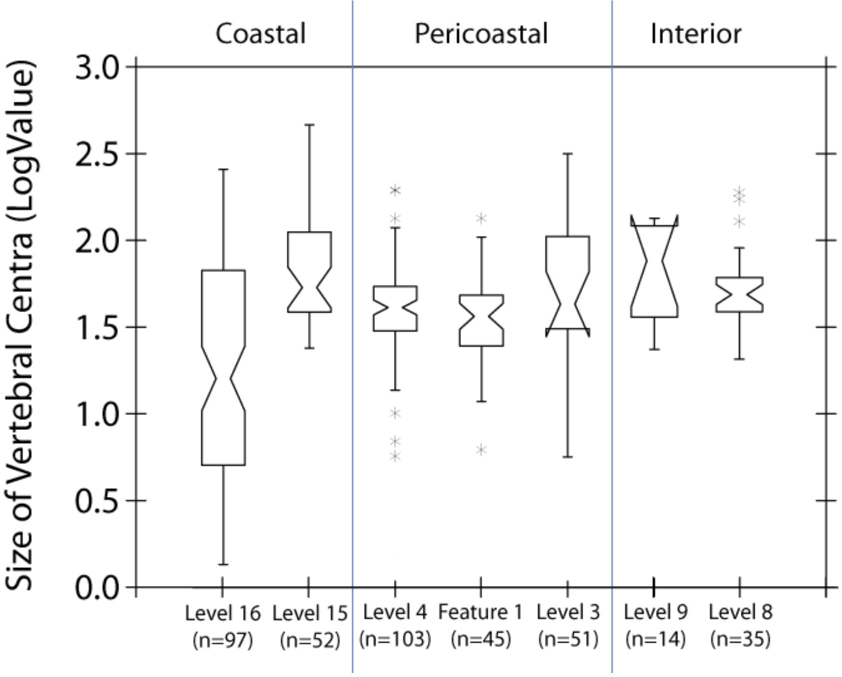


Figure 6.23 Box plots of vertebral height (proxy for fish size) in late Middle Period samples. Site attribution is indicated at the top and separated by a vertical blue line.



Box plots in figures 6.22-6.24 illustrate the distributions of vertebral size measurements for each sample assemblage from terminal Early Period, Middle Period, and late Middle Period contexts. These box plots reveal statistically significant variation (at the 0.05 level) across space within each temporal period. A one-way ANOVA was used to evaluate whether differences between site assemblages were consistent through time. The size of fish vertebrae recovered from all temporal periods at the Coastal site, Pericoastal site, and Interior site differed significantly (*F*=45.765, *d.f.*=2, *p*=0.000). Tukey post-hoc comparisons of the three sites indicate that mean size of bony fish vertebrae in assemblages from the Coastal site is significantly lower than the mean size of bony fish vertebrae in assemblages from the Pericoastal site (*p*=0.000), and the Interior site (*p*=0.000). Comparison between assemblages from the Pericoastal site and assemblages from the Interior site indicate that mean size of bony fish vertebrae recovered from Pericoastal assemblages are marginally but significantly smaller than the mean size of bony fish vertebrae recovered from Interior assemblages (*p*=0.123). These results document consistent spatial variation in the size of fish exploited during all periods of occupation at the Coastal site, Pericoastal site, and Interior sites. There is a highly significant increase the size of fish transported moving from the coast to the interior of the watershed. This suggests that throughout all temporal periods 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.

Net-Caught Fish versus Hook-Caught Fish. The preceding analysis suggests a distinctive Middle Period increase in the exploitation of small fish, likely taken by nets. However, interpretation of the distribution of fish size is not straightforward, since netting may capture large fish as well as small fish. In assemblages where net-caught fish predominate, the prevalence of net-caught fish may obscure any mode in the fish size distribution formed by fish caught with other gear. In this section I evaluate a ratio of fish taxa that would have been predominantly caught either by netting or with hook and line technology. Ethnohistoric (Hudson and Blackburn 1982), experimental archaeological (McKenzie 2007), and modern fishing information (Love 2011) provide a baseline of fish taxa most consistently caught with each type of fishing implement. I limit this analysis to just eight taxa considered to be exclusively either net-caught or hook- caught species. Net fishing is most successful with small schooling fish—particularly clupeids (sardines and herrings), mackerels, and Pacific hakes (Bertrando and McKenzie 2011:172). These three taxa are rarely taken by other fishing methods due to their small size and feeding habits. Hook and line fishing is most successful in the capture of large-mouthed aggressive predators, particularly rockfish, cabezon, sheephead, lingcod, and croakers (Bertrando and McKenzie

2011:172). These five taxa prefer rocky reef and kelp forest habitats that considerably complicate the use of other fishing implements. Primary fish taxa excluded from this analysis include, among others, larger schooling fish, such as surfperches that may be acquired successfully by both nets and hook and line technologies (Bertrando and McKenzie 2011:172).

Bar charts in Figure 6.24 illustrate the ratio of net-caught fish to hook-caught fish, based on bone NISP and bone weight, for each sample assemblage from the Coastal, Pericoastal, and Interior sites. These figures suggest substantial diachronic variation in the relative contribution of net-caught fish and hook-caught fish at each site. I note here that the overall density of fish remains is significantly lower at the Interior site than at the Coastal or Pericoastal site. I used a one-way ANOVA to evaluate whether differences in this ratio between assemblages (from all three sites) attributed to each temporal period are statistically significant. The ratio of net-caught fish to hook-caught fish recovered from terminal Early Period, Middle Period, and late Middle Period contexts differed significantly, by bone NISP (F=4.622, $d.f.$=2, p=0.026) and bone weight (F=5.509, $d.f.$=2, p=0.015). Tukey post-hoc comparisons of the three temporal periods indicate that the ratio of net-caught fish to hook-caught fish in terminal Early Period assemblages is significantly higher than the ratio of net-caught fish to hook-caught fish in Middle Period assemblages, by both NISP (p=0.118) and weight (p=0.043). Comparison between Middle Period assemblages and late Middle Period assemblages indicate a significant decrease in the ratio of net-caught fish to hook-caught fish between the Middle Period and late Middle Period by bone NISP (p=0.026) and bone weight (p=0.022). However, additional comparisons reveal no significant difference between the ratio of net-caught fish to hook-caught fish in assemblages from terminal Early Period and late Middle Period contexts by bone NISP (*p*=0.855) or bone weight (*p*=0.997).

Figure 6.24 Bar chart of common net-caught versus hook-caught taxa recovered in floated samples, ratio calculated by NISP and by weight (WT) from the Coastal site (left), Pericoastal site (middle), and Interior site (right). Ratio is plotted by excavation level for bone NISP (solid black bar) and bone weight (striped bar). Temporal Period attribution is indicated at the top and periods are separated by a vertical blue line.

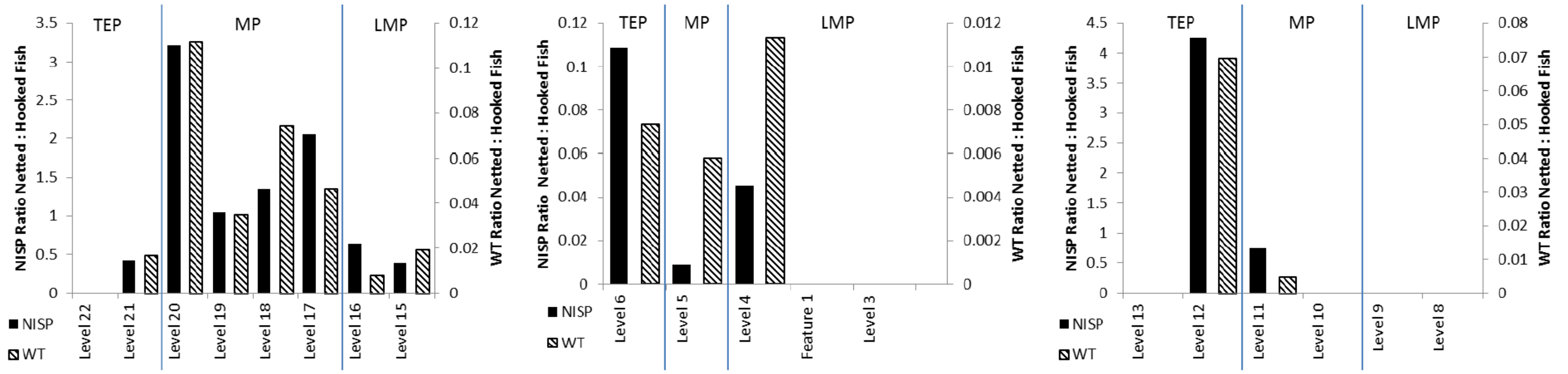
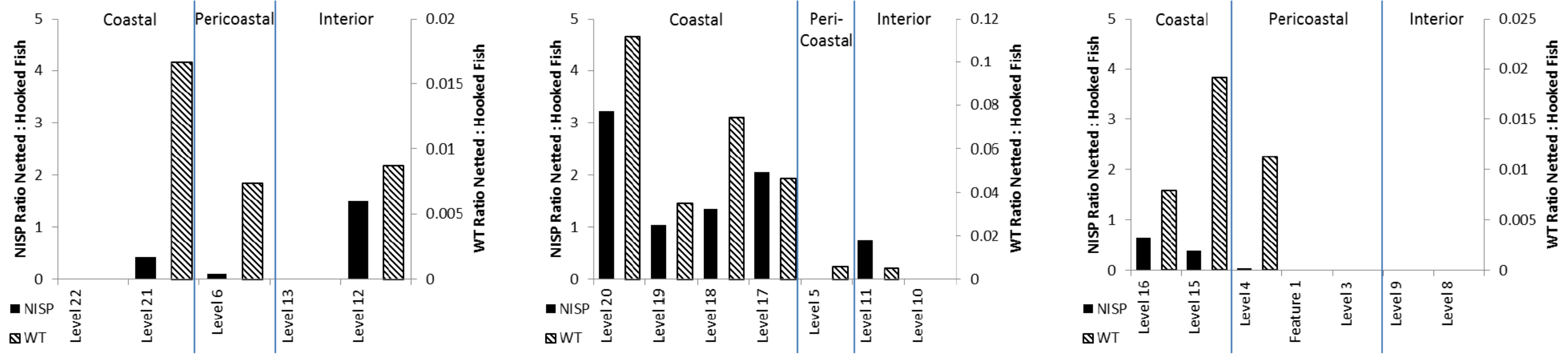


Figure 6.25 Bar chart of common net-caught versus hook-caught taxa recovered in floated samples, ratio calculated by NISP and by weight (WT) from the terminal Early Period (left), Middle Period (middle), and late Middle Period (right). Ratio is plotted by excavation level for bone NISP (solid black bar) and bone weight (striped bar). Site attribution is indicated at the top and separated by a vertical blue line.



These results suggest an increased contribution of net-caught taxa relative to hook-caught taxa during the Middle Period. However, consistent with an increase in fish size during the late Middle Period, there is a significant decrease in the ratio of net-caught taxa relative to hook-caught taxa during this period. This broad temporal trend is clearly reflected at the Coastal site (see Figure 6.24), which has by far the greater quantity of fish remains; however, it is contrasted at both the Pericoastal and the Interior site. This indicates that despite a highly significant temporal trend towards net-caught taxa during the Middle Period, a fair amount of spatial variability is evident as well.

Bar charts in Figure 6.25 illustrate the ratio of net-caught fish to hook-caught fish, based on bone NISP and bone weight, for each sample assemblage from terminal Early Period, Middle Period, and late Middle Period contexts. These charts suggest substantial across-space variation within each temporal period. I used a one-way ANOVA to evaluate whether differences between site assemblages were consistent through time. The ratio of net-caught fish to hook-caught fish recovered from all temporal periods at the Coastal site, Pericoastal site, and Interior site is marginally significant by bone weight (F=3.447, *d.f.*=2, p=0.057) but not by bone NISP (F=2.460, *d.f.*=2, p=0.117). Tukey post-hoc comparisons of the three sites suggests that the ratio of net-caught fish to hook-caught fish in assemblages from the Coastal site is higher than in assemblages from the Pericoastal site by bone NISP (p=0.101) and by bone weight (p=0.094); however, these differences are not statistically significant. Comparison between assemblages from the Coastal site and the Interior site also suggests a meaningful, albeit not statistically significant, pattern in the ratio of net-caught fish to hook-caught fish. It appears that this ratio is higher at the Coastal site than at the Interior by bone weight (p=0.110); however, there is no difference between assemblages from the Coastal site and the Interior site by bone NISP (*p*=0.513). Additional comparison between assemblages from the Pericoastal site and assemblages from the Interior site indicates no significant difference in the ratio of net-caught fish to hook-caught fish at these two sites by bone NISP (*p*=0.544) or by bone weight (*p*=0.981).

These results document consistent spatial variation in the relative abundance of commonly net-caught fish versus commonly hook-caught fish represented in assemblages from the Coastal, Pericoastal, and Interior sites. There is a significant decrease in the abundance of net-caught taxa relative to the abundance of hook-caught taxa transported away from the coast to the Pericoastal and Interior sites. This suggests that throughout all temporal periods people preferentially transported hook-caught fish taxa one kilometer up the watershed to the Pericoastal site and three kilometers up the watershed to the Interior site.

***Spear-Caught Fish versus Hook-Caught Fish*.** The two preceding analyses fail to consider the relative contribution of cartilaginous fish, such as sharks and rays, due to individual variation in the size of their vertebral centra and because these taxa are not typically net-caught or hook-caught taxa. Indeed the mouth structure of these large-bodied fish limits the effectiveness of hook and line fishing (Bertrando and McKenzie 2011:172). Ethnohistoric documents indicate that sharks and rays were commonly acquired through spear fishing (Hudson and Blackburn 1982); although they may have also been acquired in nets deployed in their preferred closed water sandy bottom habitats. Experimental studies suggest that spear fishing is most effective when large targets are available in proximity to the fisher or in a closed-setting fishing (Bertrando and McKenzie 2011:172). In addition to Pacific angel sharks, hound sharks, shovelnose guitarfish, California thornbacks, round stingrays, and California bat rays likely acquired by spears, I include California barracuda.

Ethnohistoric records clearly indicate that the Island Chumash captured barracuda by spear or harpoon thrown from watercraft (Hudson and Blackburn 1982). I calculate the ratio of spear-caught to hook-caught fish taxa based on the total bone NISP and weight of these seven commonly spear-caught taxa in each sample relative to the total bone NISP and weight of primarily hook-caught taxa identified in the preceding section: rockfish, cabezon, sheephead, lingcod, and croakers.

Bar charts in Figure 6.26 illustrate the ratio of spear-caught fish to hook-caught fish, based on bone NISP and bone weight, for each sample assemblage from the Coastal, Pericoastal, and Interior sites. These charts suggest substantial diachronic variation in the relative contribution of spear-caught fish to hook-caught fish at each site. As I noted earlier, the overall density of fish remains is significantly lower at the Interior site than at the Coastal or Pericoastal site. I used a one-way ANOVA to evaluate whether differences in this ratio between assemblages attributed to each temporal period (from all three sites) are statistically significant. The ratio of spear-caught fish to hook-caught fish recovered from terminal Early Period, Middle Period, and late Middle Period contexts differed marginally by bone weight (F=3.241, *d.f.*=2, p=0.066) and not at all by bone NISP (F=2.211, *d.f.*=2, p=0.142). The striking difference in significance based on the two different measures, bone NISP and bone weight is expected. The much larger vertebrae of sharks and rays that comprise the speared taxa are overrepresented in weight and underrepresented in NISP. I will continue to discuss both measures for the purpose of this analysis. Tukey post-hoc comparisons of the three temporal periods indicate that the ratio of spear-caught fish to hook-caught fish in terminal Early Period assemblages is significantly higher than the ratio of spear-caught fish to hook-caught fish in Middle Period assemblages by bone weight (p=0.043) but not by bone NISP (*p*=0.209). Comparison between terminal Early Period and late Middle Period assemblages also indicates that the ratio of spear-caught fish to hook-caught fish in terminal Early Period assemblages is marginally higher than in the late Middle Period assemblages by bone weight (*p*=0.073) and not at all by bone NISP (*p*=0.157). There is no statistical difference in the ratio of spear-caught fish to hook-caught fish recovered from Middle Period and late Middle Period assemblages by bone weight (*p*=0.958) or by bone NISP (*p*=0.980).

These results document a significant decrease in the contribution of spear-caught fish to hook-caught fish during the Middle Period that persists through the late Middle Period. This broad temporal trend is clearly reflected at the Coastal site (see Figure 6.26), which has by far the greatest quantity of fish remains; however, this pattern is reversed at both the Pericoastal and the Interior site. This indicates that despite a highly significant temporal trend towards hook-caught taxa during the Middle Period, a fair amount of spatial variability is evident as well.

Bar charts in Figure 6.27 illustrate the ratio of spear-caught fish to hook-caught fish, based on bone weight and bone NISP, for each sample assemblage from terminal Early Period, Middle Period, and late Middle Period contexts. These figures suggest substantial variation across space within each temporal period. Unfortunately due to the small number of assemblages from each site attributed to each temporal period, it is not possible to test the statistical significance of spatial variation within a single temporal period. To overcome this, I used a one-way ANOVA to evaluate whether differences between site assemblages were consistent throughout all temporal periods. The results of this test indicate that the ratio of spear-caught fish to hook-caught fish recovered from all temporal periods at the Coastal site, Pericoastal site, and Interior site differ marginally by bone weight (*F*=2.543, *d.f.*=2, *p*=0.110) and not at all by bone NISP (*F*=1.581, *d.f.*=2, *p*=0.236). It is clear that the significant spatial patterns evident in Figure 6.27 are obscured in this analysis by greater temporal variation. Qualitative assessment suggests that the ratio of spear-caught fish to hook-caught fish was highest at the Coastal site during the terminal Early Period and late Middle Period, but higher at the Interior site during the Middle Period. The ratio of spear-caught fish to hook-caught fish appears to be consistently quite low at the Pericoastal site. This qualitative assessment suggests strong spatial patterns in the overall abundance of spear-caught fish relative to hook-caught fish that vary through time. It is impossible to discern a broad diachronic trend based on this dataset alone.

Broad Trends in Fish Size and Method of Capture. The preceding analyses demonstrate significant diachronic variation in the size of fish captured during terminal Early Period, Middle Period, and late Middle Period and the likely method of capture used to acquire these important food resources. Exploitation of large bodied, spear caught taxa contribute variably through time and inconsistently across space. There are indications that these taxa contributed significantly to assemblages at the Coastal and Interior site (in different temporal periods), but not at the Pericoastal site (in any temporal period). However, it is clear that they were exploited most heavily at the Coastal site during the terminal Early Period. As with fish diversity, this may reflect persistent differences in site function, duration of occupation, or both that existed between the smaller Pericoastal site and the larger Coastal and Interior sites.

Medium bodied, hook-caught fish taxa dominate the bony fish assemblage recovered from terminal Early Period contexts at all sites. Smaller, net caught fish occur in much greater quantities during the Middle Period occupation than during the terminal Early Period or late Middle Period at site; however there is a clear increase in the frequency of these taxa at the Coastal site. An apparent decrease in the exploitation of large-bodied spear caught taxa accompanies this trend at both the Coastal and Pericoastal sites during the Middle Period. This pattern is reversed during the late Middle Period, with a significant increase in the size of fish exploited. Small, net-caught fish do not drop out of the late Middle assemblages completely, but exploitation of larger bodied hook-caught increases significantly. Fish taxa exploited during the late Middle Period tend to be even larger than those exploited prior to the importance of small, net caught taxa, during the terminal Early Period. These highly significant temporal trends in the fish assemblage are most evident at the Coastal site, but are less consistent at the Pericoastal and Interior sites, which are heavily influenced by a persistent bias towards transportation of larger, hook caught fish away from the coast.

Figure 6.26 Bar chart of common spear-caught versus hook-caught taxa recovered in floated samples, ratio calculated by NISP and by weight (WT) from the Coastal site (left), Pericoastal site (middle), and Interior site (right). Ratio is plotted by excavation level for bone NISP (solid black bar) and bone weight (striped bar). Temporal period attribution is indicated at the top and periods are separated by a vertical blue line.

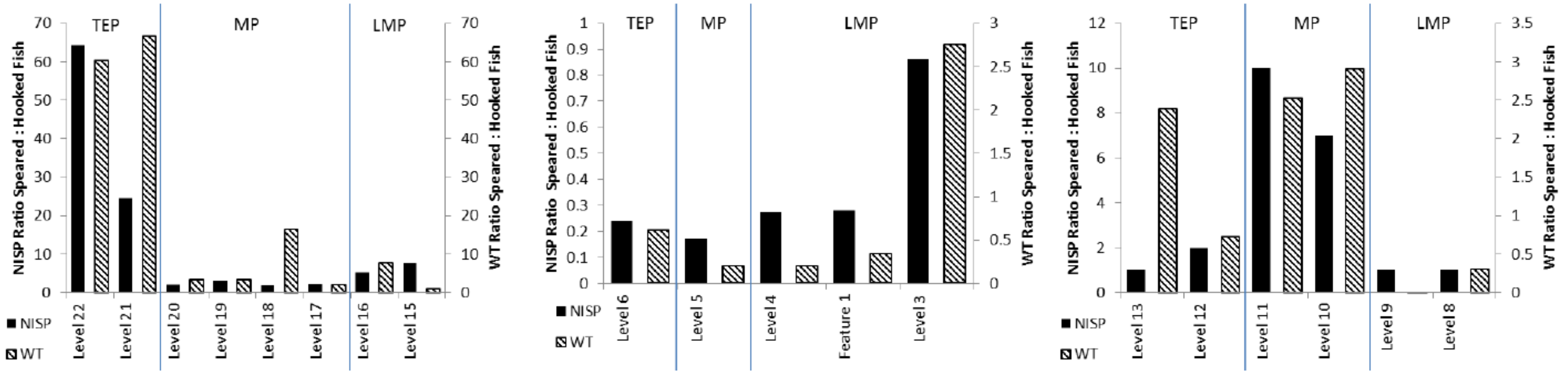
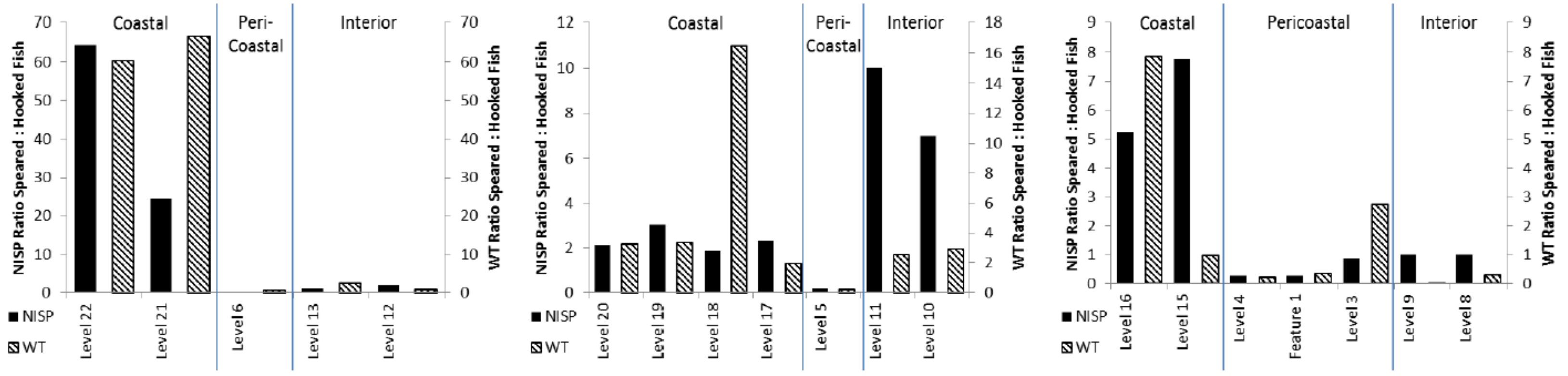


Figure 6.27 Bar chart of common spear-caught versus hook-caught taxa recovered in floated samples, ratio calculated by NISP and by weight (WT) from the terminal Early Period (left), Middle Period (middle), and late Middle Period (right). Ratio is plotted by excavation level for bone NISP (solid black bar) and bone weight (striped bar). Site attribution is indicated at the top and separated by a vertical blue line.



Quantitative Analysis of the Invertebrate Assemblages

The preceding analysis effectively demonstrates significant temporal and spatial variation that characterized the exploitation of vertebrate animal food resources—in terms of quantity, relative class importance, diversity, and technology—from the terminal Early Period to the late Middle Period. Similarly, there are also notable trends in the density, diversity, and size of invertebrate animal food resources exploited at each of the three sites through time.

Abundance (Density) of Invertebrate Remains

In order to evaluate patterns in shellfish abundance across space and through time, as well as correct for comparison between large and small samples, I standardized shell weight and shell MNI recovered from each sample by the original soil volume of the sample. I rely on box plots to explore broad patterns in shell weight density condensed by site and temporal period. I supplement interpretation of the broad trends with reference to bar charts that represent individual samples by site and spatial variation by temporal period.

Figure 6.28 Box plots of standardized shell density by temporal period. Shell weight (WT) density is graphed on the left and shell MNI density is graphed on the right. Values on Y-axis are log transformed. Temporal periods represented include terminal Early Period (TEP), Middle Period (MP), and late Middle Period (LMP).

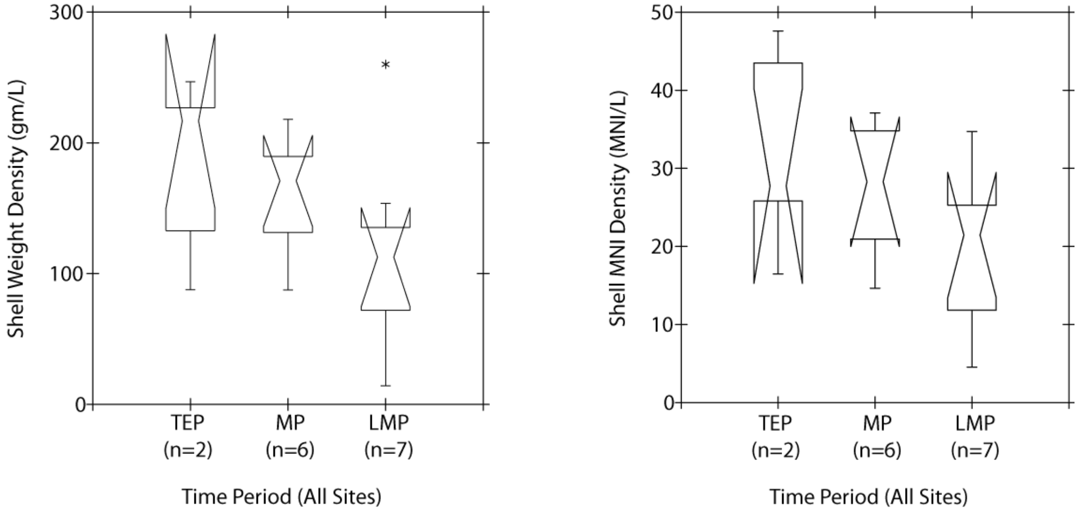


Figure 6.29 Bar chart of shell weight (WT) density (grams/liter) recovered from floated samples at the Coastal site. Temporal periods represented include terminal Early Period (TEP) n=2, Middle Period (MP) n=4, and late Middle Period (LMP) n=2.

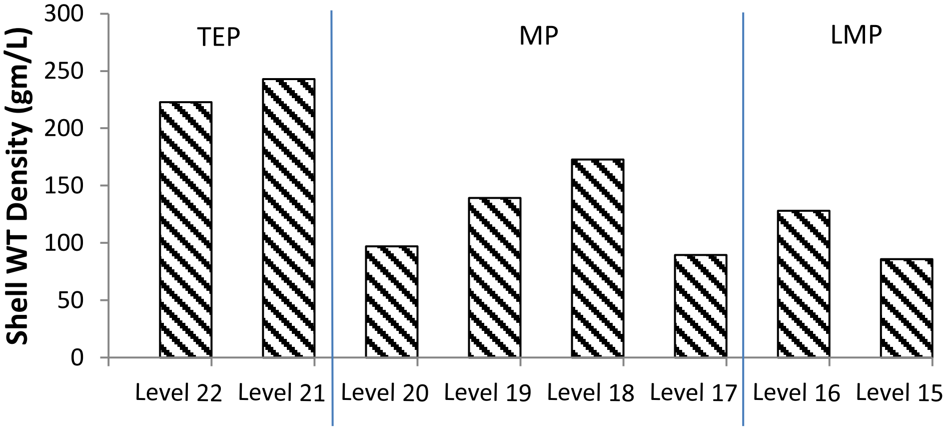


Figure 6.30 Bar chart of shell weight (WT) density (grams/liter) recovered from floated samples at the Pericoastal site. Temporal periods represented include terminal Early Period (TEP) n=1, Middle Period (MP) n=1, and late Middle Period (LMP) n=3.

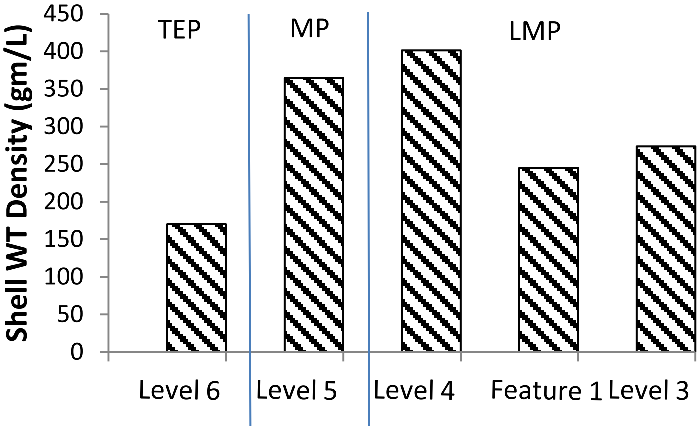
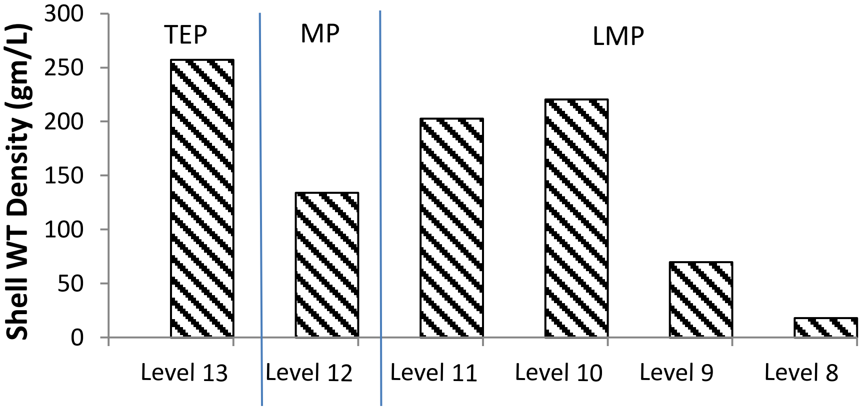


Figure 6.31 Bar chart of shell weight (wt) density (grams/liter) recovered from floated samples at the Interior site. Temporal periods represented include terminal Early Period (TEP) n=2, Middle Period (MP) n=2, and late Middle Period (LMP) n=2.



Broad Temporal Trends in Invertebrate Abundance. In Figure 6.28 box plots illustrate differences in the overall abundance of invertebrate remains relative to soil volume in assemblages from each temporal period. The shellfish assemblages from all terminal Early Period contexts contain a higher median density of invertebrate remains than do assemblages from later Middle Period and late Middle Period contexts. A consistent, but not significant, decline in the overall abundance of invertebrate remains is evident moving from the earliest terminal Early Period occupation to the latest late Middle Period occupation. Though, quite evident, the decreased abundance of invertebrate remains between assemblages from terminal Early Period and late Middle Period contexts is only marginally significant (*p*=0.140, *d.f.*=1). In this analysis, a great deal of spatial variation between the site assemblages within a given temporal period (see Figures 6.29 - 6.31) obscures broad diachronic variation evident when assemblages are grouped by temporal period. Due to the small sample size attributable to each temporal period at each of the three sites, it is not possible to test the statistical significance of diachronic variation in shell density based on intrasite assemblages alone. Qualitative assessment based on the bar graphs suggests that shell density was highest during the terminal Early Period at the Coastal site and Interior sites, with evidence of substantial decreases through time at these two locations, but was highest during the Middle Period and late Middle Period at the Pericoastal site. Similar diachronic trends evident at the Coastal and Interior site contrast with the patterns evident at the Pericoastal site. This suggests a persistent difference in site function, seasonality of resource use, or both existed between the larger Coastal and Interior sites and the smaller Pericoastal site throughout the Middle and late Middle Period.

Figure 6.32 Bar chart of shell weight (WT) density (grams/liter) recovered in floated samples from terminal Early Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.

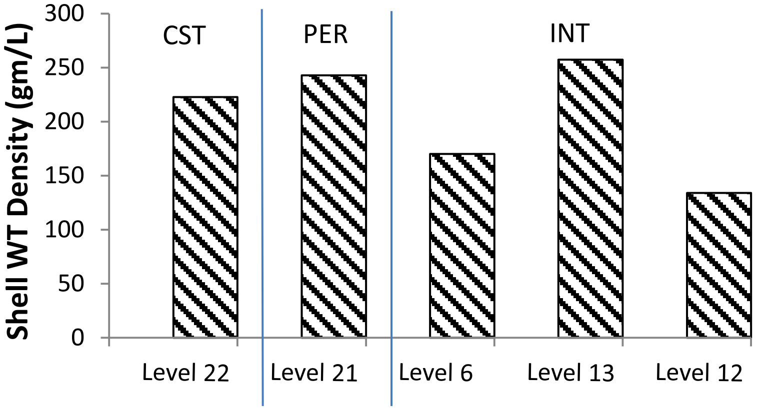


Figure 6.33 Bar chart of shell weight (WT) density (grams/liter) recovered in floated samples from Middle Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.

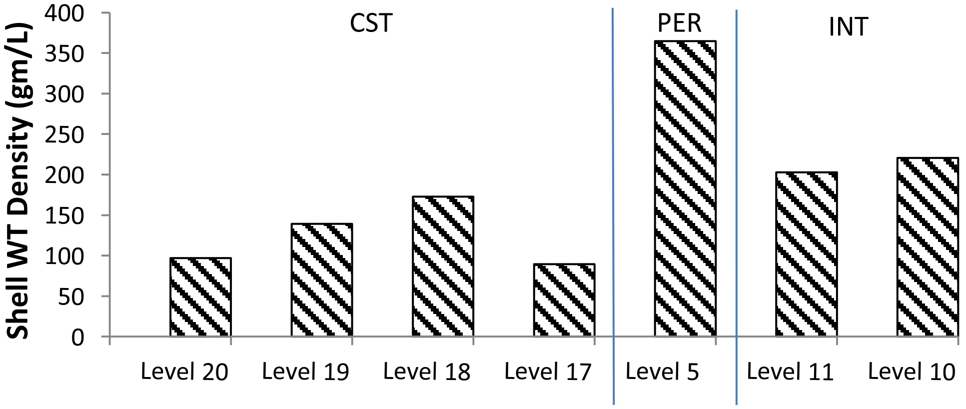


Figure 6.34 Bar chart of shell weight (WT) density (grams/liter) recovered in floated samples from late Middle Period contexts at all three sites. Sites are indicated as Coastal (CST), Pericoastal (PER), and Interior (INT) and separated by a thin blue line.

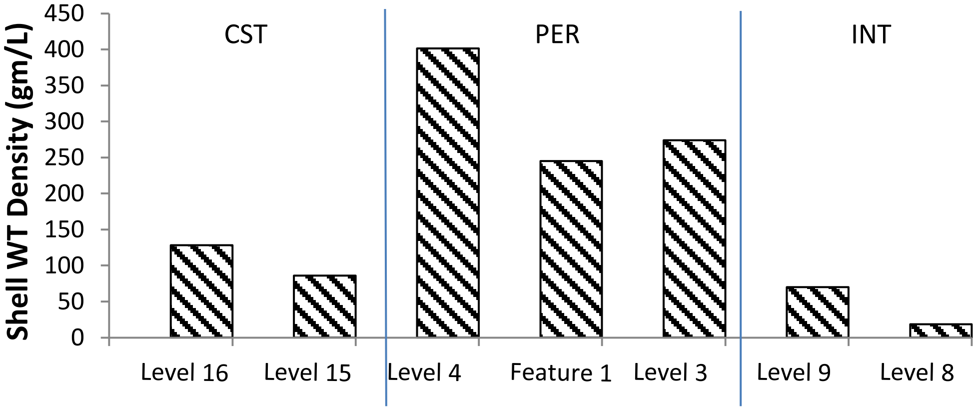
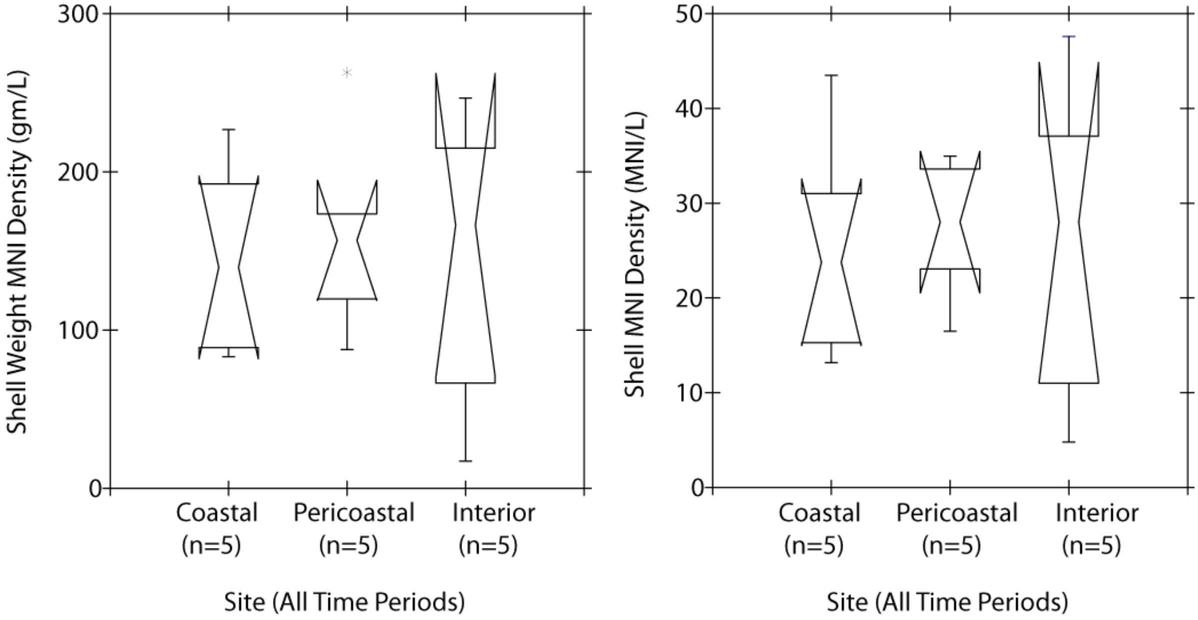


Figure 6.35 Box plots of standardized shell density by site. Shell WT (weight) density is graphed on the left and shell MNI density is graphed on the right. Values on Y-axis are log transformed.



Broad Spatial Trends in Invertebrate Abundance. Despite an apparent increase in the mean overall abundance of invertebrate remains relative to soil volume at the Pericoastal and Interior sites, the box plots in Figure 6.35 do not reveal any significant differences between the three sites. In this analysis, strong diachronic variation documented at each site obscures broad spatial patterns between sites when temporal periods are condensed. Due to the small number of samples attributed to each temporal period at each of the three sites, it is not possible to test the statistical significance of spatial variation in shell density by temporal period. However qualitative assessment of assemblages by temporal period in Figures Figures 6.32-6.34 suggests that the relative density of invertebrate remains varies greatly between the three sites within individual temporal periods.

Qualitative assessment based on the bar graphs (Figures 6.32-6.34) suggests that shell density was most similar at all three sites during the terminal Early Period with evidence of substantial peaks at the Pericoastal site during the Middle Period and late Middle Period. Shellfish exploitation appears to be consistently lower and more similar at the Coastal and Interior sites during these two later periods of site occupation. Comparable to evidence from the vertebrate assemblage, this pattern affirms a persistent difference in site function, seasonality of resource use, or both existed between the larger Coastal and Interior sites and the smaller Pericoastal site throughout the Middle and late Middle Period.

Diversity of Shellfish Remains

In this section, I consider measures of shellfish assemblage diversity that allow for effective evaluation of land use patterns across space as well as specialization or diversification in diet breadth through time. I focus specifically on *food* taxa, excluding all identified taxa unlikely to represent food resources. The goal of this analysis is to identify how the composition of shellfish species exploited through time and across space changed in relationship to the broad trends identified previously.

DIVERS Computer Simulation. I use Kintigh′s (1984, 1989) DIVERS computer simulation to evaluate shellfish species diversity and control for potential effects of sample size. I rely on shell weight as the basic quantitative measure that represents the contribution of each species. In multiple iterations of this analysis, I verified that the amount of California mussel included in every sample overwhelmed variation in the diversity of taxa, represented by richness and evenness, included in each shellfish assemblage. Therefore, in the analysis presented here, I evaluate diversity in the non-mussel assemblage. I consider these results relative to variation in mussel shell density for each sample. Figures 6.38, 6.39, and 6.40 plot calculated richness and evenness by sample size. I do not directly compare the diversity of archaeological shellfish assemblages to each other; rather I compare the archaeological shellfish assemblages to expected values simulated for the same size assemblage (Kintigh 1984, 1989).

Figure 6.36. Bar chart of California mussel density by weight (grams/liter) and by MNI (MNI/liter) recovered in floated samples from all temporal periods at the Coastal site. Density is graphed by excavation level for shell weight (solid black bar) and shell MNI (striped bar) to indicate relative variation in abundance. Samples from terminal Early Period contexts are denote by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.

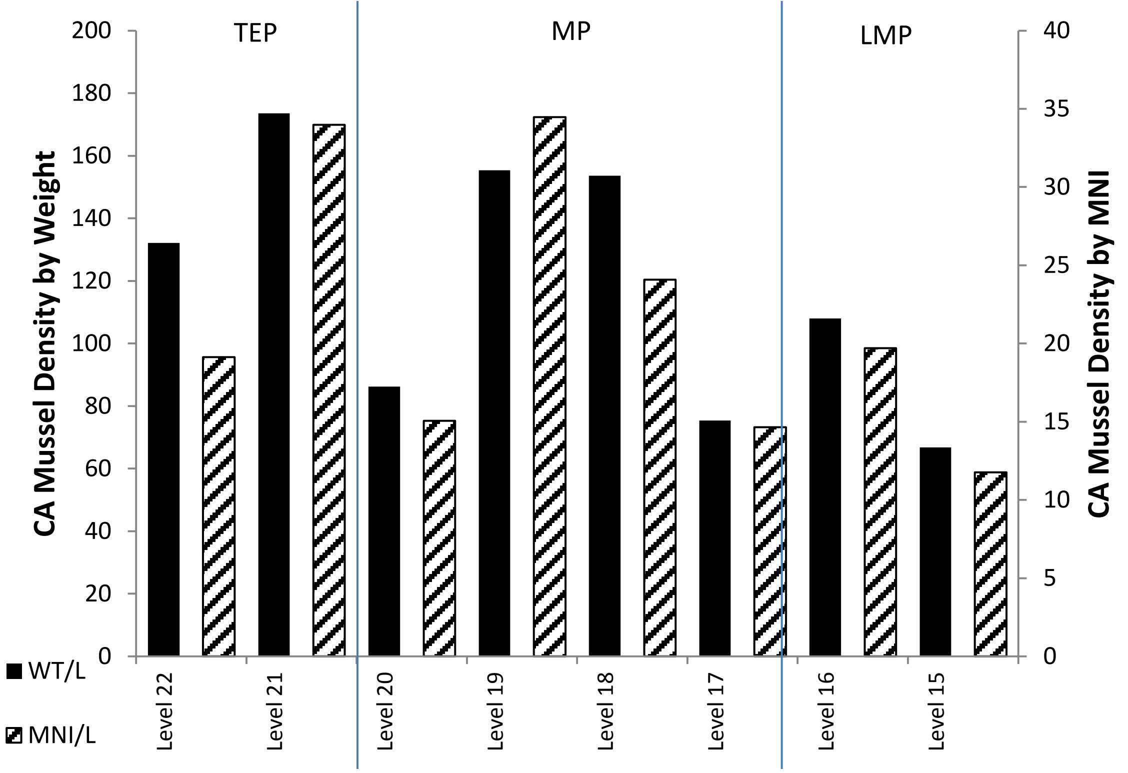
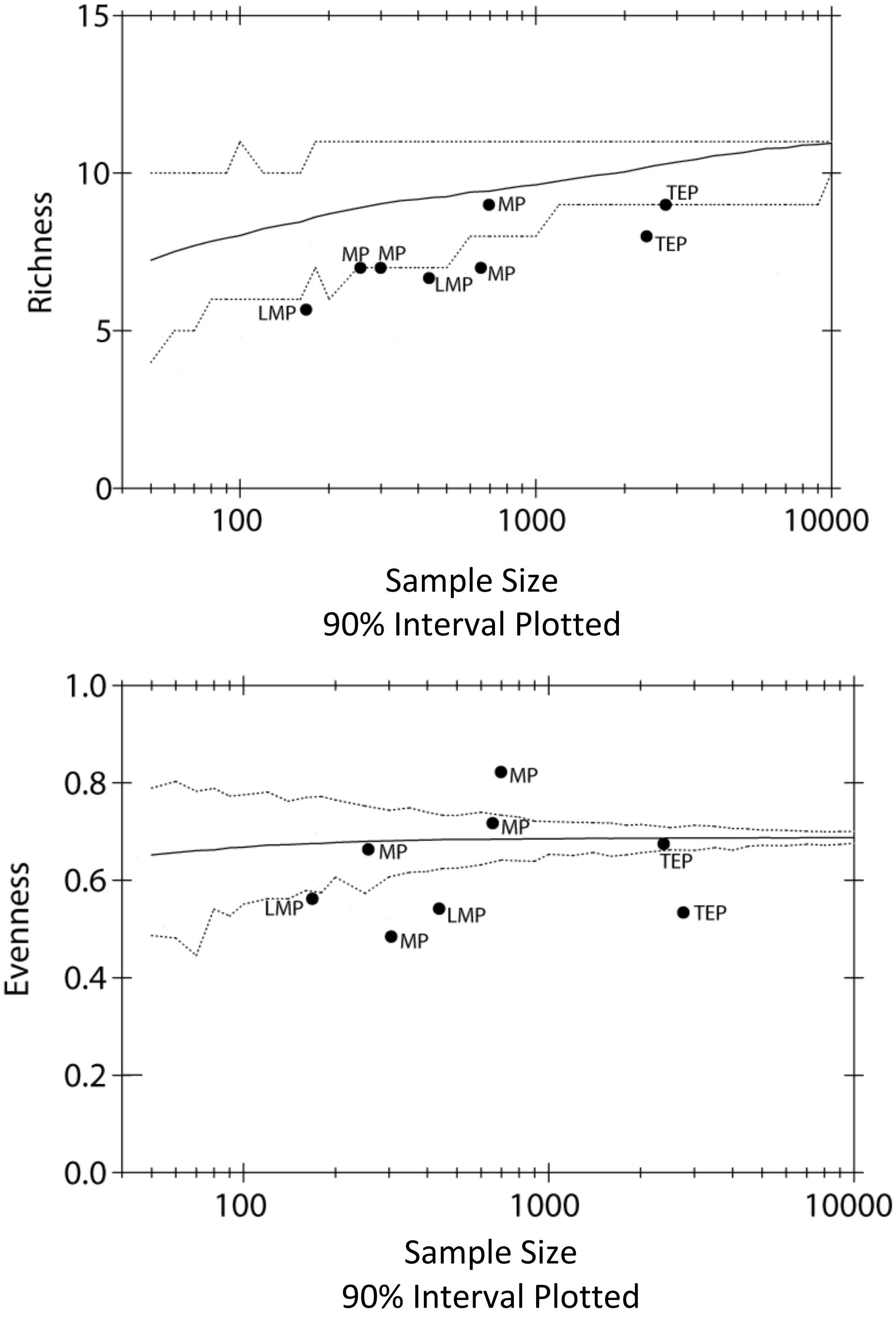


Figure 6.37 DIVERS richness (top) and evenness (bottom) plots of all identified shellfish taxa (other than California mussel), based on shell weight at the Coastal site. The solid centerline in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dotted lines above and below the centerline represent the 95% confidence interval for expected values. Samples from terminal Early Period contexts are denote by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.



Evaluation of Individual Samples at the Coastal Site. The two terminal Early Period shellfish assemblages from the Coastal site are quite different from each other. The sample recovered from Level 22 falls just within the lowest richness value expected, but well below the expected evenness values (Figure 6.37). In contrast, the sample recovered from Level 21 falls below the expected range of richness values, but within the range of expected evenness values, given its sample size. This indicates statistically significant variability in the diversity of shellfish species exploited at the Coastal site during the terminal Early Period. When considered in relation to the density of California mussel exploited during the terminal Early Period this variability in the diversity of other taxa exploited appears to be a function of the importance of California mussel. The shellfish assemblage from Level 22 is characterized by a lower density of California mussel (see Figure 6.36) and a wider range of other edible taxa that are not exploited equitably. There is a clear preference for black abalone, sea urchin, and red abalone in this assemblage. In contrast, the shellfish assemblage from Level 21 is characterized by high density of California mussel and a slightly more narrow range of other edible taxa, which are exploited significantly more equitably. California mussel appears to become more important as other large species decrease, or drop out of the assemblage. This finding indicates a significant shift in the exploitation of shellfish at the end of the terminal Early Period.

The diversity of shellfish in Middle Period assemblages is also variable, albeit less so than during the terminal Early Period. Three of the four assemblages from this temporal period fall right at or within the confidence interval, indicating that these samples are as rich as expected based on their respective sample sizes. The shellfish assemblage from Level 18 is the only Middle Period assemblage that falls below the expected range of richness values.

Evenness values calculated indicate significant Middle Period increase in the equitably in the exploitation of non-mussel shellfish taxa at the Coastal site. As with the terminal Early Period samples, variation in the diversity of other shellfish species correlates with variation in the density of California mussel. The shellfish assemblage from Level 20 is characterized by a lower density of California mussel, relative to the terminal Early Period assemblage from Level 21 and the Middle Period assemblage from Level 19, (see Figure 6.36) and an expected richness of other edible taxa that are not exploited equally. Pismo clam and black abalone appear more important than other non-mussel species in this assemblage. The shellfish assemblages from Levels 19 and 18 are characterized by a high density of California mussel and an expected richness of other edible taxa (in Level 19) and a lower than expected range of other edible taxa (in Level 18). In both of these samples, the non-mussel taxa are exploited as equitably as expected. The last shellfish assemblage recovered from Middle Period contexts (Level 17) is quite different from the other Middle Period assemblages. In this sample, the density of California mussel declines sharply as the diversity of other edible taxa increases significantly. This assemblage indicates that people collected a wider range of shellfish taxa, significantly more equitably than expected at the end of Middle Period site occupation.

A distinct pattern of increasing diversity in the shellfish assemblage throughout the Middle Period is completely reversed during the late Middle Period occupation at the Coastal site. Both late Middle Period shellfish assemblages fall below the confidence intervals, indicating that these assemblages are significantly less rich and less evenly distributed than expected. This decline in overall diversity of the non-mussel shellfish assemblage accompanies a similar decline in the density of California mussel. This shift suggests a decline either in the relative importance of shellfish or perhaps less intensive occupation at the Coastal site during the late Middle Period.

Overall, the results of DIVERS considered alongside the density of California mussel, indicate that the diversity of shellfish species exploited at the Coastal site varies significantly through time, and even within individual temporal periods. There is a striking increase in the importance of California mussel and equitability in the exploitation of other shellfish taxa at the end of the terminal Early Period occupation, followed by increasing diversity that persists through the Middle Period before decreasing significantly during the late Middle Period. It is apparent that the Middle Period inhabitants of the Coastal site exploited a relatively wide range of non-mussel shellfish taxa with increasing equitability. Middle Period shellfish diversity reaches an apex in the assemblage from Level 17, as the density of California mussel plummets. These results also suggest that during the late Middle Period occupation at the Coastal site, people exploited significantly fewer shellfish taxa than expected, biased towards a few specific species, and fewer California mussels.

Figure 6.38 Bar chart of California mussel density by weight (grams/liter) and by MNI (MNI/liter) recovered in floated samples from all temporal periods at the Pericoastal site. Density is graphed by excavation level for shell weight (solid black bar) and shell MNI (striped bar) to indicate relative variation in abundance.

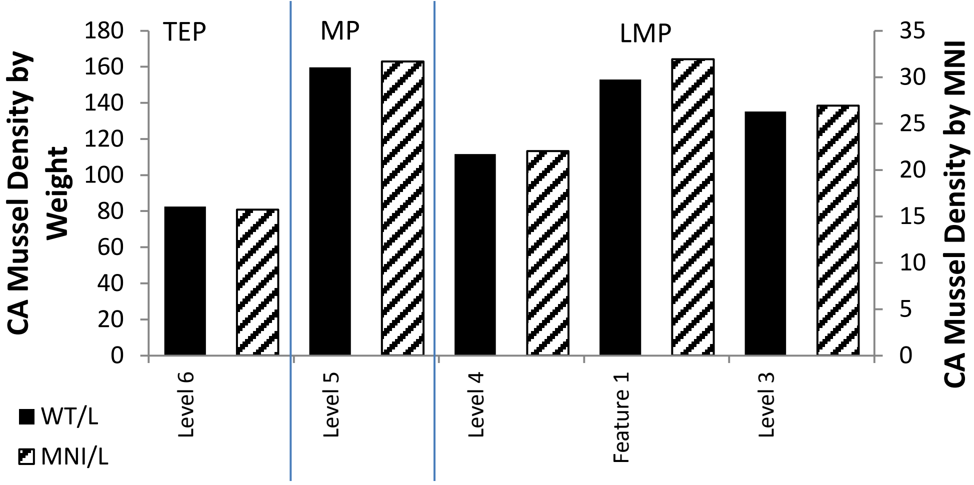
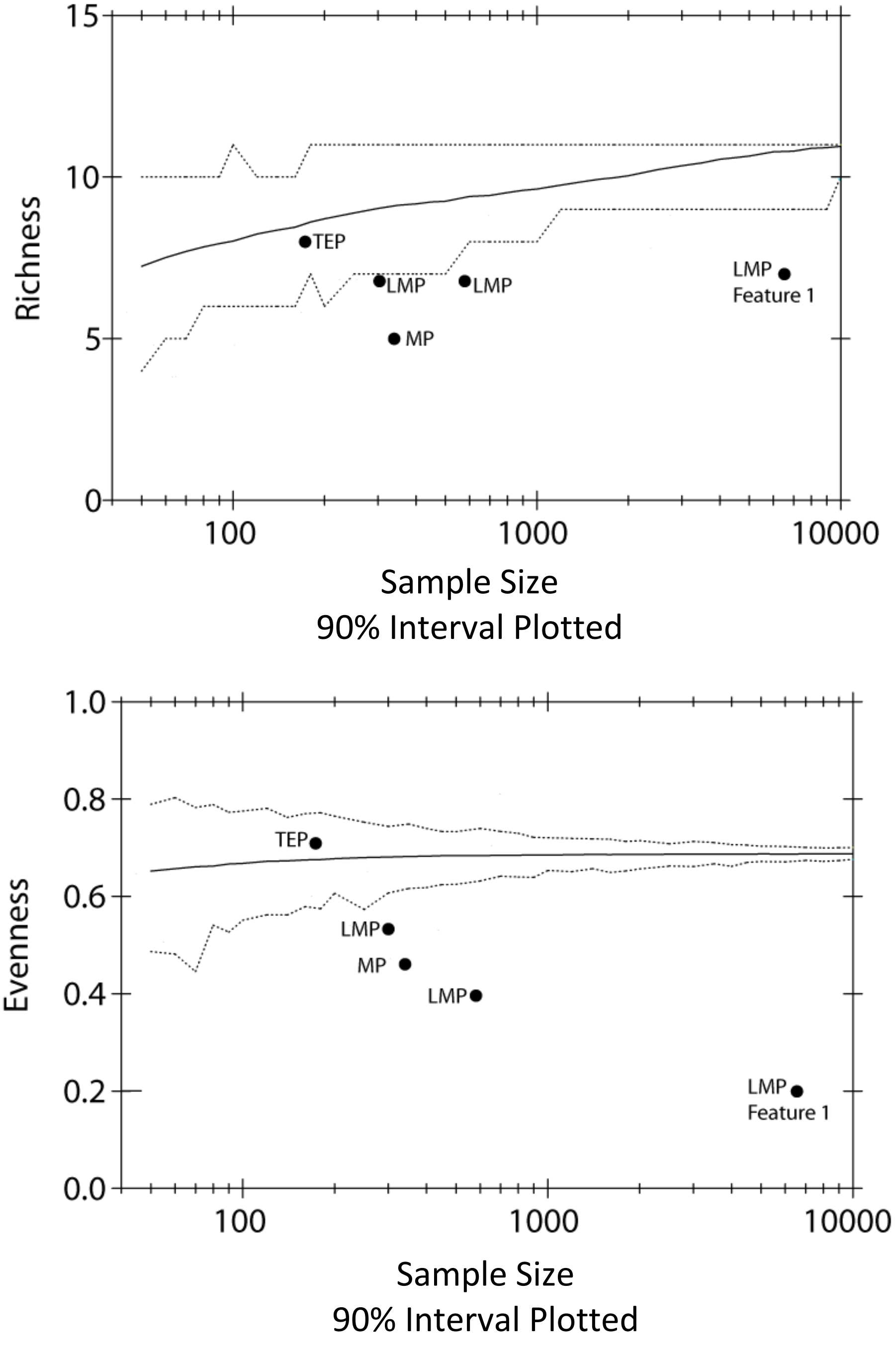


Figure 6.39 DIVERS richness (top) and evenness (bottom) plots of all identified shellfish taxa (other than California mussel), based on shell WT at the Pericoastal site. The solid centerline in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dotted lines above and below the centerline represent the 95% confidence interval for expected values. Samples from terminal Early Period contexts are denote by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.



Diachronic Trends at the Pericoastal Site. Richness and evenness values calculated for the terminal Early Period shellfish assemblage from the Pericoastal fall within the confidence intervals, indicating that this assemblage is as rich and as evenly distributed as expected (Figure 6.39). This relatively high diversity of non-mussel species is accompanied by a very low density of California mussel. It is clear that the terminal Early Period inhabitants at the Pericoastal site exploited a relatively small quantity of California mussel along with a fairly wide range of other edible taxa, exploited equitably. These patterns of shellfish exploitation suggest that very few shellfish were transported to the Pericoastal site either due to low intensity occupation or low importance of shellfish during the terminal Early Period. Furthermore, the specific composition of the shellfish taxa in the assemblage suggests that California mussel was either not as available or was not as preferred during the this temporal period, evidence by marked diversity in the species transported to the site.

This pattern sharply contrasts with the shellfish assemblage from Middle Period context at the Pericoastal site. Significant decrease in the diversity (both richness and evenness are significantly lower than expected) of non-mussel taxa complements a substantial increase in the density of California mussel (Figure 6.39). Of the non-mussel taxa exploited there is a strong bias towards black turban snails and black abalone. Overall, these results indicate during the Middle Period, people transported a greater quantity of fewer shellfish species to the Pericoastal site, with a specific focus on California mussel supplemented by black turban snails and black abalone. This provides clear evidence of specialized exploitation of a few shellfish taxa during the Middle Period.

This pattern of shellfish exploitation persists into the late Middle Period. Despite some decline in the density of California mussel (Figure 6.39), which correlates with a similar decline in the overall density of shellfish, all three samples from late Middle Period contexts at the Pericoastal site demonstrate significantly lower richness and evenness values than expected for their samples sizes. Of the non-mussel taxa exploited, there is a strong bias towards Pismo clam and black turban snails in the assemblage from Level 4, Pismo clam and black abalone in the assemblage from Feature 1, and just Pismo clam in Level 3. The dramatic increase in the importance of this sandy beach clam during this temporal period may be related to a recent recruitment event that introduced great quantities of the taxon to the beach nearby (see Thakar 2011). Overall, these results indicate that during the late Middle Period, people transported a slightly lower quantity (relative to the preceding temporal period) of a narrow range of shellfish taxa to the Pericoastal site. The shellfish assemblage reflects a specific focus on California mussel (Figure 6.39) supplemented primarily by Pismo clam, black turban snails, and black abalone. These patterns provide clear evidence of continued specialized exploitation of a few shellfish taxa during the late Middle Period.

Overall, the results of DIVERS considered alongside the density of California mussel, indicate that the diversity of shellfish species exploited at the Pericoastal site varied significantly through time, particularly between the terminal Early Period and Middle Period occupations. There is a striking increase in the importance of California mussel and decrease in the equitability of other shellfish taxa after the terminal Early Period occupation. The relatively low density of diverse shellfish taxa exploited in the earliest assemblage gives way in the Middle Period to a substantially higher density of just a few shellfish taxa, a strategy that persists throughout the late Middle Period.

Figure 6.40 DIVERS richness (top) and evenness (bottom) plots of all identified shellfish taxa (other than California mussel), based on shell weight at the Interior site. The solid centerline in the DIVERS plots represents expected richness and evenness values based on 1000 simulated assemblages for each sample size. The dotted lines above and below the centerline represent the 95% confidence interval for expected values. Samples from terminal Early Period contexts are denote by TEP; samples from Middle Period contexts are denoted by MP; and samples from late Middle Period contexts are denoted by LMP.

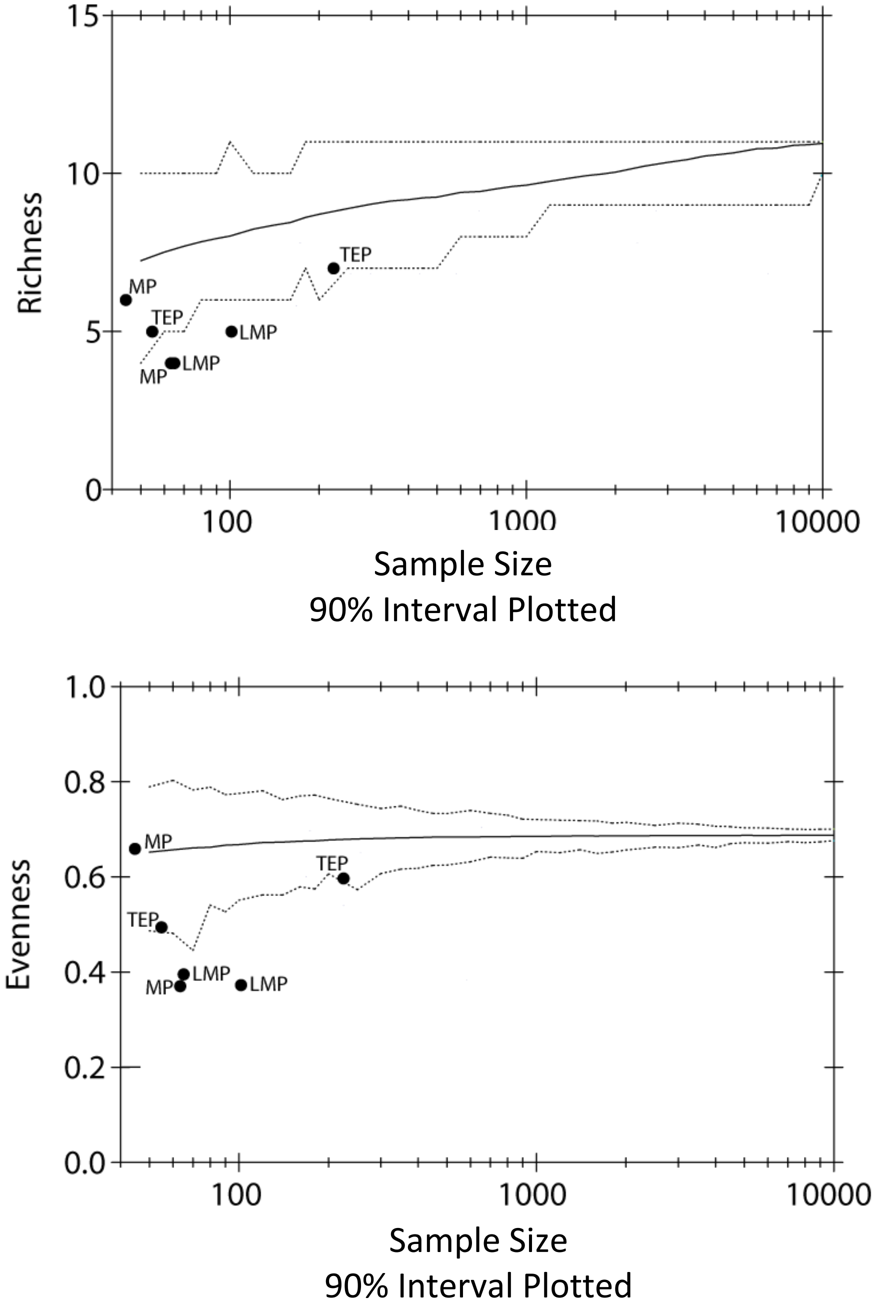
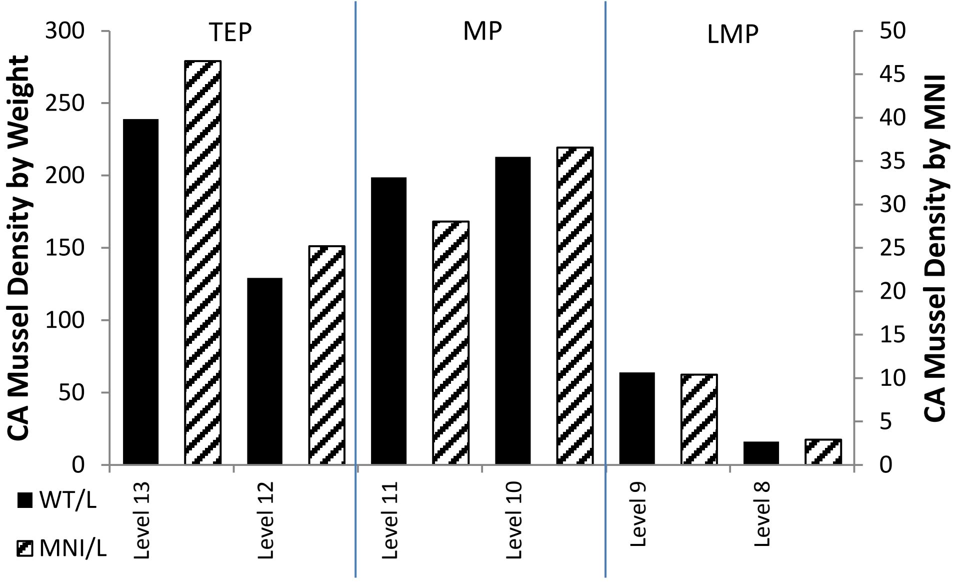


Figure 6.41 Bar chart of California mussel density by weight (grams/liter) and by MNI (MNI/liter) recovered in floated samples from all temporal periods at the Interior site. Density is graphed by excavation level for shell weight (solid black bar) and shell MNI (striped bar) to indicate relative variation in abundance.



Diachronic Trends at the Interior Site. The two shellfish assemblages from terminal Early Period contexts at the Interior site mirror terminal Early Period assemblages from the Pericoastal site. Richness and evenness values calculated for non-mussel shellfish taxa from Level 13 and Level 12 fall within the confidence intervals, indicating that these assemblages are as rich and evenly distributed as expected (Figure 6.40). The relatively high diversity of non-mussel species is accompanied by a relatively high density of California mussel. It is evident that when living at the Interior site, people transported a wide range of edible shellfish taxa relatively equitably, along with substantial quantities of California mussel (Figure 6.41). Overall, shellfish exploitation during this temporal period may reflect either a more intense occupation or a greater importance of a diverse array of shellfish than in subsequent periods of occupation.

This pattern sharply contrasts with the shellfish assemblage from Middle Period contexts at the Interior site. Indeed, the two Middle Period shellfish assemblages from the Interior site are also quite different from each other. The sample recovered from Level 11 falls well within the expected range of richness and evenness values, given its sample size (Figure 6.40). In contrast, the sample recovered from Level 10 falls below the expected range of richness and evenness values, given its sample size. This indicates statistically significant variability in the diversity of shellfish species exploited at the Interior site during the Middle Period. When considered in relation to the density of California mussel exploited during the terminal Early Period, this variability in the diversity of other taxa exploited appears correlated with the importance of California mussel. The shellfish assemblage from Level 11 is characterized by a lower density of California mussel (see Figure 6.41) and a wider range of other edible taxa, exploited equally. In contrast, the shellfish assemblage from Level 10 is characterized by higher density of California mussel and a narrower range of other edible taxa, which are exploited significantly less equitably. There is a clear preference for California mussel supplemented by black abalone in the assemblage from Level 10. This indicates a significant shift in the exploitation of shellfish at the end Middle Period occupation at the Interior site. An initially high diversity of shellfish and lower density of California mussel at the beginning of the Middle Period gives way to low diversity of shellfish (and emphasis on black abalone) and higher density of California mussel. This shift accompanies a broader trend toward decreased shell density, which suggests either a lower intensity occupation or decreased emphasis on shellfish during Middle Period occupation at the Interior site.

This trend towards decreasing abundance and diversity of shellfish transported to the Interior site persists and becomes more pronounced during the late Middle Period. Continued decline in the density of California mussel, which correlates with a similar decline in the overall density of shellfish, is evident in both late Middle Period samples. Both assemblages, from both Level 9 and Level 8, demonstrate significantly lower richness and evenness values than expected for their samples sizes. Of the non-mussel taxa exploited there is a strong bias towards black abalone and black turban snails in the assemblage from Level 9, as well as platform mussels in the assemblage from Level 8. Overall, these results indicate that during the late Middle Period people transported a much lower quantity, relative to the preceding period, of a narrow range of shellfish taxa to the Interior site, with a specific focus on California mussel supplemented primarily by black abalone, black turban snails, and platform mussels. This provides clear evidence of continued specialized exploitation of a few shellfish taxa during the late Middle Period.

The results of DIVERS considered alongside the density of California mussel, indicate that the diversity of shellfish species exploited at the Interior site varies significantly through time. There is an almost continuous decrease in the abundance of California mussel and diversity of other shellfish taxa after the terminal Early Period occupation. These results suggest that people living at the Interior site either became less dependent on marine invertebrate food resources through time or that they began to visit the Interior site less frequently, staying for shorter periods of time. It is not possible, based on this dataset alone, to determine whether decreased abundance and diversity of shellfish reflect increasingly lower intensity occupation or increasingly lower dependence on shellfish.

Broad Trends in Shellfish Diversity. Overall, the results of DIVERS considered alongside the density of California mussel, indicate that the diversity of shellfish species recovered from the Coastal, Pericoastal, and Interior sites varies through time and across space. Evaluation of individual samples within site contexts reveals that the overall richness and evenness of shellfish taxa exploited appears high during the terminal Early Period, variable during the Middle Period, and quite low during the late Middle Period. Thus, it is clear that an overall decrease in the diversity of shellfish exploited through time accompanies an apparent decrease in the overall quantity of shellfish exploited through time.

Despite this broad temporal trend, there is also evidence for substantial variation between the three site assemblages within individual temporal periods. During the terminal Early Period the broad temporal trend towards high shellfish diversity best characterizes the Pericoastal and Interior site, with some variability at the Coastal site. However, this high diversity of shellfish is supplemented by a variable contribution of California mussel, which is highest at the Interior site, slightly lower at the Coastal site, and much lower at the Pericoastal site.

During the Middle Period, the assemblages from the Coastal and Interior site stand out with respect to both relatively high diversity (measured by richness and equitability) of non-mussel shellfish exploited. People continue to exploit non-mussel taxa relatively equitably at the Coastal site until the late Middle Period. However, emphasis on a just a few shellfish taxa is apparent at the Pericoastal site and in the latest occupation at the Interior site during the Middle Period. People supplemented a lower diversity of shellfish taxa with more California mussel than previously exploited at the Pericoastal site. Nonetheless, the quantity of California mussel transported to the Pericoastal site remains much lower than the quantity of California mussel transported to the Interior site. These data provide clear evidence for increased variability in the abundance and diversity of shellfish taxa exploited across space during the Middle Period.

During the late Middle Period spatial variation pales in comparison to a precipitous decrease in the overall diversity and abundance of shellfish exploited, particularly at the Coastal and Interior sites. This broad temporal trend is evident despite substantial variation in the density of California mussel at each site, which is higher at the Pericoastal and Coastal site than at the Interior site. Indeed a substantially higher density of California mussel first evident in the Middle Period assemblages persists in late Middle Period assemblages at the Pericoastal site. This persistent difference between the larger Coastal and Interior sites and the smaller Pericoastal site affirms the previous assessment of variation in site function or seasonality during the late Middle Period. Nonetheless, the broad temporal trends suggest that during the late Middle Period people may have become less dependent on marine invertebrate food resources.

Size of Primary Shellfish Taxa Exploited

Given the incredible focus on mussel throughout all temporal periods and clear variation in the abundance of diversity of other shellfish taxa exploited across space and through time, it is necessary to consider how the physical characteristics of this important resource may have changed as well. Changes in shellfish size result from natural variations in water temperature, marine productivity, and turbidity, as well as other factors (Erlandson et al. 2008:2148). However, many researchers document reductions in the mean size of many shellfish populations related to heavy predation by humans and other large predators (Erlandson et al. 2008). Relying on direct measurement of the muscle attachment scar (MAS) visible on the interior of the California mussel shell near the umbo, I evalate spatial and temporal variation in mussel shell size (see Chapter 3 for discussion and evaluation of this method). Assisted by just one assistant, I measured 9,371 MASs from the three sites. We were consistently able to replicate each other's measurements, lending confidence to the reduced interpersonal variability that makes this method attractive. I restricted measurement to either right or left sided valves, based on which valve side determined MNI for each sample. It was not possible to measure an MAS on every single umbo, due to lack of visibility, fragmentation, or a variety of other issues.

A one-way ANOVA demonstrates that the relative size of California mussel shells from terminal Early Period, Middle Period, and late Middle Period contexts (samples from all three sites are represented in each period grouping) differ significantly (*F*=5.129, *d.f.*=2, *p*=0.006). Tukey post-hoc comparisons of the three temporal periods indicate that mean size of California mussel shells in terminal Early Period assemblages (n=2937, *M*=0.776) is significantly higher than the mean size of California mussel shells in Middle Period assemblages (n=3450, *M*=0.747), *p*=0.004. Comparisons between Middle Period assemblages (n=2984, *M*=0.747) and late Middle Period assemblages (*M*=0.758) indicate that there is no significant difference in the mean size of California mussel shells between these temporal periods. Overall, there is a small but highly significant decrease the size of California mussel collected during the Middle Period. This trend began at the end of terminal Early Period occupation at both the Coastal site and the Interior site. The mean size of California mussel shells in the assemblage from Level 21 at the Coastal site and Level 12 at the Interior site are both significantly lower than the in the preceding assemblages from Level 22 and level 13, respectively. This pattern of size decrease persists through late Middle

Period. This suggests a significant shift in either harvesting strategies or the size of shellfish available. This broad temporal trend is most evident at the Pericoastal site. At the Interior site there is a statistically significant decrease in the mean size of California mussel shells through all three temporal periods, (*F*=4.976, *d.f.*=2, *p*=0.000), including a highly significant decrease between the Middle Period and late Middle Period that is not evident in the broad temporal trend. This result suggests that a fair amount of spatial variability may complicate how this broad temporal trend is reflected at each individual site.

I used a one-way ANOVA to evaluate whether differences in the size of California mussel shells between site assemblages were consistent through time. The mean size of California mussel shells pertaining to the Coastal site, Pericoastal site, and Interior site (from all temporal periods) differed significantly (*F*=13.246, *d.f.*=2, *p*=0.000). Tukey post-hoc comparisons of the three sites indicate that mean size of California mussel shells in assemblages from the Coastal site (n=3392, *M*=0.734) is significantly lower than the mean size of California mussel shells in assemblages from the Pericoastal site (n=2978, *M*=0.780), *p*=0.000 and the Interior site (n=3001, *M*=0.768), *p*=0.001. 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, *p*=0.429. These results document consistent spatial variation in the size of California mussel exploited during all periods of occupation at the Coastal site, Pericoastal site, and Interior sites. There is a small, but highly significant increase the size of California mussel transported away from the coast. This suggests that throughout all temporal periods people preferentially transported larger mussels up the watershed to the Pericoastal and Interior sites.

Reconstructing Animal Use across Space and through Time

During the terminal Early Period (3000–2440 cal years B.P.) much more abundant faunal remains at the Coastal site supports a preferential summertime, coastal focus on the exploitation of a relatively narrow range of lean nearshore, medium-bodied, bony fish (e.g., rockfish, surfperch, rock wrasse, and sheephead) easily captured by hook or spear from shore. Furthermore, an abundance of diverse shellfish taxa (e.g., black abalone, sea urchin, and red abalone), exploited equitably along with large quantities of California mussel, contributed greatly to terminal Early Period diets across space and throughout all seasons represented by the assemblages. Along with a greater reliance on plant food resources, evident at the Pericoastal and Interior sites, people carried very low quantities of portions of marine mammals (specifically of California sea lion), large-bodied cartilaginous fish, and nearshore bony fish with them to supplement their diet while away from the coast. Marine mammals were of relatively greater importance at the Pericoastal site than at the Interior site. Fish decreased in importance but increased in size with distance from the coast. This pattern indicates that people preferentially transported low quantities of larger marine fauna away from the coast during the Terminal Early Period. These data are consistent with the hypothesis that terminal Early Period inhabitants of Canada Christy were mobile foragers that employed broad spectrum subsistence pursuits with minimal technological investment. There is no evidence of food storage or specialization in foraging behavior at the three sites investigated. This pattern persisted until ca. 2750 cal B.P., at which point all three sites are abandoned for approximately one millennium.

When the three sites are reoccupied during the Middle Period ca. 1650 cal B.P. much greater densities of faunal remains at the Coastal site and Interior sites suggest that these locations served as primary residential bases that were occupied simultaneously. The greater array of fish taxa collected relatively equitably, along with a dramatic decrease in the size of fish collected, suggest that net-fishing contributed substantially to the diet of people living at both the Coastal and Interior site during the Middle Period. Indeed, the overall abundance and array of marine fauna exploited at the Coastal site increased during this temporal period. However, as in the preceding temporal period the Chumash preferentially transported or traded low quantities of larger bony and cartilaginous fish, supplemented by low quantities of portions of sea mammals, to the Interior site. In contrast, great quantities of small migratory fish (e.g., clupeids), along with an increased emphasis on sea mammals and cartilaginous fish (relative to the preceding temporal period) contribute a greater proportion at the Coastal site than at the Pericoastal or Interior site. This important distinction, along with a greater relative contribution of shellfish (specifically California mussel) at the Interior site, reflects a persistent spatial trend evident throughout time. Throughout all temporal periods, bony fish are significantly less important and shellfish are significantly more important at the Interior site than at the Coastal site. While living at the Pericoastal site people exploited great quantities of a relatively narrow array of medium-bodied fish taxa, favoring just a few commonly hook-caught taxa (such as rockfish and surfperch) as well as an abundance of California mussel supplemented by a low diversity of other shellfish species (such as black turban snails and black abalone). Clear seasonal variation in the array of marine resources exploited at the Pericoastal site, is complemented by similar distinction in the array of terrestrial resources exploited. The distinct contrasts between the Coastal, Pericoastal, and

Interior sites provide strong evidence for both seasonal and spatial variation in site function, as well as resource use. Nonetheless, based on overwhelming diachronic trends evident in these datasets, Middle Period inhabitants atallthree locations appear to be more specialized foragers, focused on the exploitation of small oily net-caught fish and protein-dense mussel persisted until ca. 1420 cal B.P., at which point the Coastal, Pericoastal, and Interior sites once again appear to be abandoned for approximately 200 years.

When the Island Chumash reoccupied all three locations during the late Middle Period, there is evidence that many of the novel foraging behaviors that first appear during the earlier Middle Period occupation persist during the late Middle Period. People living at the Coastal site relied on the exploitation of vertebrate animal food resources, albeit in lower quantities than during the Middle Period, particularly a low diversity of fish taxa (such as migratory clupeids and nearshore rockfish and surfperch), than did people living away from the coast. California mussels and a high diversity of fish taxa were exploited at the Pericoastal site, and sea mammals were transported to the Interior site. Overall there is a general decrease in the relative contribution and diversity of fish and shellfish taxa during the late Middle Period. Although people continued to exploit small, net-caught fish, exploitation of larger bodied hook-caught fish increases significantly, resulting in an overall increase in the size of fish exploited. Based on these broad diachronic trends, late Middle Period inhabitants appear to be diversified foragers (relative to the preceding temporal period), maintaining the novel foraging behaviors of the Middle Period while expanding their resource base through continued use of new technologies.

CHAPTER 7

RISK-REDUCING FORAGING BEHAVIORS AND POPULATION GROWTH ON THE NORTHERN CALIFORNIA CHANNEL ISLANDS: SYNTHESIS AND EVALUATION OF THE DATA

The basic goals of the preceding analyses (presented in Chapters 4 through 6) involved establishing how the prehistoric Chumash moved about the landscape and exploited the terrestrial and marine environments. These analyses provide a foundation for understanding whether the specific suite of plant and animal food resources exploited or the manner in which they were exploited changed through time, from the terminal Early Period until the late Middle Period. This study has established one of the most complete reconstructions of human foraging behavior, including nuanced analyses of mobility and foodways, ever attempted in the Santa Barbara Channel Region.

In this chapter, synthesis of the analyses provides an essential context for understanding prehistoric demographic shifts among hunter-gatherer populations. I integrate the chronological, isotopic, macrobotanical, and faunal datasets by temporal period and evaluate mobility and subsistence strategies documented in each temporal period. I consider diachronic variation with respect to the expectations of risk-reducing foraging behaviors and evidence of demographic, technological, and environmental developments. Ultimately I evaluate whether changes in foraging behavior favored the energetics of human reproduction. In doing so, I integrate biological and behavioral ecological approaches to evaluate an evolutionary model of prehistoric demographic shifts within hunter-gatherer societies.

Diachronic Evaluation of Foraging Behavior and Risk-Reducing Strategies

During the terminal Early Period (3000–2440 cal years B.P.) the Chumash were quite mobile, repeatedly visiting the Coastal, Pericoastal, and Interior site throughout the year, but rarely staying put for more than two or three months at a time. Occupation at the Coastal site appears more consistent than at the Pericoastal or Interior sites. Although all three sites indicate some degree of seasonal overlap, the high rate of accumulation and evidence of more consistent occupation at the Coastal site indicate that this location was a focus of repeated occupation and, perhaps, aggregation during the productive fishing months of the summer and early fall. Indeed, much more abundant faunal remains at the Coastal site supports a preferential summertime, coastal focus on the exploitation of a relatively narrow range of lean nearshore, medium-bodied, bony fish (e.g., rockfish, surfperch, rock wrasse, and sheephead) easily captured by hook or spear from shore. Furthermore, an abundance of diverse shellfish taxa (e.g., black abalone, sea urchin, and red abalone), exploited equitably along with large quantities of California mussel, contributed greatly to terminal Early Period diets across space and throughout all seasons represented by the assemblages.

Occupation at the Pericoastal site peaked briefly during the late spring/early summer. Occupation at the Interior site peaked briefly during the late fall/early winter. Evidence of dispersed and intermittent occupation throughout the year and low rates of accumulation suggest that smaller groups visited these two locations frequently, perhaps during periods of dispersal and for acquisition of terrestrial food resources located away from the coast. Indeed, a much greater abundance of charred plant remains at the Pericoastal site and Interior sites, in comparison to the Coastal site, suggests primary plant exploitation during the terminal Early Period occurred away from the coast, as the Island Chumash moved towards the interior of the island to access a greater range of vegetation communities. Along with a greater reliance on plant food resources, people carried very low quantities of portions of marine mammals (specifically of California sea lion), large-bodied cartilaginous fish, and nearshore bony fish with them to supplement their diet while away from the coast during the late spring/early summer and late fall/early winter months. Marine mammals were of relatively greater importance during late spring/early summer occupation at the Pericoastal site than during late fall/early winter occupation at the Interior site. Fish decreased in importance but increased in size with distance from the coast. This pattern indicates that people preferentially transported low quantities of larger marine fauna away from the coast during the Terminal Early Period. These marine food resources complemented dietary staples such as blue dicks, manzanita, and acorns, in addition to a wide diversity of small seeds, greens, and fruits, collected within immediate proximity of the Pericoastal and Interior sites without specific focus on any particular taxon or group of taxa.

These data are consistent with the hypothesis that terminal Early Period inhabitants of Canada Christy were mobile foragers that employed broad spectrum subsistence pursuits with minimal technological investment. There is no evidence of food storage or specialization in foraging behavior at the three sites investigated. Potential periods of aggregation and dispersal correlate with the expected seasonal and spatial distribution of food resources. This pattern persisted until ca. 2750 cal B.P., at which point all three sites are abandoned for approximately one millennium.

During the Middle Period (2440–1300 cal years B.P.), people reoccupied all three locations almost simultaneously ca. 1650 cal B.P. Patterns of mobility and subsistence indicate significant reorganization of foraging behavior. During the Middle Period the Chumash appear substantially less mobile, tied to the Coastal and Interior sites for perhaps as many as eight months of the year, and visiting the Pericoastal site biannually for shorter periods of time. High rates of accumulation, much greater densities of faunal and botanical remains, and evidence of consistent occupation throughout the summer and into the fall at the Coastal site and Interior sites suggest that these locations served as primary residential bases that were occupied simultaneously (e.g., two groups based out of separate locations indicating a more saturated environment from the IFD perspective). The greater array of fish taxa collected relatively equitably, along with a dramatic decrease in the size of fish collected, suggest that net-fishing contributed substantially to the diet of people living at both the Coastal and Interior site during the Middle Period. Indeed, the overall abundance and array of marine fauna exploited at the Coastal site increased during this temporal period. However, as in the preceding temporal period the Chumash preferentially transported or traded low quantities of larger bony and cartilaginous fish, supplemented by low quantities of portions of sea mammals, to the Interior site. In contrast, great quantities of small migratory fish (e.g., clupeids), along with an increased emphasis on sea mammals and cartilaginous fish (relative to the preceding temporal period) contributed a greater proportion at the Coastal site than at the Pericoastal or Interior site. Given a similarity in seasonal occupation, this important distinction, along with a greater relative contribution of shellfish (specifically California mussel) at the Interior site, reflects a persistent spatial trend evident throughout time. Throughout all temporal periods, bony fish are significantly less important and shellfish are significantly more important at the Interior site than at the Coastal site. Despite these spatial trends, evidence of an overall decrease in residential mobility, focused on primary residential bases at the Coastal and Interior sites, is supported by greater similarity in the abundance and array of plant food remains recovered from these two site locations. Increased similarity in the abundance and array of plant foods exploited across space is due, in part, to evidence of transportation of important plant foods over greater distances to the Coastal site as well as a significantly increased reliance on plant foods at all three sites. One key distinction is the greater abundance of wood charcoal at the Coastal site, which may be related to fish processing, greater access to fuel (e.g. drift wood), or both. Although the array of plant taxa exploited during the Middle Period is similar to the array of plant taxa exploited during the terminal Early Period, there is an intense focus on the acquisition of just a few select taxa, particularly small seeds such as goosefoot, canary grass, clover, red maids, tarweed, and legumes. However, there is no clear evidence of storage of these important food resources.

Two shorter, discrete seasonal occupations of similar intensity at the Pericoastal site bookend seasonal occupation at the Coastal site, indicating that this location also served as a residential base during leaner months when mobility was higher. Variation evident in faunal and botanical subsistence corresponds with seasonal variation in the availability of food resources during the early spring and late fall/early winter. While living at the Pericoastal site people exploited great quantities of a relatively narrow array of medium-bodied fish taxa, favoring just a few commonly hook-caught taxa (such as rockfish and surfperch) as well as an abundance of California mussel supplemented by a low diversity of other shellfish species (such as black turban snails and black abalone). Clear seasonal variation in the array of marine resources exploited at the Pericoastal site, is complemented by similar distinction in the array of terrestrial resources exploited. Despite an overwhelming diachronic trend towards increased exploitation of a wide range of plant food resources, it is apparent that a relatively lower quantity of plants was collected more equitably during the short-term early spring and late fall/early winter occupations at the Pericoastal site than during the extended summer and fall occupation of the Coastal and Interior sites. The distinct contrasts between the Coastal, Pericoastal, and Interior sites provide strong evidence for both seasonal and spatial variation in site function, as well as resource use.

Nonetheless, based on overwhelming diachronic trends evident in these datasets, I consider the Middle Period inhabitants to be less mobile, specialized foragers, focused on the exploitation of small seeds and net-caught fish, both of which required increased investment. This pattern of decreased mobility focused on intensively used summer/fall residential bases and winter/early spring dispersal as well as specialized exploitation of small starchy and oily seeds, small fatty fish, and protein-dense mussel persisted until ca. 1420 cal B.P., at which point the Coastal, Pericoastal, and Interior sites once again appear to be abandoned for approximately 200 years.

During the late Middle Period (1300–800 cal years B.P.), the Island Chumash reoccupied all three locations beginning with the Coastal site ca. 1220 cal B.P. Although there is evidence that many of the novel foraging behaviors that first appear during the earlier Middle Period occupation persist during the late Middle Period, there is also evidence of further reorganization in foraging behavior. During the late Middle Period, primary periods of site occupation did not exceed a maximum of five months at both the Coastal and Interior sites and no more than two or three months at the Pericoastal site. Similar rates of accumulation at all three sites suggest a pattern of residential mobility with elongated stays at the Coastal site during the summer months and at the Interior site during the fall and winter.

This suggests a continued focus of occupation at the Coastal site, and potentially also at the Interior site. However, collection, processing, and consumption of plant food taxa once again shifted away from the coast to the Pericoastal and Interior sites, which were not occupied during the peak summer months. Although late Middle Period inhabitants continued to exploit a similar quantity of plant food resources as did their Middle Period predecessors, the manner in which they exploited these terrestrial resources shifted quite dramatically. People living at the Pericoastal and Interior sites during the fall, at the Interior site during the early winter, and at the Pericoastal site during the spring relied much more on plant food resources than did people living at the Coastal site during the summer. In contrast, people living at the Coastal site relied on the exploitation of vertebrate animal food resources, albeit in lower quantities than during the Middle Period, particularly a low diversity of fish taxa (such as migratory clupeids and nearshore rockfish and surfperch), than did people living away from the coast. Although California mussels and a high diversity of fish taxa supplemented plant food resources exploited during the fall and spring at the Pericoastal site, and sea mammals supplemented plant food resources exploited during the fall and winter at the Interior site, there appears to have been a renewed focus on food resources located within proximity to the seasonal residential base.

Overall, a wide diversity of plant food resources collected with greater equitability during the late Middle Period suggests a diversified exploitation strategy. Novel fruit and nut resources such as lemonadeberry, prickly pear, toyon, and black walnut (the latter which was likely traded from the mainland) appeared for the first time, even as the importance of small seeds, greens, and geophytes persisted. Diversified exploitation of plant food resources during the late Middle Period accompanies a general decrease in the relative contribution and diversity of fish and shellfish taxa. Although people continued to exploit small, net-caught fish, exploitation of larger bodied hook-caught fish increases significantly, resulting in an overall increase in the size of fish exploited. Based on these broad diachronic trends, late Middle Period inhabitants appear to be more mobile and diversified foragers (relative to the preceding temporal period), maintaining the novel foraging behaviors of the Middle Period while expanding their resource base through continued use of new technologies and trade.

Foraging Behavior in Context

Detailed reconstruction of how the prehistoric Chumash moved about the landscape and exploited marine and terrestrial resources provides evidence of significant shifts in foraging behaviors practiced before (terminal Early Period), immediately prior to (Middle Period), and after (late Middle Period) substantial intrinsic population growth occurred ca. 1500 cal B.P. Key technological innovations ca. 2500-1500 cal B.P. and climate-induced environmental change ca. 2800-1850 cal B.P. also occurred during this period of significant reorganization. Thus, it is necessary to consider specific changes in foraging behavior in relation to demographic, technological, and environmental contexts.

Demographic Context. As discussed in Chapters 1 and 2, initial occupation of the Northern Channel Islands is defined by demographic patterns expected in simple foraging societies. For at least ten thousand years, the prehistoric Chumash experienced cyclical periods of population increase and decrease, resulting in slow and incremental population growth over the long term. This demographic pattern holds throughout the temporal period referred to as the terminal Early Period in this study. The generalized foraging behaviors evident in terminal Early Period assemblages reflect the subsistence and mobility strategies of small, sparsely distributed groups that moved frequently in response to the distribution of food resources.

However, roughly coeval with—or perhaps slightly after—the adoption of novel foraging behaviors evident in Middle Period assemblages at all three sites, there was a substantial increase in population growth on the Northern Channel Islands. This demographic shift ca. 1500 cal B.P. defies the patterns that long defined Chumash demography. When all three study sites were reoccupied ca. 1650 cal B.P., much more specialized foraging behaviors provide evidence of substantial reorganization in subsistence and mobility patterns. Given the coarseness of prehistoric demographic proxies, it seems likely, but not certain, that decreased mobility and increased exploitation of energy-dense small seeds and fish reflected in the Middle Period assemblages precede evidence of significant population growth across the Northern Channel Islands. Population levels remained quite high but variable moving into the late Middle Period ca. 1220 cal B.P. as people became somewhat more mobile and diversified their subsistence base.

Technological Context. Evidence of significant shifts in foraging behaviors between the three temporal periods also correlates with major technological innovations. At the time of European contact, the coastal and island Chumash had a diverse array of fishing and maritime hunting technologies, including single-piece fishhooks, nets, sophisticated oceangoing boats, toggling harpoons, and other tools used in the gathering, processing, and cooking of marine foods. Despite considerable evidence for persistence of earlier technologies, most of the aforementioned technologies were invented or significantly refined during the Middle Period and their effects are discernible within the subsistence assemblages at the Coastal, Pericoastal, and Interior sites.

Fishhooks. Fishing tackle as simple as bone bipoints (gorges) and plant fiber cordage facilitated a marine-focused subsistence economy on the Northern Channel Islands for more than ten thousand years (Rick et al. 2002b:940). Between 5000 to 4000 years ago during the Early Period, use of composite bone fishhooks expanded, but did not replace, this simple toolkit (King 1990:80-81). The exploitation of a relatively narrow range of medium-bodied, bony fish (e.g., rockfish, surfperch, rock wrasse, and sheephead) during terminal Early Period occupation at the Coastal, Pericoastal, and Interior sites, represents the array of nearshore taxa readily caught using bone gorges and composite bone fishhooks. Indeed, these early fishing technologies were likely quite efficient (see Salls 1988:130, 191-194; Tartaglia 1976: 105; Rick et al. 2002b:940) and persisted in use throughout the Middle Period and late Middle Period despite the appearance of the single-piece fishhook ca. 2500 cal B.P. (Rick et al. 2002b). The initial innovation and proliferation of the single-piece fishhook is widely regarded by archaeologists as a key development associated with the more intensive (and efficient) exploitation of the nearshore and offshore fisheries evident during the Middle Period (Kennett 2005:193; Rick et al. 2002b:940; Rick et al. 2005a:194; Vellanoweth et. al. 2002:98). Diversity in size and form of single-piece fishhooks (see Hoover 1973:5; Strudwick 1985, 1986) suggests that a range of fish species was targeted (Kennett 2005:193). Ethnographic analogy, functional analysis, and fishing experiments using modern replicas suggest that single-piece fishhooks were designed for a specific set of ecological and biological conditions (Tartaglia 1976:173-175) and that they were most effective along rocky shores at moderate depths (Strudwick 1986). Although initial development of this new technology occured during the post-terminal Early Period interval of site abandonment, single-piece fishhooks are increasingly common in archaeological deposits that are roughly coeval with Middle Period reoccupation at the Coastal, Pericoastal, and Interior sites (Rick et al. 2002b). Increased abundance of fish bone recovered in these Middle Period assemblages indicates an emphasis on year-round exploitation of kelp forest and rocky shore taxa (e.g., rockfish). Substantial increases in the abundance of these taxa, evident at the Pericoastal and to a lesser degree at the Coastal site, confirm more intensive exploitation of mid-water and rocky nearshore habitats efficiently exploited using single-piece fishhooks. Commonly hook-caught fish continue to increase in importance in late Middle Period assemblages, reflecting the continued importance of this new technology.

Nets. Based on the presence of grooved and notched stone sinkers (King 1990:83) and net fragments (Erlandson and Colten 1991:7) in early archaeological deposits, it is likely that the Island Chumash practiced some form of net fishing for thousands of years. Use of a variety of small and large nets including beach seines, dip nets, drag nets, and gill nets are reported in early ethnographic accounts (Hudson and Blackburn 1982:38-41). Although net fishing is more efficient than hook and line fishing, the cost of manufacture and maintenance of nets appears to have prohibited reliance on this technology until the Middle Period. Lower diversity and larger fish size evident in terminal Early Period fish assemblages from the Coastal, Pericoastal, and Interior sites corresponds with a much lower ratio of commonly net-caught to commonly hook-caught taxa. This pattern began to shift in the latest terminal Early Period assemblages, but is completely reversed in Middle Period assemblages. This suggests that the relative benefits of net-fishing began to outweigh the costs of investment just prior to abandonment of all three site locations at the end of the terminal Early Period. Much higher diversity and smaller fish size evident in Middle Period assemblages corresponds with a much higher ratio of commonly net-caught to commonly hook-caught taxa. This pattern firmly establishes the increased importance of net-fishing during the Middle Period, which persists during the late Middle Period. However, late Middle Period net-fishing is complemented by increasing importance of much larger taxa, likely caught by hook and line, harpoon, or nets in deeper nearshore or pelagic waters.

Sophisticated Boats. The earliest inhabitants of the Northern Channel Islands certainly possessed watercraft such as tule reed balsas (see Hudson and Blackburn 1982:331) capable of crossing the Santa Barbara Channel in calm conditions. These early boats permitted basic, albeit unreliable and low-capacity, transportation between the islands and the mainland (Arnold 1995:737), but were poorly suited to efficient cross-channel exchange or deep-sea and mid-channel subsistence pursuits (Rick et al. 2005a:208). Such restrictive boat technology tethered terminal Early Period inhabitants of Santa Cruz Island to fishing only in the nearshore marine environments. Despite a heavily marine-focused subsistence economy, the array of vertebrate and invertebrate taxa evident in assemblages at the Coastal, Pericoastal, and Interior sites reflects a littoral lifeway. This contrasts with the maritime lifeway that predominates after the development of the sewn wooden plank canoe (Arnold 1995:738). Archaeological evidence indicates that this oceangoing watercraft may have initially appeared 2000 to1500 years ago, during the post-terminal Early Period interval of abandonment, but was fully developed by at least 1300 years ago by the end of Middle Period occupation at the Coastal, Pericoastal, and Interior sites (Gamble 2002, 2008:158). Middle Period inhabitants at these three locations benefitted from greater access to maritime resources, such as large pelagic fish, stable platforms for mid-water net, hook and line, and harpoon fishing, as well as safer and more reliable long-distance exchange (Arnold 1995:739; Fagan 2004:12; Gamble 2002:301; Rick et al. 2005a:208). Recovery of swordfish bill fragments at the Pericoastal site confirms exploitation of large pelagic fish during the Middle Period. More intensive exploitation of sea mammals during the Middle Period and late Middle Period likely reflect increased access to productive rookeries, increased ease of pursuit, and decreased transportation costs provided by plank canoes. The larger loads afforded by the plank canoe (up to 1,814 kg when fully loaded Hudson et al. 1978:56) also permitted more efficient transportation of plant food resources to the Northern Channel Islands (Arnold 1995:741). The appearance of black walnut, a species that does not currently grow on Santa Cruz Island, suggests that island-mainland trade contributed to plant food resources consumed by the prehistoric Chumash during the late Middle Period. Increased trade also provides a reasonable explanation for the disappearance of acorn nutmeat and nutshell in the later assemblages at the Pericoastal and Coastal sites. As described in the previous discussion (Chapter 5) of plant use in cultural context, the Chumash traded only dry, shelled acorns (Fauvelle 2012; 2013), which would lead to a very reduced archaeological signature on the islands. Off-island processing of this food resource may contribute to underrepresentation in late Middle Period island contexts. Overall, it is evident that the combined investment in sophisticated seaworthy plank canoes, fishing nets, and efficient single-piece fishhooks signal a clear intensification in the exploitation of marine resources that accompanied a much greater focus on terrestrial food resources, prior to significant population growth ca. 1500 cal B.P.

Environmental Context. A recently recognized climatic transition likely altered the geographic distribution and productivity of marine and terrestrial resources across the Northern Channel Islands, favoring the adoption of novel foraging behaviors evident during the Middle Period and late Middle Period. The “Late Holocene Dry Period” ca. 2800-1800 cal B.P. evident in paleoclimatic records from the central Great Basin and southern California is linked to changes within the oceans, including a persistent negative Pacific Decadal Oscillation (PDO) and decreased El Niño-Southern Oscillation (ENSO) (Mensing et al. 2013:279-280). Although the local effects of climate-induced environmental change during this interval were complex and varied across the western United States (i.e. , wetter than average conditions in northern Great Basin due to the north-south shifts in weather patterns), the primary effects on the Northern Channel Islands certainly included decreased sea-surface temperature variability and decreased coastal upwelling (Mensing et al. 2013:279-280). Laminated sediments recovered from the Santa Barbara Basin marine core reveals a sudden decrease in summer and fall coastal upwelling ca. 2800 years ago accompanied by the onset of less variability in local sea-surface temperatures (Kennett et al. 2007:354). As discussed in Chapter 6, oceanographic conditions—particularly the upwelling of cold nutrient-rich water—mediate the structure of nearshore biological communities and provide the foundation for high marine productivity and the rich nearshore fishery in the region (Blanchette et al. 2008:162). Decreased upwelling would have had a negative impact on many marine organisms. Thus, it is conceivable that a sudden decrease in marine upwelling had a profound impact on terminal Early Period inhabitants of Santa Cruz Island, who depended heavily on nearshore and littoral food resources. This marine-related climatic shift coincided with post-terminal Early Period site abandonment at the Coastal, Pericoastal, and Interior sites and persisted throughout the date range (2750 to 1650 cal B.P.) estimated for post-terminal Early Period site abandonment at the Coastal, Pericoastal, and Interior sites.

In addition to the primary marine effects of decreased upwelling during this interval of climate change, the inhabitants of the Northern Channel Islands also experienced additional terrestrial effects related to rainfall. There is evidence from several different proxies for drier than modern climate in the southern Great Basin between 2800 and 2300 cal B.P., after which the records become more variable (Mensing et al. 2013:278). A pattern of decreased precipitation between 2800 and 2300 cal yr B.P. is reflected in distinct declines in the bristlecone pine treeline on Campito Mountain in the White Mountains of Eastern California (Mensing et al. 2013:278). Yet, subsequent to ca. 2300 cal yr B.P.the bristlecone pine record indicates a general pattern of increased precipitation that began ca. 2300 years ago and lasted until ca. 1500 years ago (Kennett et al. 2007:355). Indeed, most of the paleoenvironmental records from locations in the southern Great Basin appear to have had an increase in effective moisture beginning 2300 cal yr B.P. (Mensing et al. 2013:280). Although the bristlecone pine record is not derived from the Santa Barbara Channel Region, a broad trend towards increased precipitation is supported by local pollen and macrobotanical analyses ca. 2100-1900 B.P. (Wigand 2005). This evidence suggests that after 2300 cal B.P. increased precipitation would have enhanced the abundance and distribution of terrestrial plant food resources available to the inhabitants of Santa Cruz Island. Thus, shortly after marine upwelling and presumably marine productivity decreased significantly, disrupting existing foraging strategies, increased precipitation may have created a more favorable terrestrial environment. This terrestrial-related climatic shift occurs approximately half-way through the date range (2750 to 1650 cal B.P.) estimated for post-terminal Early Period site abandonment at the Coastal, Pericoastal, and Interior sites.

I propose that these environmental changes favored the adoption of novel foraging behaviors reflected in the Middle Period archaeological record. Evidence of decreased abundance and diversity of shellfish, increased innovation and investment in maritime technologies, and increased reliance on terrestrial plant food resources is consistent with adaptation to decreased productivity of the nearshore marine environment and increased productivity terrestrial food resources.

Variation in Foraging Behavior and Human Energetics

Based on the preceding integration of a multiscalar chronological framework, I evaluate site occupation history and mobility patterns, alongside multiple lines of subsistence data, which I use to evaluate exploitation of marine and terrestrial environments. This data-rich analysis illuminates significant diachronic shifts in foraging behavior prior to evidence of intrinsic population growth. When examined in light of human reproductive ecology, the novel foraging behaviors in place when the Coastal, Pericoastal, and Interior sites were re-occupied ca. 1650 cal B.P. have clear implications for understanding intrinsic population growth on the Northern Channel Islands. As discussed in Chapter 2, the physiology of human reproduction, particularly women's fecundity, is sensitive to variation in how human foragers move about and exploit environment. It is well established that high population mobility, seasonal food risk, and restricted access to resources high in energy-producing fats and carbohydrates limit energy availability and suppress fecundity in hunter-gatherer populations. Key changes in mobility and diet breadth evident in Middle Period assemblages may have reduced fluctuations in long-term energy balance by reducing energy expenditure and alleviating macronutrient imbalance, thereby easing physiological constraints on fecundity and population level fertility.

Mobility and High Energy Expenditure

Archaeologists recognize that evidence of decreased population mobility corresponds with evidence of population growth on the Northern Channel Islands (Kennett 2005; Kennett et al. 2009; Winterhalder et al. 2010). However, the research presented in this study suggests that decreased population mobility precedes evidence of population growth, and indeed, may have contributed to population growth by alleviating pre-existing energetic restrictions on fecundity. Reproductive ecology effectively demonstrates that changes in mobility, regardless of the contributory mechanisms, can set into motion a series of interrelated biological and behavioral changes that affect population-level fertility and mortality patterns (Kelly 2013:212). Archaeologists are increasingly aware that high mobility in hunter-gatherers leads to low population level fertility (Kelly 2013:210; Shennan 2009:340) because of high energy expenditure and high energy flux associated with carrying heavy burdens over long distances or frequently moving camp while carrying children. Kelly (2013:210) argues that changes in women’s aerobic workload associated with decreased mobility reduces energetic stress, alleviating physiological controls on women’s fecundity. Thus, increased fecundity may be an unintended consequence of decreased population mobility. Indeed, ethnographic research documents significant increases in population fertility rates as population mobility decreases (e.g., Binford and Chasko 1976; Ellanna 1990; Gomes 1990; Hitchcock 1982; Roth and Ray 1985). Evaluation of diachronic shifts in prehistoric Chumash mobility suggests that this may also be the case for the prehistoric Chumash.

Relatively high population mobility associated with a pattern of generalized resource exploitation is evident during the terminal Early Period occupation at the Coastal, Pericoastal, and Interior sites. During this period, people did not stay at residential bases for more than two or three months at a time and appear to have dispersed widely during the leanest seasons of the year. This indicates a high and persistent aerobic workload as residential bases were frequently established, taken down, and moved throughout the year. Furthermore, increased mobility during the leanest seasons of the year may have exacerbated periodic intake restriction, leading to a negative energy balance. Low-level, intermittent visitation at all three locations throughout the year indicates that at least some portion of the population foraged widely from the residential base. Although the Chumash ethnohistoric record offers little insight regarding gender roles (i.e., who gathered and transported construction materials, who constructed shelter, who carried other household items) this pattern of high mobility certainly affected women's energy expenditure and may have contributed to reproductive suppression throughout the early occupation of the Northern Channel Islands.

Significantly decreased population mobility associated with a pattern of specialized resource exploitation is evident during the Middle Period occupation at the Coastal, Pericoastal, and Interior sites. During this period as compared with earlier, people were tethered to the Coastal and Interior sites for much greater portions of the year, with a relatively greater emphasis on marine resources at the Coastal site and terrestrial resources at the Interior site. Although resources were clearly exchanged between the two locations, this novel mobility pattern certainly decreased the aerobic workload associated with frequent residential base mobility. Thus, it is possible that an overall decrease in population mobility during the Middle Period reduced energy flux, favoring increased fecundity and facilitating intrinsic population growth.

Seasonality and Periodic Intake Restriction

Along with decreases in aerobic activity associated with decreased population mobility, shifts in subsistence strategies that alleviate seasonal intake restriction contributed to a more constant energy balance and increased fecundity. Indeed researchers have suggested that specialized exploitation and storage of acorns in California (Walker 2006), piñon nuts in the Owens Valley (Bettinger 1976, 1977), and salmon along the Northwest coast (Ames 1994) were effective means of increasing seasonal resource stability that contributed to local population increase. Similarly an emphasis on novel food resources that are less variable may also have increased seasonal resource stability. This is supported by reproductive ecology studies that demonstrate significantly higher fertility and lower mortality among foraging populations who have a more constant diet with less annual or seasonal fluctuation in their food supply (Kelly 2013:210).

However, evaluation of diachronic shifts in prehistoric Chumash subsistence does not provide conclusive evidence that increased seasonal resource stability contributed to population increase among the prehistoric Chumash. Plant foods contributed more consistently to Middle Period diets across space and throughout all seasons represented by the Middle Period assemblages. However, it is not clear whether increased consistency is related to storage of plant foods or a simple increase in the importance of plant foods. Low-level intermittent occupation at the Coastal, Pericoastal, and Interior occurred throughout the year during both the terminal Early Period and the Middle Period, 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 during any of the three temporal periods considered provides little support that food resources were stored from one season to the next. Furthermore, the novel food resources incorporated into Middle Period and late Middle Period subsistence strategies are highly seasonal food resources. Without clear evidence of storage, neither specialization nor diversification of prehistoric Chumash diet appears to have increased seasonal resource stability prior to evidence of population growth. Although this does not rule out the possibility that periodic reduced intake restriction contributed to prehistoric population growth on the Northern Channel Islands, it is also not possible to confirm that it did based on the data collected in this study.

Food Resources and Macronutrient Imbalance

Nonetheless, the energetic impact of decreased mobility may have been amplified by contemporaneous shifts in the relative contribution of dietary macronutrients during the Middle Period. Archaeologists have long recognized that evidence of specialized exploitation of plant and animal food resources corresponds with evidence of population growth on the Northern Channel Islands (Kennett 2005; Walker and Erlandson 1986; Winterhalder et al. 2010). However, the research presented in this study suggests that rather than simple intensification of subsistence strategies in response to increasing population pressure, significant dietary changes precede evidence of population growth, and indeed, may have contributed to population growth by alleviating pre-existing macronutrient imbalance. Researchers are increasingly aware that the ratio of proteins, carbohydrates, and fats consumed must also be considered among the factors that influence the amount of energy available to support reproductive function in natural fertility in societies (Bentley et al. 2001:207) because the metabolic costs required for the human body to process energy from protein are significantly higher than required to process energy from fats and carbohydrates (Speth 1990:152). Increased exploitation of energy-dense food resources contributes to a more constant energy balance, alleviating physiological controls on women's fecundity. Thus, changes in the macronutrient content of important food resources can set into motion a series of interrelated physiological mechanisms that affect population-level fertility and mortality patterns. Evaluation of diachronic shifts in prehistoric Chumash subsistence suggests that this may be the case for the prehistoric Chumash.

Generalized exploitation of the nearshore and littoral marine environment complements low-level contributions of terrestrial plant food resources evident during the terminal Early Period occupation at the Coastal, Pericoastal, and Interior sites. During this period, people consumed a relatively high quantity of protein-dense shellfish and nearshore fish taxa throughout the year, complemented seasonally with low quantities of marine mammals and a diversity of plant foods. Similar to other marine food resources exploited during the terminal Early Period, marine mammals, specifically the California sea lion, provided valuable source of meat and animal protein exploited using simple shore-based hunting tactics (discussed earlier in Chapter 6). Although a healthy sea lion would also provide a fair amount of dietary fat, the relatively low quantities of sea lion bones implies a low hunting success rate. A very low quantity of blue dicks, manzanita, and acorns, in addition to a wide diversity of small seeds, greens, and fruits provided access to essential carbohydrates. Exploitation of these terrestrial resources peaked during the late fall occupation at the Interior site, but were also of increased importance during the early summer occupation at the Pericoastal site. Despite low carbohydrate consumption during these restricted seasons, these data indicate an overall pattern of seasonal and chronic macronutrient imbalance as terminal Early Period foragers relied heavily on protein-rich marine food resources for caloric sufficiency throughout much of the year. Thus, it is likely that significant macronutrient imbalance contributed to negative energy balance and reproductive suppression throughout the early occupation of the Northern Channel Islands.

Specialized exploitation of the marine and terrestrial environment evident during the Middle Period occupation at the Coastal, Pericoastal, and Interior sites reflect a significant increase in the relative contribution of fats and carbohydrates in the prehistoric Chumash diet. During this period, increased investment in new and refined marine technologies contributed to a significant increase in exploitation of migratory clupieds, rich in necessary fats. Evidence of exploitation of these small fatty fish throughout the summer and early fall occupation at the Coastal site and Interior sites is complemented by a similarly dramatic increase in the abundance of small starchy and oily seeds. Sufficient protein from California mussel, California sea lions, and lean nearshore fish is also apparent in Middle Period assemblages, suggesting a much greater macronutrient balance characterized prehistoric Chumash diet during this temporal period. Thus, it is possible that a significant overall increase in the contribution energy-dense food resources, associated with specialization and technological investment, during the Middle Period reduced chronic macronutrient imbalance, thereby improving energy balance, and favoring increased fecundity prior to evidence of population growth.

Energetic Implications for Population Fecundity & Growth Rate

Integrating the energetic focus of reproductive ecology with a behavioral ecological perspective provides a unique framework for understanding prehistoric demographic shifts within foraging populations. It appears that low population growth rates that defined much of

Chumash prehistory resulted from energetic trade-offs associated with high population mobility and chronic macronutrient imbalance. The data synthesized above indicate that decreased mobility and specialized exploitation of energy-dense small seeds and small fish evident during the Middle Period altered pre-existing patterns of low energy status, negative energy balance, and high energy flux that defined terminal Early Period energetics. I propose that this shift in foraging behavior and energy acquisition, perhaps instigated by climate-induced environmental change, alleviated energetic stress, contributing to increased fecundity and higher rates of population growth on the Northern Channel Islands. These results suggest that prehistoric human population growth did not always instigate major shifts in food acquisition, but rather was, in some cases, a product of subtle changes in the type, quantity, and quality of food resources upon which human foragers relied.

Broader Implications of the Study

Through the examination of diachronic variation in risk-reducing foraging behavior relative to a period of intrinsic population growth, this research has made significant theoretical and methodological contributions towards understanding the context in which population growth occurred in hunter-gatherer populations on the Northern Channel Islands, and more generally, elsewhere prior to the adoption of plant or animal domesticates. Following Shennan, I argue that the foundations for understanding demographic processes in prehistory lie in evolutionary theory (Shennan 2009:339). No longer can archaeologists rely on simplistic concepts of positive checks and Malthusian constraints to understand prehistoric demographic processes. Rather, we must look towards biologically oriented explanations. In this research, I rely on a relatively recent perspective derived from the field of human reproductive ecology, which argues that population regulation and growth in hunter-gatherer societies are linked intrinsically to patterns of subsistence and reproduction through behaviorally and physiologically mediated trade-offs. I argue that archaeologists can contribute to a more refined understanding of the timing and nature of macro-demographic changes by shifting our attention to biological mechanisms intimately associated with the processes by which energy is captured from the environment and allocated to metabolic purposes, such as dietary and foraging behaviors. Although this research specifically evaluates dietary and foraging behaviors on Santa Cruz Island, the broad theoretical perspective that macro-scale population level shifts among hunter-gatherers may be an unintended outcome of subtle shifts in foraging strategies—related to a variety of social, environmental, or economic variables—that inform dynamic biological processes is widely applicable to hunter-gatherer studies.

The methodological contribution of this work lies in the integration of a multiscalar chronological framework and multiple lines of subsistence data. Each line of evidence helps in unraveling a complex story of human occupation and foraging behavior at each of the three archaeological sites. Without rigorous chronological models to control century-level resolution and site seasonality studies to provide seasonal resolution, it would have been impossible to infer diachronic shifts in mobility patterns. Although Bayesian chronological models and oxygen isotope analysis are not new to archaeologists on the Northern Channel Islands, the scale and thoroughness to which they were employed in this study certainly is. Continued efforts to expand the existing radiocarbon database and develop more rigorous site chronologies and occupation histories will shed further light on prehistoric Chumash demography. The incorporation of data from floral remains is a novel approach for this region, where faunal analysis dominates subsistence studies. Integration of floral, vertebrate, and invertebrate datasets is essential to a thorough understanding of human foraging behavior and energetics, particularly in a marine environment that is unlikely to provision dietary sufficiency based solely on marine food resources. This study highlights the importance of analyzing and integrating both faunal and macrobotanical data in order to answer questions of resource exploitation and dietary sufficiency and broader theoretical questions. Together these diverse lines of mobility and subsistence data allowed me to reconstruct significant diachronic changes in foraging behavior and evaluate these changes with respect to evidence of climate-induced environmental change and prehistoric population growth. This work contributes to our collective understanding of the unique trajectory of Chumash prehistory that produced the complex social and political structures evident at the time of Spanish contact.

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APPENDIX A:

BASIC RESULTS OF OXYGEN ISOTOPE ANALYSIS

Table A.1 Oxygen Isotope Results from Coastal Site.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
22	1	0.26	0.10	0.00	0.98	0.68	-0.02	0.16	0.30	0.33	0.80	0.46	0.67	0.84	0.12	0.81	-0.09
22	2	1.16	0.22	0.96	0.08	0.78	-0.36	0.60	0.23	0.32	0.81	0.29	0.79	0.72	0.79	0.92	-0.11
22	3	-0.18	-0.14	-0.43	0.68	0.21	0.73	0.20	0.57	-0.17	0.61	0.40	0.43	0.31	0.05	0.39	-0.29
22	4	0.75	-0.35	0.41	0.03	0.50	0.75	0.88	0.84	1.15	0.61	1.09	0.06	0.85	-0.35	0.50	-0.35
22	5	0.85	-0.17	0.58	-0.59	-0.27	0.50	0.60	0.78	0.83	0.71	1.12	0.16	1.15	-0.10	0.57	-0.26
22	6	-0.47	0.84	0.21	0.84												
22	7	0.25	-0.12	-0.15	0.76												
22	8	0.38	-0.20	-0.18	0.63												
22	9	0.09	0.40	0.52	0.82												
22	10	0.31	0.08	0.46	-0.18												
21	1	0.82	0.82	0.97	0.14	0.81	-0.24	0.88	-0.32	0.66	0.15	0.28	0.20	-0.63	0.50	-0.60	0.46
21	2	0.07	0.64	0.31	0.68	0.30	0.51	0.85	0.83	0.58	0.33	0.37	0.46				
21	3	0.49	0.14	0.23	0.70	0.66	0.47	0.92	0.00	0.38	0.68						
21	4	0.60	-0.36	0.61	0.31	-1.06	0.40	-0.76	0.82	0.42	0.39	0.35	0.14	0.49	0.84	0.36	0.63
21	5	-0.03	0.94	0.33	-0.07	0.49	-0.21	-0.01	0.44	-0.61	0.71	0.42	0.29	0.60	-0.29	-0.22	0.55
21	6	0.59	0.53	0.65	0.09	0.45	-0.19	0.05	0.28	0.18	0.41	-0.41	0.96	0.34	0.48	0.55	0.40
21	7	0.79	-0.07	0.00	0.49	-0.27	0.94	0.20	0.25	0.26	0.78	-0.02	0.32	0.35	0.20	-0.04	0.74
21	8	-0.10	0.22	0.00	0.59	0.07	-0.05	0.05	0.91	0.23	0.79						
21	9	-0.16	0.16	-0.71	0.12												
21	10	0.59	-0.06	0.74	0.19												
21	11	0.81	0.09	0.75	-0.12												
21	12	0.65	0.05	0.78	-0.47												
21	13	0.57	-0.17	0.27	-0.24												
21	14	0.82	0.71	0.80	-0.12												

Table A.1 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
21	15	-0.78	0.20	-0.65	0.50												
20	1	0.06	-0.09	0.37	-0.37	-0.09	-0.35	-0.11	-0.36	0.00	0.14	-0.23	0.24	-0.08	0.24	0.09	0.12
20	2	0.43	-0.07	-0.23	-0.31	-0.18	-0.24	-0.25	-0.12	-0.07	-0.13	-0.06	0.02				
20	3	0.42	0.42	0.50	0.61	0.77	0.44	0.76	0.46	1.07	-0.14	0.98	0.18	0.44	0.67	0.58	0.55
20	4	-0.44	0.63	-0.43	0.63	-0.37	0.62	-0.24	0.27	-0.12	0.16						
20	5	0.31	0.34	-0.18	0.24	-0.21	0.13	1.37	-0.77	1.20	-0.85	0.41	-0.46	0.39	0.04	0.40	-0.15
20	6	0.68	-0.08	0.70	0.07	0.76	0.36	0.42	0.22	0.92	0.76						
20	7	0.16	0.58	0.45	0.78	0.60	0.72	0.13	0.21	-0.53	0.71	-0.49	0.50	-0.22	0.52	-0.05	0.41
20	8	0.44	0.66	-0.01	0.55	0.59	0.44	1.05	-0.31	0.96	-0.51	0.82	-0.68	0.86	-0.65	0.65	-0.48
20	9	-0.31	0.57	-0.25	1.03												
20	10	0.18	-0.04	-0.05	-0.89												
20	11	0.21	0.47	-0.07	-0.28												
20	12	1.01	-0.73	0.98	-1.16												
20	13	0.15	-0.31	0.72	-0.30												
20	14	0.86	-0.99	0.62	-1.45												
20	15	0.29	-0.60	0.07	-0.64												
19	1	0.35	-0.10	-0.06	0.23	-0.39	0.87	-0.59	1.15	0.95	-0.12	-0.25	1.16	0.24	0.87	0.72	0.93
19	2	-0.01	-0.46	0.25	-0.12	0.19	0.35	0.06	0.26	-0.18	0.28						
19	3	0.85	0.28	1.00	0.01	0.97	-0.23	0.65	-0.22	1.07	-0.39	1.04	-0.40	0.94	-0.13	1.04	0.34
19	4	0.22	0.50	0.50	-0.20	0.34	0.71	0.30	0.63	0.36	0.51	0.38	0.25	0.46	-0.32	0.04	0.60
19	5	1.22	-0.07	0.75	0.30	1.16	0.73	1.23	-0.02	0.58	0.46						
19	6	0.00	0.94	-0.25	0.58	0.77	-0.52	0.55	-0.29	0.01	0.46	0.01	0.51	-0.52	0.11	0.24	-0.18
19	7	0.20	-0.32	0.19	-0.03	-0.38	0.62	-0.20	0.69	-0.09	0.49	-0.09	0.71	-0.06	0.77	0.22	0.62
19	8	0.52	0.15	0.20	-0.19	0.40	-0.63	0.75	-0.63	0.68	-0.68						
19	9	0.11	0.18	0.11	0.13												
19	10	0.10	-0.66	-0.55	-0.57												
19	11	-1.30	0.57	-0.83	1.06												

Table A.1 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
19	12	0.44	0.22	0.42	-0.01												
19	13	0.46	-0.14	0.26	-0.62												
19	14	0.56	-0.51	1.31	-0.38												
19	15	0.65	0.18	0.23	0.31												
18	1	0.01	0.65	0.62	0.98	0.80	0.55	0.45	0.07	0.31	-0.05	-0.14	0.45	-0.33	0.53	-0.40	0.75
18	2	-0.12	0.44	-0.23	0.57	-0.31	0.65	-0.56	0.70	-0.21	0.47						
18	3	0.78	-0.24	0.98	-0.11	0.79	-0.32	0.77	0.22	0.58	-0.21						
18	4	0.64	0.14	0.76	-0.22	0.25	0.33	0.23	0.86	0.50	0.71	0.30	0.57	0.30	0.62	0.45	0.64
18	5	0.13	-0.27	0.39	-0.20	0.19	0.14	-0.10	0.56	-0.20	0.66	0.13	0.67	0.10	0.63	0.53	0.53
18	6	-0.12	0.09	-0.27	0.37	-0.01	-0.12	0.39	0.22	0.06	0.01						
18	7	0.60	-0.11	0.11	0.20	0.10	0.62	0.08	0.59	0.25	0.74	0.48	0.65	0.49	0.64	0.75	0.43
18	8	-0.13	0.79	0.19	-0.20	-0.06	0.58	0.13	0.56	0.35	0.69	0.48	0.54	0.27	0.65	-0.02	-0.10
18	9	-0.34	-0.48	-0.04	-0.60												
18	10	-0.22	-0.23	-0.46	0.35												
18	11	0.31	-0.36	0.65	-0.53												
18	12	0.61	0.82	0.81	0.23												
18	13	0.91	0.11	1.11	-0.19												
18	14	-0.02	-0.21	-0.22	0.54												
18	15	0.99	0.67	1.13	0.59												
17	1	1.45	0.52	0.92	-0.35	0.76	0.10	0.28	0.89	0.34	1.11	0.89	0.84				
17	2	0.40	0.27	-0.03	0.72	-0.05	0.80	0.06	1.06	0.31	0.79	0.77	0.99	0.40	0.85	0.24	0.43
17	3	0.47	0.12	0.73	0.04	0.94	-0.64	0.57	0.35	0.14	0.49						
17	4	0.30	-0.55	0.16	-0.66	0.18	-0.51	-0.36	-0.50	-0.50	-0.39						
17	5	-0.02	0.49	-0.26	1.04	-0.08	1.11	0.05	1.11	0.59	-0.01	0.55	0.00	0.03	-0.16	-0.32	0.15
17	6	1.18	-0.23	0.94	-0.07	0.71	0.53	0.64	0.63	0.36	0.60	0.15	-0.44	0.32	-0.06	-0.02	0.28
17	7	-0.05	0.59	-0.03	1.15	0.27	0.90	0.55	0.27	0.27	0.49						
17	8	0.31	0.75	0.51	0.56	0.62	0.67	0.34	0.92	0.67	0.49	0.94	-0.26	0.82	-0.54	0.83	-0.32

Table A.1 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
17	9	0.88	0.40	0.72	0.09												
17	10	-0.92	0.56	-0.82	0.79												
17	11	0.33	0.64	0.48	0.54												
17	12	1.02	-0.66	1.02	-0.74												
17	13	-0.61	0.29	0.13	0.27												
17	14	0.56	0.07	1.01	-0.44												
17	15	1.31	-0.04	1.31	-0.26												
16	1	1.17	-0.24	0.93	0.34	0.31	0.33	0.72	0.21	1.10	-0.57	1.59	-0.38	1.40	0.21	1.21	0.32
16	2	1.48	-0.15	1.30	-0.38	1.30	-0.45	1.19	-0.63	1.09	-0.45	1.01	-0.39	0.92	-0.39	0.70	-0.09
16	3	0.85	-0.46	0.84	-0.32	0.86	-0.46	0.90	-0.36	0.87	-0.15	0.72	-0.02	0.39	0.02	0.39	0.31
16	4	1.08	-0.51	1.00	-0.52	0.87	-0.54	0.66	-0.25	0.33	-0.10	0.15	0.31	0.81	0.41	1.17	0.31
16	5	-0.13	1.07	0.00	0.50	0.52	0.39	0.49	0.67	0.17	1.11	0.44	1.20	0.43	0.66	0.27	0.04
16	6	0.76	-0.43	0.61	-0.65												
16	11	0.86	-0.31	0.93	-0.10												
16	12	-0.01	-0.46	0.01	-0.39												
16	13	1.62	-0.23	1.58	-0.43												
16	14	0.29	-0.39	0.05	0.11												
16	15	0.41	-0.28	0.45	-0.17												
15	1	0.29	0.21	0.39	0.48	0.45	0.38	0.03	0.39	0.82	-0.20	0.95	-0.27	0.76	-0.16	0.27	0.08
15	2	0.56	-0.08	0.77	-0.24	0.71	-0.30	0.21	0.12	0.20	0.48	0.13	0.75	0.33	0.90	0.70	0.49
15	3	0.76	-0.36	0.56	0.22												
15	4	0.88	0.24	0.75	-0.09	0.39	-0.10	0.47	0.08	0.20	0.06	0.32	-0.06	0.23	0.16	0.05	0.07
15	5	0.43	-0.14	-0.10	0.51	-0.39	0.58	-0.58	0.81	0.84	0.45	1.09	0.23	1.16	0.30	1.25	0.17
15	6	1.06	-0.13	0.31	0.86												
15	7	0.32	0.31	0.11	-0.16												
15	8	0.48	-0.19	0.86	-0.38	0.58	-0.51	-0.11	0.31	0.05	0.64	0.73	0.51	0.86	0.50	0.95	0.09
15	9	0.88	-0.25	1.22	-0.31												

Table A.1 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
15	10	1.50	-0.25	1.25	-0.22												
15	11	0.44	0.40	0.43	0.51	0.52	0.37	0.21	0.56	0.89	0.06	1.01	-0.28	0.88	0.07	0.27	0.17
15	12	0.24	-0.41	0.39	-0.34												
15	13	-0.37	-0.10	0.27	-0.20												
15	14	0.52	-0.32	0.42	-0.48												
15	15	1.03	-0.62	0.79	-0.53												

Table A.2 Oxygen Isotope Results from Pericoastal Site.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
6	1	0.52	0.31	1.01	0.69	1.31	0.85	1.21	0.09	1.26	0.10	0.75	-0.20	0.93	-0.33	0.92	-0.14
6	2	0.08	0.65	0.01	0.74	0.08	0.69	0.15	0.69	0.29	0.66	0.55	0.81	0.50	0.02	-0.16	0.02
6	3	0.46	0.52	0.24	0.88	0.71	0.91	0.67	0.20	0.79	-0.23	0.23	-0.18	0.06	-0.32	0.01	0.29
6	4	1.17	0.31	1.17	0.43	1.38	0.53	1.24	-0.08	1.09	-0.30	0.79	-0.42	0.47	0.04	0.27	0.33
6	5	0.42	0.91	-0.38	0.59	0.33	0.64	0.66	0.68	0.79	0.71	0.84	0.44	1.29	0.37	1.08	-0.05
6	6	0.97	-0.15	0.67	0.01	1.02	-0.57	0.99	-0.50	0.86	-0.83	0.23	-0.67	0.23	0.14	0.27	0.04
6	7	0.08	0.22	0.29	0.61	-0.04	0.39	0.18	0.57	0.30	0.60	0.56	0.56	0.59	0.23	0.51	0.28
6	8	0.69	0.59	0.45	0.70	0.60	0.55	0.74	0.66	0.75	0.64	0.67	0.75	0.99	-0.17	1.00	-0.42
6	9	0.11	0.66	0.21	0.47												
6	10	0.13	0.80	0.19	0.47												
6	11	0.14	0.65	-0.12	0.61												
6	12	0.51	-0.33	0.56	-0.37												
6	13	0.78	0.09	0.90	-0.38												
6	14	0.81	0.42	0.88	0.51												
6	15	0.06	1.14	0.59	0.84												
5	1	1.33	0.04	1.24	-0.37	1.22	-0.06	1.09	0.23	0.03	0.74	0.20	0.61	0.29	0.50	0.50	0.38
5	2	0.91	1.07	1.01	0.78	1.11	0.67	1.07	0.78	0.99	0.73	1.03	0.59	1.03	0.40	0.86	0.18

Table A.2 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
5	3	-0.30	0.36	-0.04	0.20	0.03	0.76	0.17	0.03	0.32	0.01	0.28	0.87	0.27	1.27	0.35	1.08
5	4	-0.11	0.55	0.20	0.73	0.62	0.40	1.18	0.39	0.84	-0.05	0.50	-0.29	0.73	-0.21	0.61	-0.04
5	5	-0.60	1.01	-0.34	0.31	0.56	-0.10	0.25	0.31	0.11	0.66	0.33	0.66	0.51	0.54	0.77	0.48
5	6	0.39	0.74	0.01	0.90	1.05	0.88	1.25	0.48	1.27	0.14	1.15	-0.24	1.14	-0.23	1.24	-0.40
5	7	0.63	0.54	-0.05	0.66	-0.23	0.93	1.16	0.70	0.81	0.63	1.19	0.21	0.87	0.04	1.01	-0.08
5	8	0.58	0.68	0.46	0.36	1.03	0.04	-0.08	1.21	0.78	0.65	0.94	0.63	1.22	0.24	1.30	-0.07
5	9	0.44	0.93	1.01	0.11												
5	10	0.36	0.19	0.22	0.52												
5	11	0.16	0.76	-0.04	0.68												
5	12	-0.73	0.92	-0.82	0.70												
5	13	1.14	0.10	1.07	0.11												
5	14	-0.25	1.02	-0.28	1.15												
5	15	0.56	0.87	1.47	0.61												
4	1	-0.24	0.74	-0.45	0.75	-0.01	1.06	0.63	0.76	0.83	0.83	0.59	0.60	0.41	0.09	0.29	-0.07
4	2	0.52	0.72	0.57	0.97	1.60	0.34	1.64	-0.15	1.47	-0.40	1.31	-0.67	0.94	-0.18	-0.03	0.20
4	3	-0.43	1.26	-0.54	0.83	0.18	1.29	-0.01	1.01	-0.67	0.85	-0.57	1.02	0.18	1.30	-0.09	0.74
4	4	0.85	1.13	0.63	1.07	1.15	1.09	1.24	0.92	1.54	0.14	1.80	-0.27	0.84	0.55	1.05	0.58
4	5	-0.47	1.01	-0.32	1.10	-0.94	0.87	0.04	1.28	-0.31	0.64	0.13	0.84	0.09	0.83	0.19	0.97
4	6	-1.65	-0.89	0.02	0.73	-0.32	1.04	0.17	1.06	-0.05	0.76	0.39	0.21	0.21	0.05	0.11	0.47
4	7	0.21	0.95	0.05	0.57	0.03	0.81	-0.42	0.75	0.07	0.49	0.51	0.68	0.05	0.59	0.49	-0.27
4	8	-0.06	0.96	0.11	1.13	-0.59	0.93	0.24	0.80	0.49	1.22	0.50	0.32	0.75	0.25	0.65	-0.33
4	9	1.08	0.68	0.47	0.54												
4	10	-0.85	0.96	-0.52	0.91												
4	11	-0.02	1.36	0.12	1.14												
4	12	-0.51	1.08	-0.60	0.55												
4	13	0.41	0.89	0.49	-0.55												
4	14	0.39	0.92	0.64	0.76												
4	15	0.69	-0.03	0.67	1.05												

Table A.2 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
3	1	0.87	0.48	1.00	-0.18	0.95	-0.10	0.59	0.78	0.25	0.55	0.34	0.70	0.91	0.57	1.02	0.61
3	2	0.18	0.99	0.30	0.72	0.56	0.29	0.82	-0.01	0.85	-0.10	0.34	0.47	0.16	0.60	0.02	0.48
3	3	0.46	0.35	-0.18	0.63	-0.54	0.47	-0.50	0.70	-0.54	0.59	-0.49	0.71	0.40	0.88	0.92	0.71
3	4	0.61	0.48	0.56	-0.05	0.58	-0.55	0.51	-0.47	0.14	0.33	0.92	-0.07	1.09	-1.06	0.65	-1.16
3	5	0.62	0.29	0.49	0.59	0.21	0.80	0.06	0.85	0.05	1.37	0.15	1.12	0.20	0.69	0.53	0.48
3	6	0.42	0.38	0.59	0.32	1.17	0.10	1.14	-0.26	0.93	-0.52	0.66	-0.57	0.32	0.46	-0.08	0.65
3	7	0.26	0.60	-0.32	0.68	-0.65	0.93	-0.53	1.11	-0.23	1.10	0.38	0.98	0.55	0.49	0.43	0.54
3	8	0.31	0.71	0.21	0.79	0.01	0.65	0.56	0.62	0.82	0.96	0.71	0.57	0.51	0.68	0.63	0.64
3	9	0.50	0.63	0.49	0.39												
3	10	0.33	0.46	-0.18	0.90												
3	11	-0.27	1.07	0.52	0.90												
3	12	0.17	0.75	0.79	0.42												
3	13	0.35	-0.20	-0.18	0.18												
3	14	0.27	0.73	0.20	1.44												
3	15	-0.15	0.87	0.68	0.76												

Table A.3 Oxygen Isotope Results from Interior Site.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
13	1	0.44	0.50	0.02	0.84	-0.17	0.93	0.22	0.47	0.22	0.52	0.23	0.36	0.80	0.28	0.50	0.36
13	2	0.20	0.74	0.39	0.58	0.25	0.78	0.44	0.42	0.79	-0.20	0.71	-0.51	0.27	-0.41	0.13	0.00
13	3	0.86	0.08	0.60	0.81	0.97	0.17	1.33	-0.22	0.89	0.54	1.00	0.68	0.80	0.96	0.84	0.30
13	4	0.92	0.62	1.19	0.00	1.24	-0.04	1.12	0.19	0.47	0.87	0.47	0.91	0.64	0.72	0.85	0.65
13	5	1.20	-0.42	1.18	-0.43	1.11	-0.50	0.90	-0.59	0.67	-0.48	0.33	-0.62	0.25	-0.45	0.11	0.09
13	6	0.65	0.30	0.76	0.84	0.59	0.69	0.66	0.63	0.75	0.46	0.67	-0.31	0.92	-0.07	1.01	0.61
13	7	-0.86	1.11	-0.24	0.80	-0.01	0.82	0.51	0.49	0.17	0.77	0.32	0.65	0.47	0.73	0.69	-0.02
13	8	0.62	0.81	1.07	0.57												
13	9	1.21	-0.12	1.11	-0.24												

Table A.3 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
13	10	0.66	0.60	0.81	-0.26												
13	11	-0.25	0.97	-0.09	0.86												
13	12	0.16	1.20	0.30	1.15												
13	13	-0.26	1.21	0.36	0.77												
13	14	-0.95	0.61	-0.36	0.90												
13	15	0.56	0.28	0.18	0.80												
12	1	0.27	1.08	0.22	0.92	0.38	0.62	0.33	0.78	0.69	0.55	0.50	0.47	0.32	0.33	0.39	0.40
12	2	0.48	0.74	0.30	0.13	0.25	0.08	-0.01	0.58	-0.09	0.92	0.23	0.75	0.11	0.80	0.04	0.79
12	3	-0.01	0.74	0.50	0.42	0.82	0.22	0.95	0.44	1.10	0.39	0.12	0.51	0.76	-0.12	0.46	-0.31
12	4	1.01	0.66	1.02	0.40	1.05	0.17	1.01	0.27	0.96	-0.26	0.93	-0.27	0.87	0.06	0.80	-0.26
12	5	-0.37	0.85	-0.08	0.82	-0.04	0.76	0.22	0.78	0.39	0.70	0.11	0.48	-0.07	0.43	0.04	0.28
12	6	1.20	-0.74	0.89	-0.55	0.77	-0.11	0.36	0.95	0.70	0.65	0.94	0.73	1.13	-0.01	0.76	-0.20
12	7	0.34	0.66	0.49	0.13	0.51	0.08	0.33	-0.36	0.46	-0.83	0.49	-0.80	0.08	-0.64	0.19	-0.63
12	8	1.28	0.62	1.33	-0.01												
12	9	0.94	0.21	0.80	-0.37												
12	10	0.13	0.12	0.64	0.25												
12	11	0.11	0.80	0.37	0.86												
12	12	-0.28	1.08	0.81	-0.43												
12	13	0.79	0.88	0.95	0.51												
12	14	0.07	0.76	0.49	0.84												
12	15	0.00	-0.69	-0.14	0.85												
11	1	-0.33	0.03	0.32	0.08	0.36	0.57	0.15	0.38	-0.24	0.60	0.35	0.55	0.47	0.55	0.35	0.07
11	2	0.93	-0.10	1.10	-0.46	0.88	-0.34	0.70	-0.02	0.20	0.46	0.01	0.91	0.23	0.50	0.44	0.53
11	3	-1.06	0.03	0.15	0.46	-0.40	0.81	0.60	-0.03	0.76	0.01	0.05	0.43	0.47	0.46	0.58	0.33
11	4	-0.64	-0.11	-0.23	0.32	-0.59	0.31	0.04	0.61	0.42	0.49	0.37	0.01	0.35	-0.34	0.34	-0.51
11	5	0.35	-0.46	0.04	0.36	0.63	0.59	0.58	0.15	0.42	-0.45	0.26	0.40	0.17	0.76	0.30	0.60
11	6	-0.06	0.08	0.49	0.25	-0.06	0.66	0.25	0.44	-0.73	0.24	-0.33	0.84	0.52	0.65	0.74	-0.25

Table A.3 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
11	7	-0.23	0.26	-0.44	0.40	-0.56	0.23	-0.42	0.44	-0.42	-0.49	0.66	-0.62	0.52	-0.52	0.23	-0.22
11	8	-0.48	0.73	-0.23	0.68												
11	9	1.17	-0.08	1.04	-0.13												
11	10	0.12	0.69	0.10	1.05												
11	11	-0.42	-0.11	0.46	0.63												
11	13	-0.47	0.49	0.18	-0.72												
11	14	1.14	-0.32	0.12	0.85												
11	15	-0.22	0.53	0.65	-0.57												
10	1	-0.19	-0.28	-0.21	0.59	0.22	0.58	-0.17	0.04	-0.23	0.57	-0.22	-0.28	-0.29	0.70	1.10	0.22
10	2	-0.06	0.67	-0.02	0.81	-0.04	0.82	0.38	-0.09	0.42	-0.21	0.18	0.11	0.10	0.38	-0.14	0.79
10	3	0.39	0.47	0.95	0.40	0.80	0.52	0.91	0.16	0.92	-0.33	0.82	-0.36	0.79	-0.42	0.69	-0.58
10	4	0.42	-0.49	0.28	0.22	0.70	-0.03	1.15	0.05	0.31	0.17	0.97	0.61	1.34	-0.16	1.60	-0.12
10	5	0.66	-0.34	0.29	0.02	-0.06	0.23	-0.25	0.34	-0.44	0.90	-0.42	0.65	0.13	0.98	0.53	0.72
10	6	0.14	0.63	0.05	0.50	0.66	0.34	0.75	-0.17	0.84	-0.13	0.86	-0.30	0.89	-0.56		
10	7	0.52	0.20	0.66	-0.45	0.48	-0.44	0.37	-0.54	-0.25	-0.61	-0.20	-0.31	-0.37	0.07	-0.40	0.88
10	8	0.18	0.65	0.23	0.31												
10	9	1.06	0.96	1.01	0.97												
10	10	-0.02	0.76	0.33	0.46												
10	11	0.61	-0.24	1.08	0.01												
10	12	-0.02	0.46	-0.11	0.55												
10	13	0.04	0.76	-0.03	0.99												
10	14	0.10	-0.43	-0.10	-0.44												
10	15	0.57	-0.39	0.37	-0.16												
9	1	0.82	0.81	0.79	0.52	0.62	0.25	0.30	0.01	-0.04	-0.42	0.11	-0.49	-0.54	-0.37	-0.53	0.11
9	2	0.46	-0.04	-0.32	0.31	-0.42	0.73	-0.90	0.87	-0.39	0.56	-0.41	0.66	-0.66	0.98	0.33	0.92
9	3	-0.28	0.57	0.04	0.60	0.49	0.54	0.30	0.22	0.02	-0.17	-0.02	-0.21	0.07	-0.26	0.35	-0.29
9	4	0.49	0.57	0.57	0.51	0.76	0.23	0.69	-0.27	0.70	0.00	0.22	0.32	-0.01	0.32	0.22	0.54

Table A.3 Cont.

		Sample A		Sample B		Sample C		Sample D		Sample E		Sample F		Sample G		Sample H	
Level	Shell	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰	δ13C ‰	δ18O ‰
9	5	1.21	0.32	1.38	-0.07	0.84	0.55	0.35	0.49	0.15	0.83	0.28	0.77	0.58	0.78	1.02	0.36
9	6	0.99	0.25	0.98	0.07	0.70	0.66	1.22	0.52	1.05	0.50	0.89	0.29	1.01	-0.07	0.86	-0.21
9	7	0.59	-0.20	0.73	-0.33	0.61	0.35	0.50	0.50	-0.29	0.56	0.59	0.28	0.70	0.36	0.72	0.63
9	8			0.32	0.69												
9	9			0.10	0.66												
9	10	0.31	0.63	0.62	-0.37												
9	11	0.47	0.96	0.52	0.50												
9	12	1.26	0.53	0.90	0.88												
9	13	0.31	0.37	0.35	0.27												
9	14	0.64	0.24	0.49	0.21												

Figure A.1 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 22 at the Coastal Site.

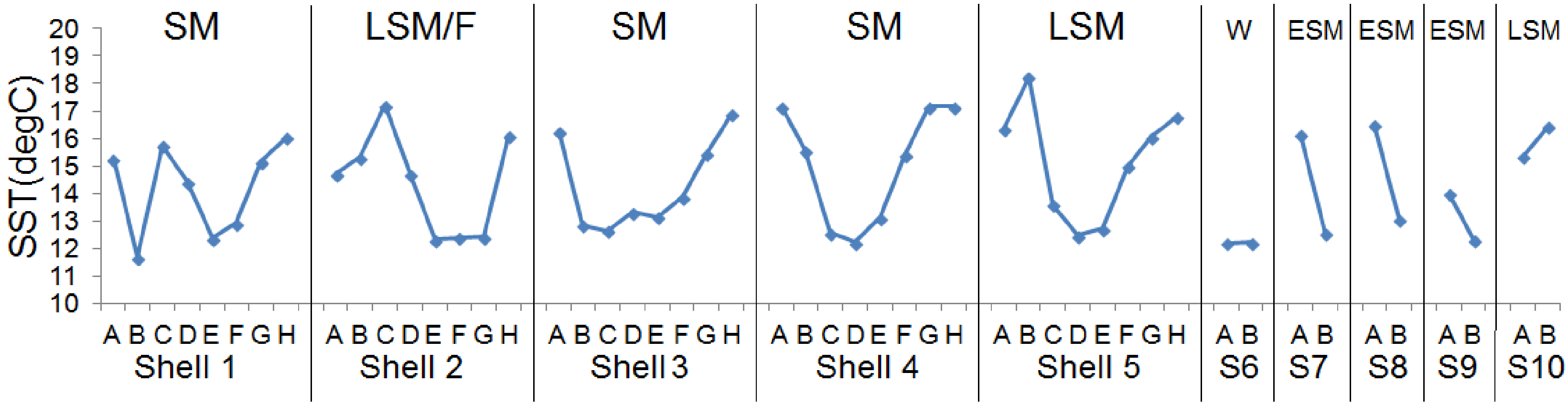


Figure A.2 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 21 at the Coastal Site.

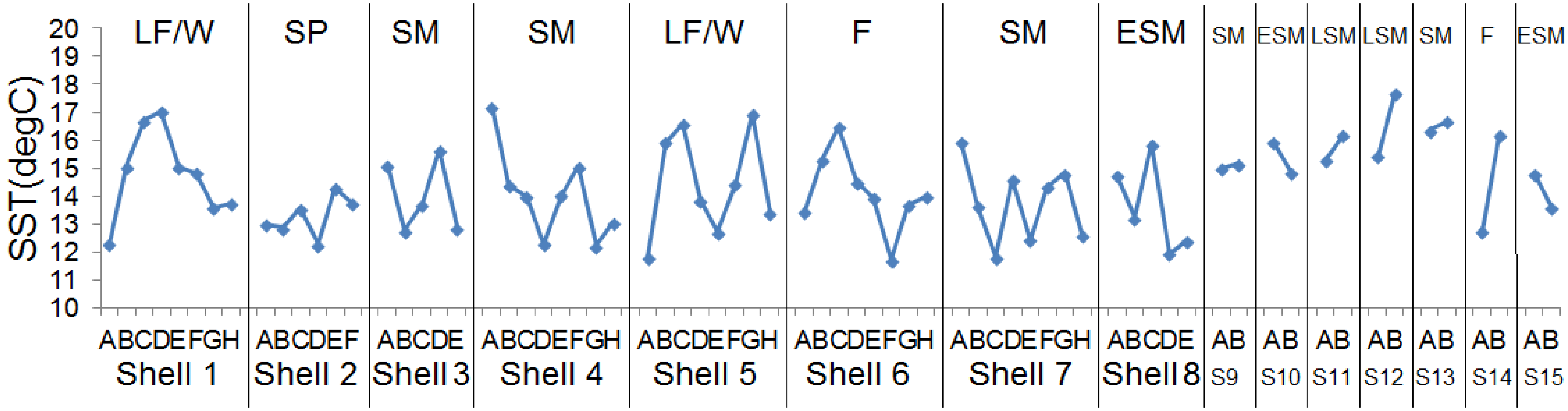


Figure A.3 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 20 at the Coastal Site.

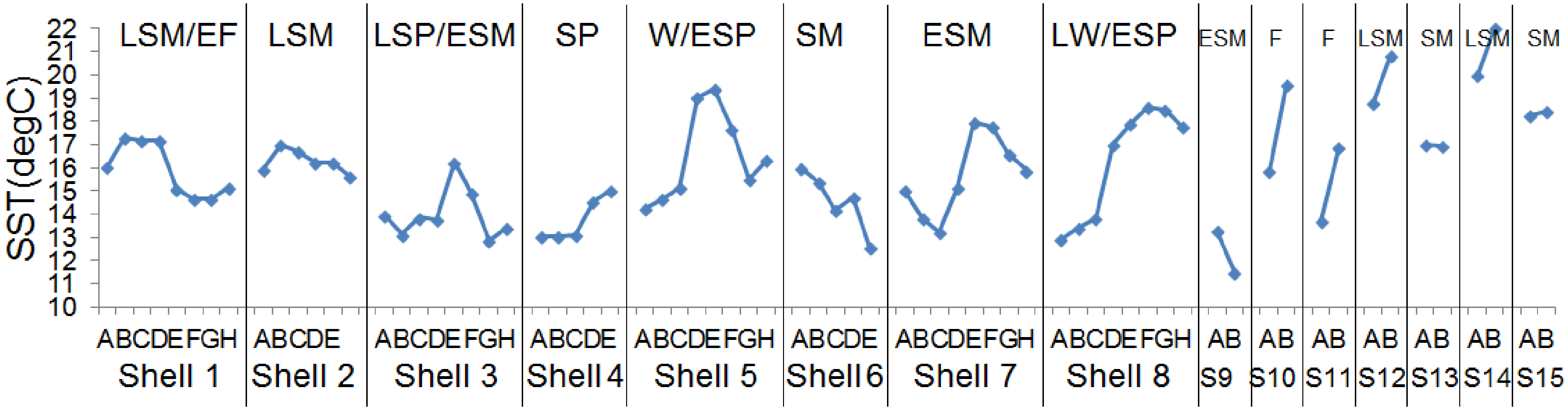


Figure A.4 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 19 at the Coastal Site.

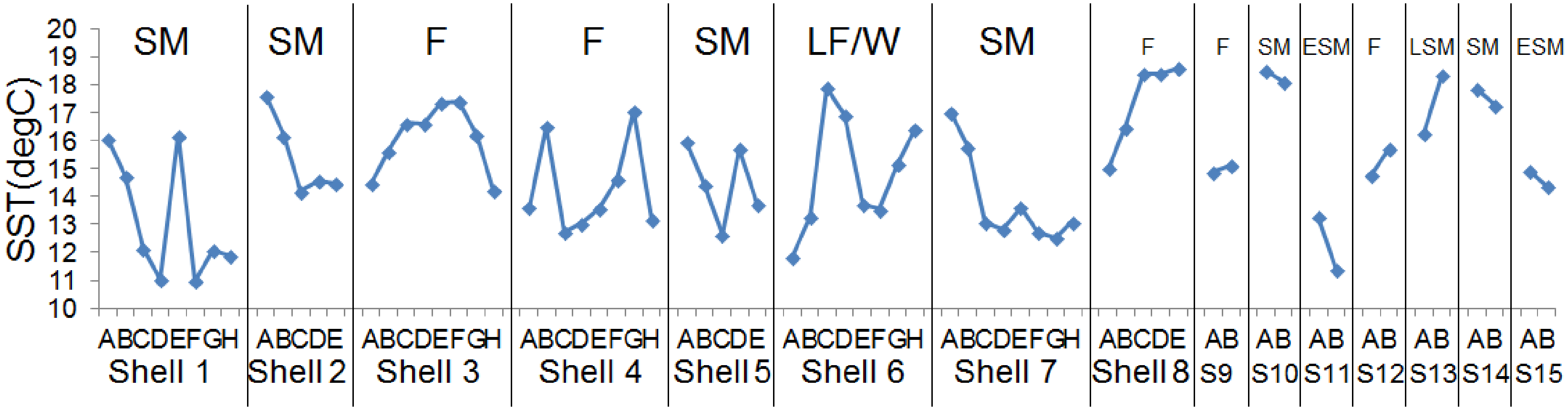


Figure A.5 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 18 at the Coastal Site.

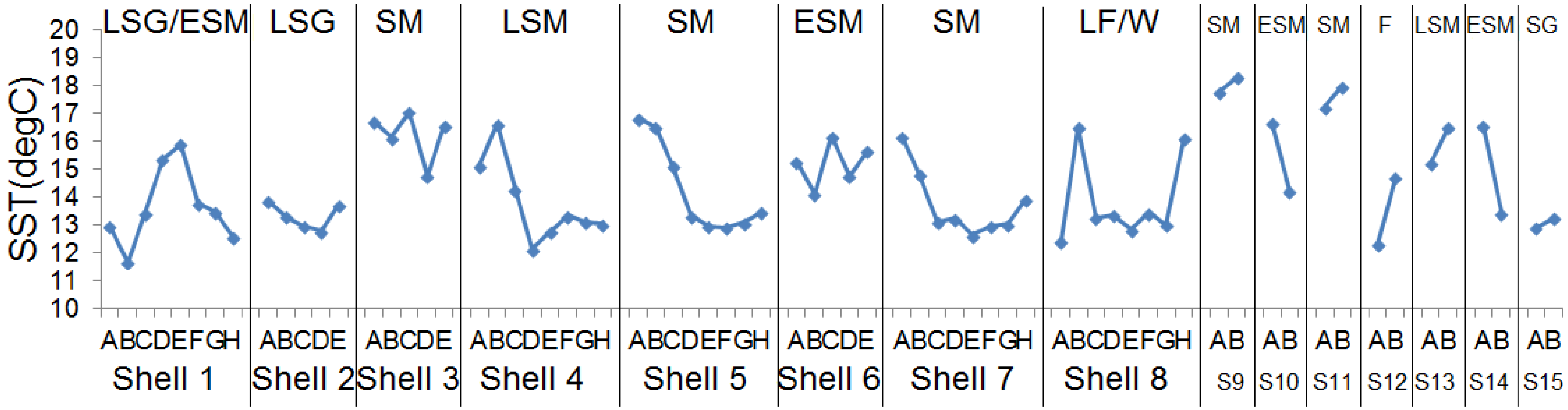


Figure A.6 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 17 at the Coastal Site.

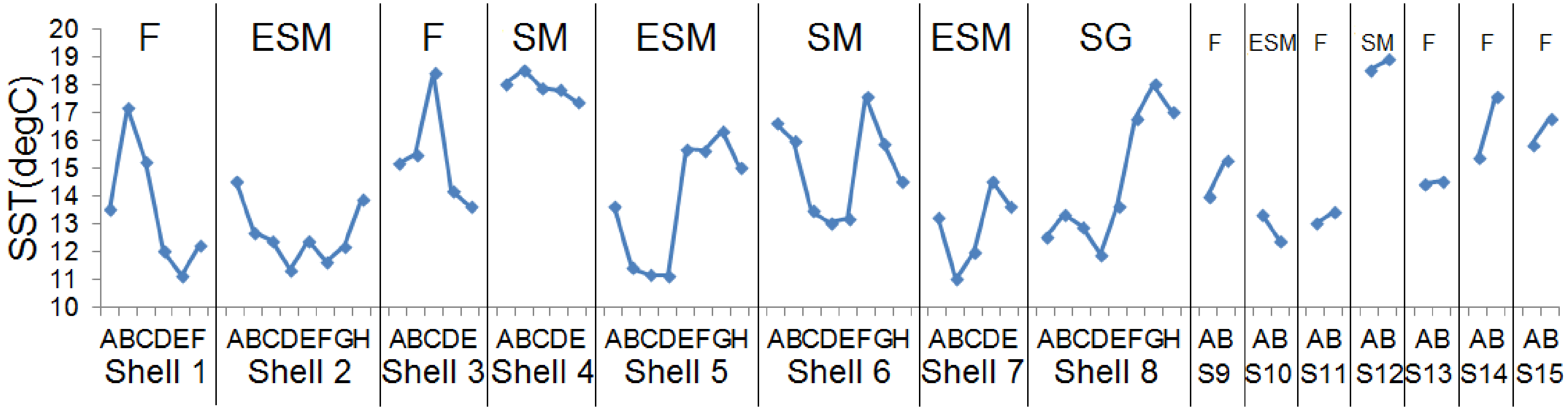


Figure A.7 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 16 at the Coastal Site.

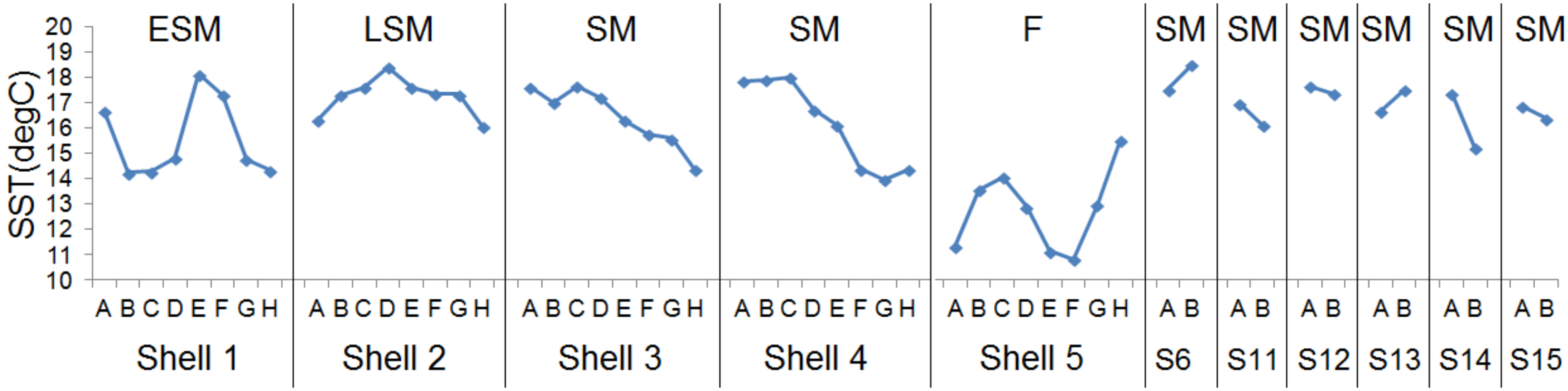


Figure A.8 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 15 at the Coastal Site.

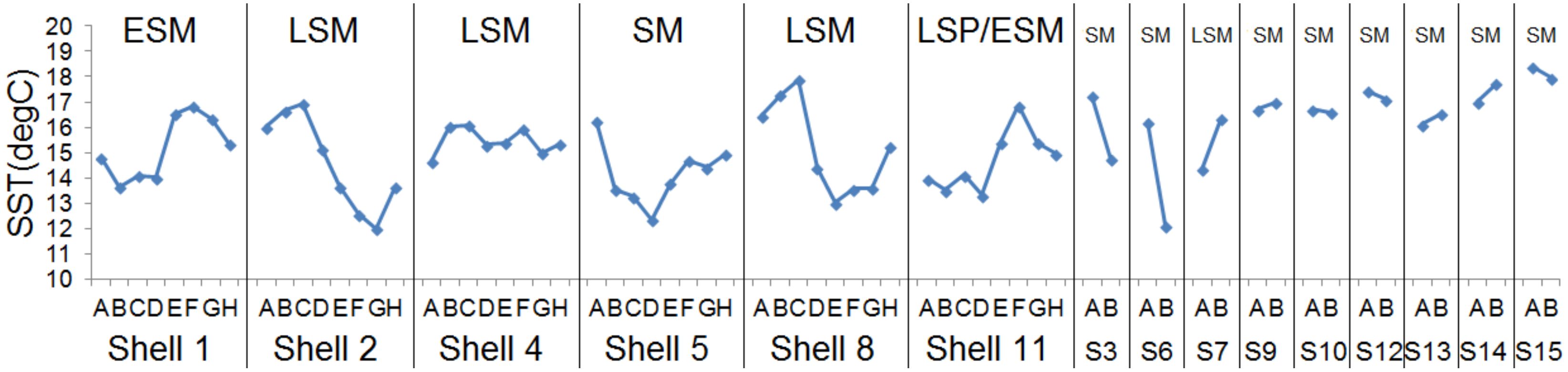


Figure A.9 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 6 at the Pericoastal Site.

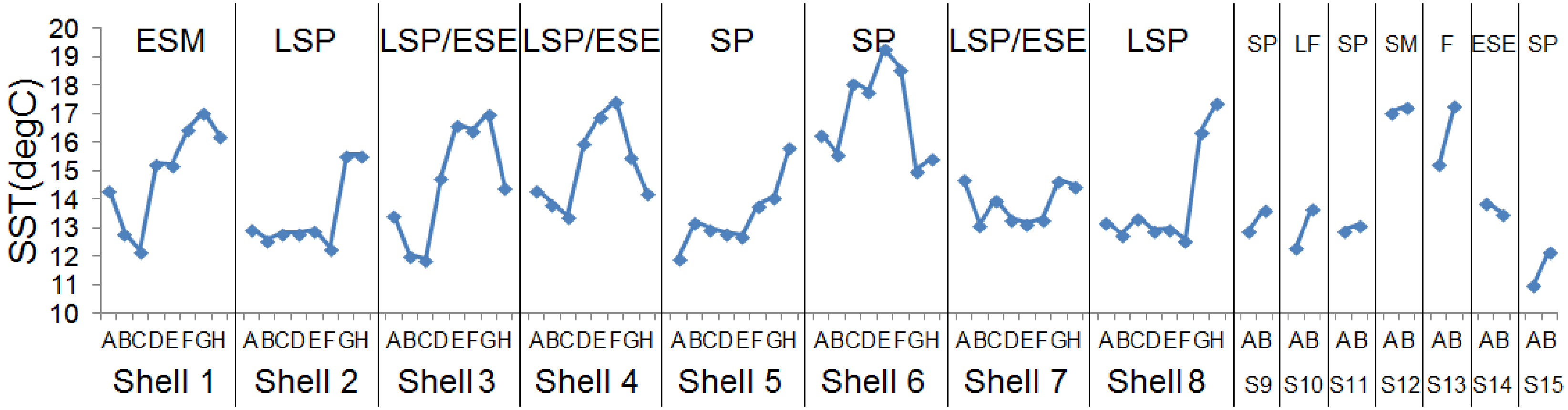


Figure A.10 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 5 at the Pericoastal Site.

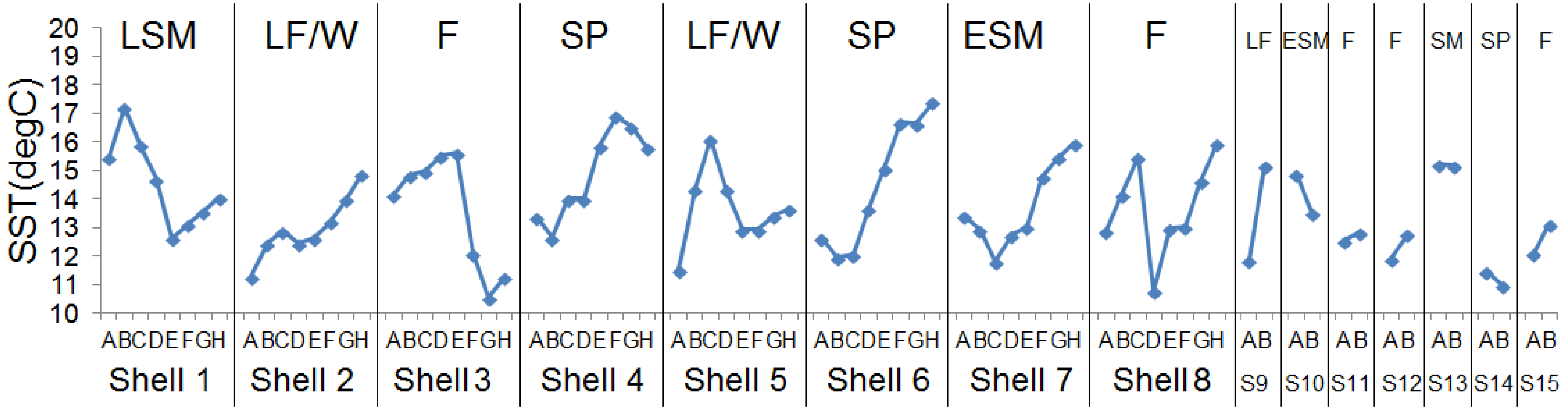


Figure A.11 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 4 at the Pericoastal Site.

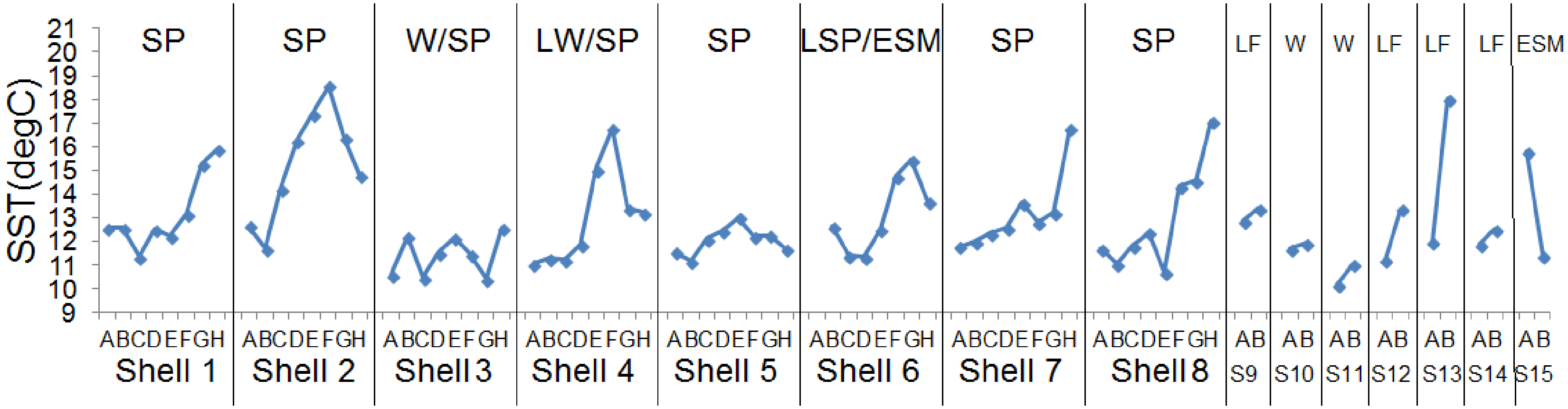


Figure A.12 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 3 at the Pericoastal Site.

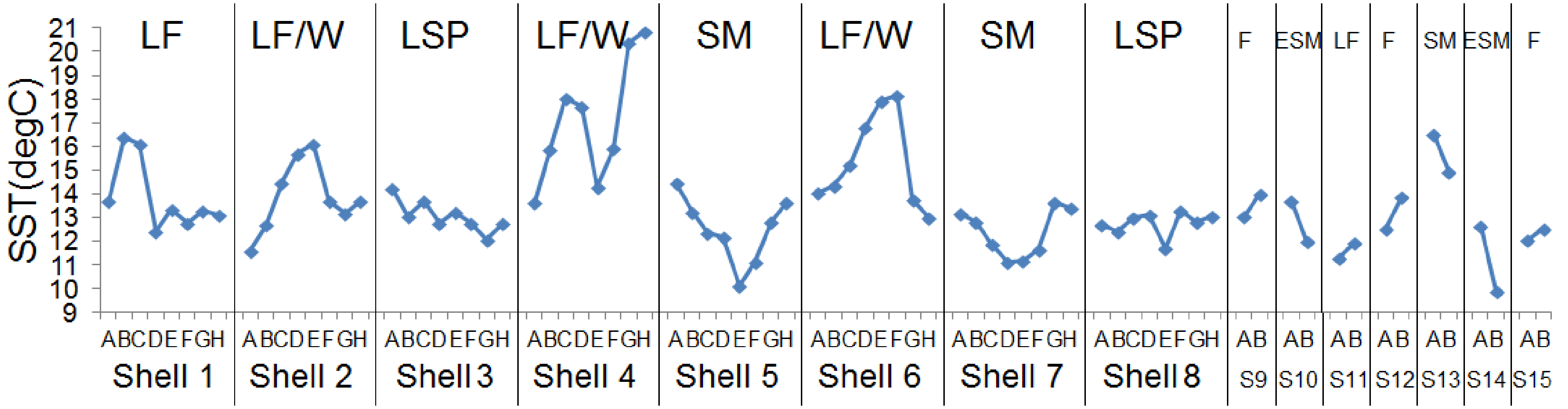


Figure A.13 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 13 at the Interior Site.

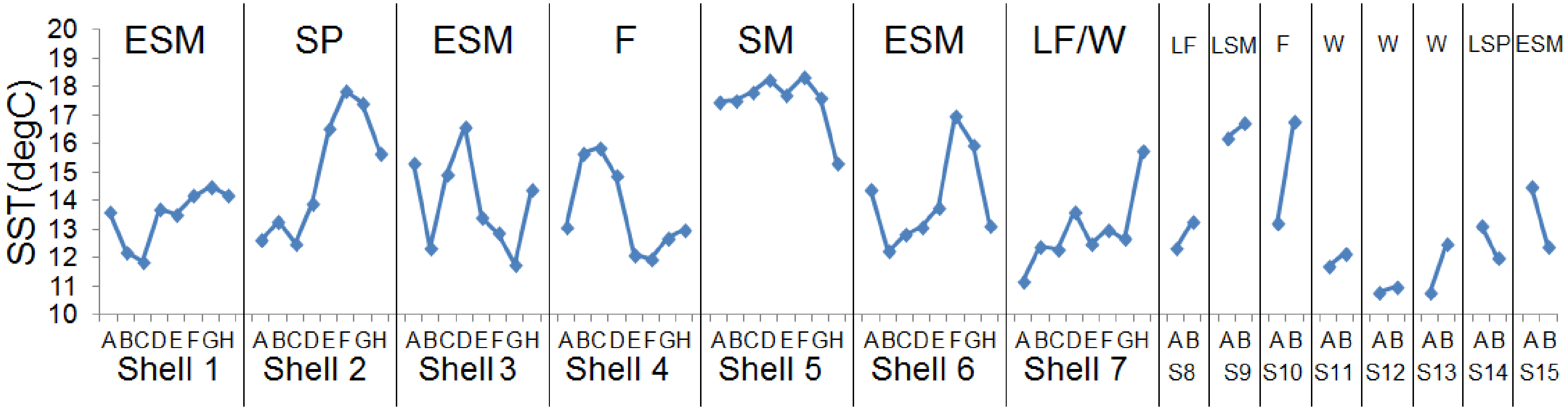


Figure A.14 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 12 at the Interior Site.

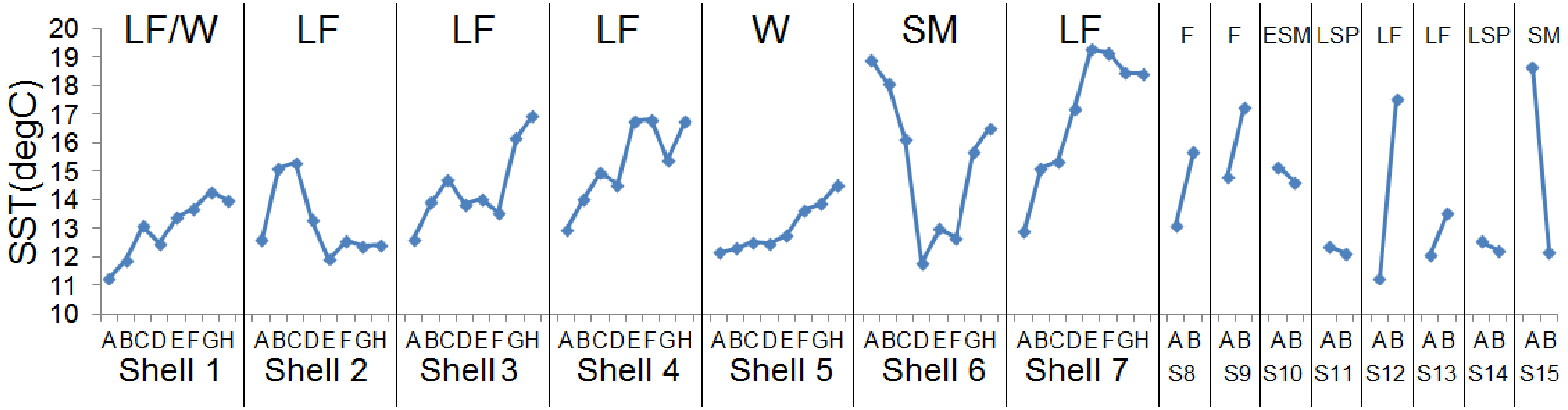


Figure A.15 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 11 at the Interior Site.

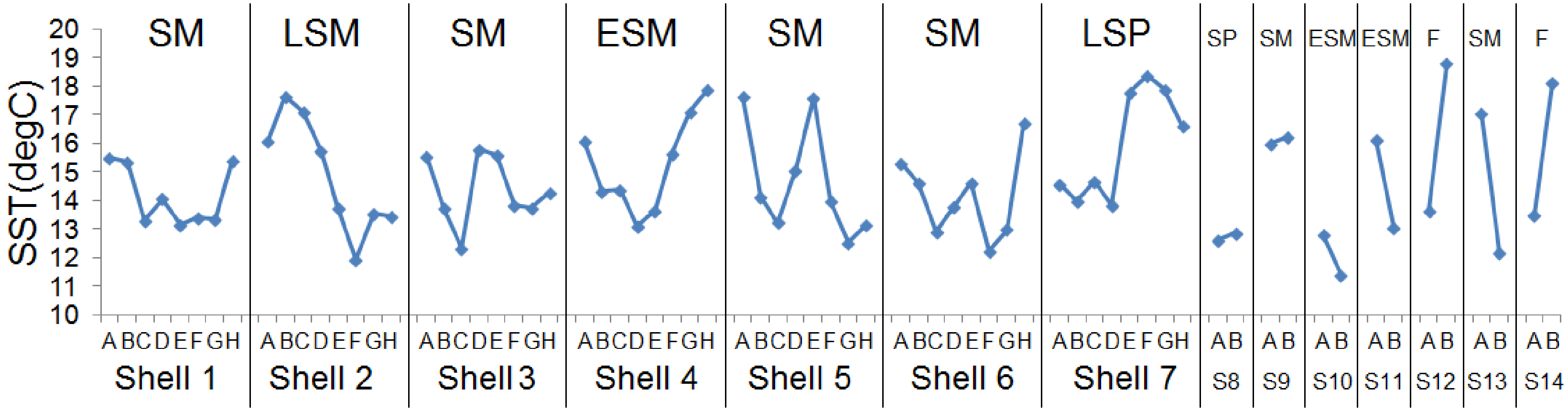


Figure A.16 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 10 at the Interior Site.

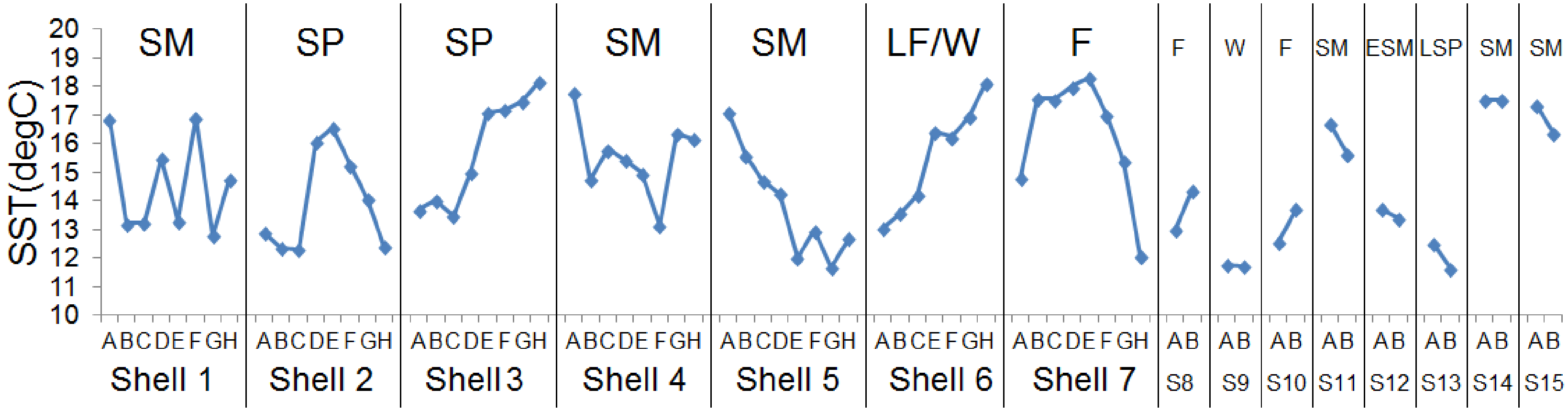
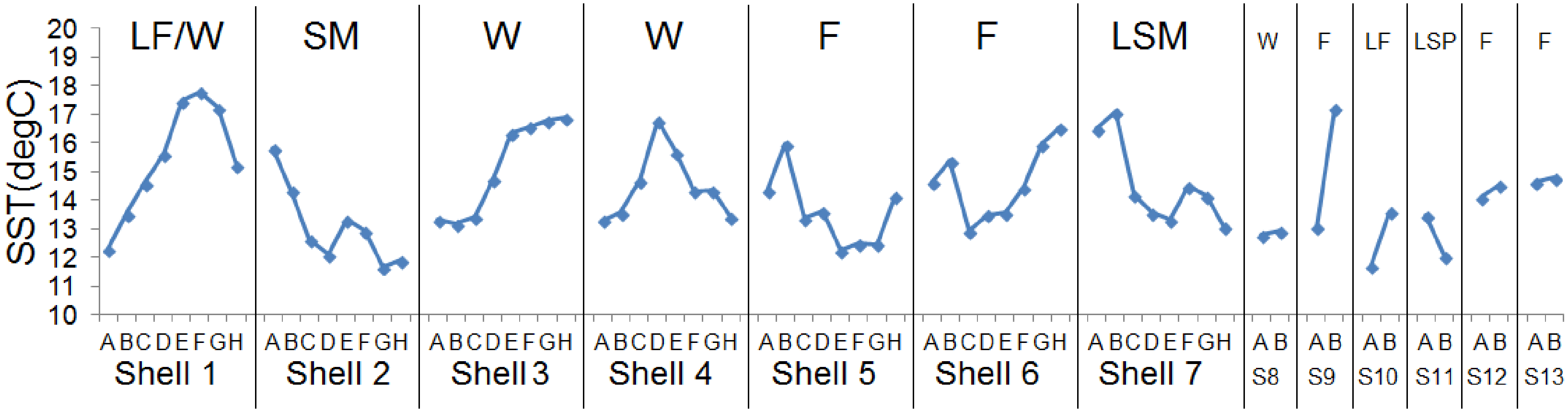


Figure A.17 Sea-surface Temperature Reconstruction based on Oxygen Isotope Analysis of marine shell carbonate from Level 9 at the Interior Site.



APPENDIX B:

BASIC RESULTS OF PALEOETHNOBOTANICAL ANALYSIS

Table B.1. All Plant Taxa Identified in Archaeological Assemblages at the Coastal site.

	TEP		MP				LMP	
	L22	L21	L20	L19	L18	L17	L16	L15
Total Soil Volume (liters)	34	47	49	35	50	83	26	30
Total Wood WT (grams)	98.23	189.31	101.66	101.67	181.12	54.01	40.96	62.1
Total Plant WT (grams)	98.43	190.9	104.34	104.15	190.85	58.63	41.43	62.24
SEEDS								
Sunflower Family	4		4	8	19	70	2	
Coast Tarweed cf.					19			
Common Tarweed				1012	2807	11	16	2
Fiddleneck Family	4					43		
Fiddleneck				798				
Peppergrass				755	146			
Saltbush	4		113	411	56	28	21	85
Goosefoot	73	21	31	3071	991	198	2	15
Soaproat		29	18	367	32			
Morning glory							1	
Sage Family	8	9					6	
Chia						4		32
Farewell to Spring	8							9
Grass Family	48	9		16	293	170		43
Brome grass	212	18	35	367		1220	273	
Canary grass	4	7	166	214	167	81	15	4
Red maids		7	129	1732	3198	362		9
GREENS								
Phacelia		7	35	24	8	151	23	15
Sedge						4		
Bean Family		10	4	48		14	20	
Bean Family cf.		10				87		6
Lupine			9	4		4	2	
Chaparral Pea				4				
Clover	24	7	78	72	195	77		15
Poppy Family cf.							10	4
Checker mallow	4		31			70	16	4
Miners lettuce			9		196		1	
Bedstraw	4				37			
FRUITS								
Prickly Pear				22	179	28		
Manzanita		24	97	43	44	112	4	5
Rose Family cf.						4	2	
Toyon				4	111			
Island Cherry				8	9			
Island Cherry cf.			17			7		

Table B.1. continued

	TEP		MP				LMP	
	L22	L21	L20	L19	L18	L17	L16	L15
Total Soil Volume (liters)	34	47	49	35	50	83	26	30
Total Wood WT (grams)	98.23	189.31	101.66	101.67	181.12	54.01	40.96	62.1
Total Plant WT (grams)	98.43	190.9	104.34	104.15	190.85	58.63	41.43	62.24
NUTS								
Acorn (nutmeat)				4				
Acorn (shell)		18	33	25	24	33		
Acorn (shell) cf.			4					
CORMS								
Blue Dicks			50	97	8	8	33	13
NON-FOOD								
Beach ragweed					8		14	
Sagebrush						28		
Wild cucumber	36	94	218	534	583	182	20	
Bulrush					8	4		
Carolina cranesbill						7		2
Verbena						28		
Plantain	4			112	43			
Ceanothus cf.						8		
Tobacco						28		
MISCELLANEOUS								
Unidentified Seeds	12	48						
Unidentifiable Seed Fragments	20	17	253	168	106	58	12	49
Unidentifiable Plant Parts	65	243	380	884	407	188	84	39

Table B.2. All Plant Taxa Identified in the Archaeological Assemblages from the Pericoastal site.

	TEP	MP	LMP		
	Level 6	Level 5	Level 4	Feature 1	Level 3
Total Soil Volume (liters)	40	28	42	60	30
Total Wood WT (grams)	46	58.39	40.71	66.38	25.91
Total Plant WT (grams)	48.64	60.58	42.71	70.58	30.3
SEEDS					
Sunflower Family			4		2
Common Tarweed	17	77	8	28	17
Fiddleneck Family					2
Fiddleneck	22		4		
Saltbush	40				2
Goosefoot	44	123	158	41	84
Soaproat					24
Morning glory					4
Sage Family	4				6
Grass Family	44	79	107	579	58
Brome grass	390	203	87	122	286
Wild Barley				10	
Canary grass	92	48	226	130	137
Gilia	4	8	6	10	
Buckwheat Family	2				
Red maids	89	127	307	85	137
GREENS					
Phacelia	127	37		21	1
Mustard Family			17		
Bean Family	8		8		18
Pacific Pea	2	4			3
Lotus	15				
Lupine				28	
Clover	124	37	320		223
Checker mallow			37	5	38
Miners lettuce				28	4
Bedstraw	14	34	138	123	36
California Wild Rose				5	
Figwort Family	4				
Johnny jump up					2
FRUITS					
Lemonadeberry/Sugar bush			4		
Prickly Pear				5	2
Manzanita	46	35	53	39	21
Rose Family cf.	7				
Toyon					6
Toyon cf.					4
Nightshade					5
NUTS					
Acorn (shell)	12	4			
Acorn (shell) cf.					
Black Walnut (shell)			13		2

Table B.2. continued

	TEP	MP	LMP		
	Level 6	Level 5	Level 4	Feature 1	Level 3
Total Soil Volume (liters)	40	28	42	60	30
Total Wood WT (grams)	46	58.39	40.71	66.38	25.91
Total Plant WT (grams)	48.64	60.58	42.71	70.58	30.3
Black Walnut (shell) cf.			17		
Black Walnut (nutmeat)					2
Black Walnut (nutmeat) cf.					8
CORMS					
Blue Dicks	40	12	75	148	50
NON-FOOD					
Beach ragweed				28	
Wild cucumber	312	342	863	310	746
Bulrush	6		4		
Blue eyed grass	58	11		31	69
Plantain	6		8	28	7
Willow Family					8
Tobacco			66		13
MISCELLANEOUS					
Unidentified Seeds	9	11		5	55
Unidentifiable Seed Fragments	157	185	363	1650	467
Unidentifiable Plant Parts	442	394	122	162	230

Table B.3. All Plant Taxa Identified in the Archaeological Assemblages from the Interior site.

	TEP		MP		LMP	
	Level 13	Level 12	Level 11	Level 10	Level 9	Level 8
Total Soil Volume (liters)	40	36	39	35	38	37
Total Wood WT (grams)	24.88	32.24	17.03	24.94	17.37	41.68
Total Plant WT (grams)	26.3	33.14	21.28	26.43	18.76	52.09
SEEDS						
Sunflower Family					50	44
Coast Tarweed cf.						26
Common Tarweed		8	33	13	15	26
Fiddleneck					15	
Saltbush		1				45
Goosefoot			97	40	81	
Spurge Family cf.	4		4			
Sage Family				72	7	
Grass Family	9	16	248	303	103	175
Brome grass	8	10		99	224	276
Wild Barley		15	14		15	8
Canary grass		40	326	280	112	93
Red maids	8	53	643	131	154	386
GREENS						
Bean Family			4	23	7	25
Bean Family cf.				10		
Locoweed						4
Pacific Pea		1	8	34	7	56
Lotus			4	4		
Lupine				4		
Chaparral Pea						4
Clover		15	54	74	47	168
Poppy Family cf.						
Checker mallow			159	114	81	
Miners lettuce						
Bedstraw		8	4		51	45
Figwort Family				13		
Johnny jump up				13	15	
FRUITS						
Prickly Pear			6			
Manzanita	24	13	247	86	29	
Rose Family cf.				4		
Island Cherry			2	20		
Island Cherry cf.					7	
California Wild Rose				13		
NUTS						
Acorn (shell)	14	8	7		7	74
Acorn (shell) cf.	30					
GEOPHYTES						
Blue Dicks	76	23	167	135	143	326
NON-FOOD						
Beach ragweed					4	

Table B.3. continued

	TEP		MP		LMP	
	Level 13	Level 12	Level 11	Level 10	Level 9	Level 8
Total Soil Volume (liters)	40	36	39	35	38	37
Total Wood WT (grams)	24.88	32.24	17.03	24.94	17.37	41.68
Total Plant WT (grams)	26.3	33.14	21.28	26.43	18.76	52.09
Wild cucumber	85	146	213	535	147	
Sleepy catchfly				13		
Blue eyed grass		2			23	
Plantain				30	15	
Tobacco			4		15	
MISCELLANEOUS						
Unidentified Seeds	2		90	116	33	66
Unidentifiable Seed Fragments	35	23	84	888	15	117
Unidentifiable Plant Parts	101	87	57	1600	634	1063

APPENDIX C:

BASIC RESULTS OF ZOOARCHAEOLOGICAL ANALYSIS

This appendix presents the results of the taxonomic identifications of the floated and screened zooarchaeological assemblages by site. The vertebrate assemblages are summarized by NISP, MNI, and weight; the invertebrate assemblages are summarized by weight and MNI in Appendix Tables C.1-C.15, along with the soil volume used to standardize the data.

Coastal Site (CA-SCRI-236)

The screened (n=8) and floated (n=8) zooarchaeological samples from the Coastal site come from terminal Early Period, Middle Period, and late Middle Period contexts. The screened vertebrate assemblage from the Coastal site includes 275 identified mammal bone fragments weighing 199.25 grams (Appendix C.1). This sample was analyzed in order to augment the mammal bone assemblage recovered from the floated samples. I identified another 27,684 bone fragments weighing 958 grams recovered from the floated samples to at least the level of class (Appendix C.2 and C.3). Altogether 39 unique animal taxa—three land mammal, four marine mammals, four bird, seven cartilaginous fish, and 21 bony fish—are represented in the vertebrate assemblage at the Coastal site. An additional 16 shellfish taxa, 11 of which likely are food resources, are included in the invertebrate assemblages recovered at the Coastal site (Appendix C.5).

Terminal Early Period Samples. The vertebrate samples from excavation Levels 22 and 21 pertaining to terminal Early Period occupation at the Coastal site yielded a total of 13 mammal bone specimens, weighing 4.49 grams in the screened assemblages and 5,511 bone specimens, weighing 249.18 grams in the floated assemblages (Appendix C.1). Mammal remains identified in the screened assemblages are represented in similar proportions in the floated assemblages from Levels 22 and 21. From the floated samples I identified a minimum of 41 individuals, including birds, land mammals, marine mammals, and fish representing at least 25 unique animal taxa (Appendix C.2 and C.3). Of the specimens identifiable to taxonomic class, fish dominate the vertebrate assemblage by percent NISP, percent weight, and percent MNI (Appendix C.4).

Birds, land mammals, and marine mammals represent small proportions of the identified assemblage (see Appendix C.4). California gull was the only taxon identified to genus, most of the avian bone specimens were too fragmented for further attribution. Of the specimens attributed to land mammals, several were identified to species, including one metapodial condyle attributed to mule deer and another seven specimens identified as phalanges and long bone fragments of the Island fox. The presence of the mule deer metapodial indicates that at least some mainland-island interaction occurred during the terminal Early Period. The remaining land mammal specimens represent very small, unidentified rodent and unidentifiable small mammal remains. It is likely, although not certain, that the unidentifiable small mammalian remains may also represent Island fox. The very small rodent bones most likely represent the presence of a habitational pest as opposed to food resource. I identified California sea lion and harbor seal remains, as well as highly fragmented pinniped bones that could not be further differentiated. One unfused vertebral epiphysis from a small cetacean does not provide compelling evidence for the exploitation of dolphins or very small whales during the terminal Early Period occupation.

The invertebrate assemblage recovered from excavation Levels 22 and 21 pertaining to terminal Early Period occupation at the Coastal site yielded shell weights of 7,659 grams and 11,421 grams respectively. I identified a minimum of 878 individuals in Level 22 and 2,044 individuals in Level 21. These values represent the highest densities of shellfish remains relative to soil volume recovered at the Coastal site, whether calculated by weight or MNI. Of the 16 identified taxa, 11 species that were likely collected as food resources (see Appendix C.5).

Middle Period Samples. The vertebrate assemblage recovered in screened assemblages from excavation Levels 20, 19, 18, and 17, pertaining to Middle Period occupation at the Coastal site, yielded a total of 238 mammal bone specimens, weighing 167.46 grams (Appendix C.1). Of the specimens identifiable beyond taxonomic class, marine mammals—specifically pinniped and California sea lion—dominate the assemblage, by NISP and by weight. Along with one rib fragment and one unfused vertebral epiphysis from a small cetacean, the remaining fraction of the screened assemblages is primarily comprised of land mammals including Island fox (represented by one tarsal bone), Island spotted skunk (represented by one right mandible fragment), a very small unidentified rodent, as well as unidentifiable small and medium mammal bone specimens. It is not clear whether the very limited contribution of identified land mammals represent exploitation of these taxa as animal food resources.

The vertebrate assemblage recovered in floated samples pertaining to Middle Period contexts is comprised of 16,896 bone specimens, weighing 551.62 grams and representing a minimum of 72 individuals and 37 unique taxa (Appendix C.2). In contrast to the mammal bone assemblage from screened samples, the relative density of vertebrate remains in the floated samples from Middle Period contexts is roughly similar to those from terminal Early Period contexts; however, there is a clear increase in the number of unique taxa identified. I identified 27 cartilaginous and bony fish species (see Appendix C.2). Of the specimens identifiable to taxonomic class, fish dominate the vertebrate assemblage by percent NISP, percent WT, and percent MNI (Appendix C.4). Shortfin mako is represented by a single tooth recovered from Level 17 and may not represent an animal food resource.

Marine mammals recovered in the floated samples represent the second greatest contribution to the Middle Period vertebrate assemblages and occur in roughly similar proportions as in the screened assemblages from the same contexts (see Appendix C.4). As with the screened samples, I identified the vast majority of marine mammal bone as California sea lion or unidentifiable pinniped, with the exception of five possible harbor seal carpal and rib fragments in Level 20 and three definite sea otter carpals in Level 18.

Land mammals contribute the least, whether calculated by percent NISP, percent WT, or percent MNI (Appendix C.4). I identified several specimens to species, including one distal tibia fragment from an Island fox in Level 20, one left mandible fragment from an Island spotted skunk in Level 18, as well as one metapodial and six long bone fragments from Mule deer also recovered in Level 18. The presence of the mule deer bones indicates that mainland-island trade continued to occur during the Middle Period. The remaining land mammal specimens represent very small unidentified rodent and unidentifiable small to medium sized mammal remains. It is likely, although not certain, that the unidentifiable small mammal remains may also represent Island fox or Island spotted skunk as these taxa were confidently identified in screened assemblages from this temporal period. The very small rodent bones most likely represent the presence of a habitational pest as opposed to food resource. Birds contribute slightly more to the Middle Period vertebrate assemblage than they did during the preceding temporal period (Appendix C.4). Although most of the avian bone was too fragmented for further attribution, I did identify three taxa: pelican (in Level 20), cormorant (in Level 19, 18, and 17), and scoter (in Level 17).

The invertebrate assemblage recovered from excavation Levels 20, 19, 18 and 17 pertaining to Middle Period occupation at the Coastal site yielded shell weights of 4,756 grams, 5,974 grams, 8,846 grams, and 7,448 grams respectively. I identified a minimum of 779 individuals in Level 20, 1,260 individuals in Level 19, 1,300 individuals in Level 18, and 1,216 individuals in Level 17. Of the 15 identified taxa, 10 species were likely collected as food resources.

Late Middle Period Samples. The vertebrate assemblage recovered in screened assemblages from excavation Levels 16 and 15 pertaining to late Middle Period occupation at the Coastal site yielded a total of 24 mammal bone specimens, weighing 27.77 grams (Appendix C.1). Of the specimens identifiable beyond taxonomic class, marine mammals—specifically California sea lion, harbor seal, and unidentifiable pinniped—continue to dominate the assemblage, by percent NISP and percent weight. The small fraction attributed land mammal is represented by three small bone fragments that could not be further differentiated.

The vertebrate assemblage recovered in floated samples pertaining to late Middle Period contexts is comprised of 5,277 bone specimens, weighing 157.20 grams, and representing a minimum of 15 individuals and 16 unique taxa (Appendix C.2). Of the specimens identifiable to taxonomic class, fish—represented by 12 unique taxa— continue to dominate the vertebrate assemblage, by percent NISP, percent weight, and percent MNI (Appendix C.4).

Marine mammals recovered in the floated samples represent the second greatest contribution to the late Middle Period vertebrate assemblages and occur in roughly similar proportions as in the screened assemblages from the same contexts (Appendix C.3 and C.4). Most of the marine mammal bone was too fragmented to identify beyond the pinniped family, with the exception of two California sea lion metatarsal fragments and four California sea lion rib fragments recovered from Level 16 (Appendix C.2).

Land mammals and birds contribute minimally to the late Middle Period vertebrate assemblages recovered from the floated samples, whether calculated by percent NISP, percent weight, or percent MNI (Appendix C.4). Only one specimen could be identified to species, a single metapodial condyle attributed to mule deer (Appendix C.2). The presence of the mule deer metapodial indicates mainland-island trade for bone tool materials continued to occur through the late Middle Period. The remaining land mammal specimens represent very small unidentified rodent and unidentifiable small sized mammal remains. I identified most of the avian remains as cormorant, represented by one humerus fragment and five other bone fragments in Level 16 and one complete vertebra in Level 15.

The invertebrate assemblage recovered from excavation Levels 16 and 15 pertaining to late Middle Period occupation at the Coastal site yielded shell weights of 3,068 grams and 2,579 grams respectively (Appendix C.5). I identified a minimum of 568 individuals in Level 16 and 395 individuals in Level 15. Of the 13 identified taxa, eight species including California mussel, black abalone, sea urchin, black turban snail, Pismo clam, platform mussel, red abalone, and crab were likely collected as food resources.

Table C.1. NISP and weight (grams) of all mammals (>1/4th") identified in screened samples from the Coastal site (CA-SCRI-236).

	Terminal Early Period				Middle Period								Late Middle Period			
	Level 22		Level 21		Level 20		Level 19		Level 18		Level 17		Level 16		Level 15	
Soil Volume (liters)	34		47		49		35		50		83		26		30	
LAND MAMMALS	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Island Fox					1	0.24										
Island Spotted Skunk									2	0.84						
UNID Small Rodent							1	1.31								
UNID Small Mammal	2	1.27			1	0.21			1	0.05	5	1.30	3	1.50		
UNID Medium Mammal									2	1.02						
MARINE MAMMALS																
Small Whale/Dolphin					2	4.97										
UNID Seal/Sea Lion	5	2.5	6	0.72	31	9.68	38	7.08	28	5.77	32	14.00	7	1.71	8	2.23
California Sea Lion					15	9.87	26	29.20	37	66.68	16	15.19	1	1.32	4	7.78
Harbor Seal															1	12.76
Total	7	3.77	6	0.72	50	25	65	37.6	70	74.36	53	30.5	11	4.53	13	22.77
Density (Total / Soil Volume)	0.21	0.11	0.13	0.02	1.02	0.51	1.86	1.07	1.40	1.49	0.64	0.37	0.42	0.17	0.43	0.76

Table C.2. NISP and weight (grams) of all birds (>1/8th"), mammals (>1/8th"), and fish (>1/16") identified in floated samples from the Coastal site (CA-SCRI-236).

	Terminal Early Period				Middle Period								Late Middle Period			
	Level 22		Level 21		Level 20		Level 19		Level 18		Level 17		Level 16		Level 15	
Soil Volume (liters)	34		47		49		35		50		83		26		30	
BIRDS	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Pelican					1	11.13										
Cormorant							1	1.43	7	4.03	1	0.78	7	4.62	1	0.62
Gull			4	0.45												
Scoter											2	0.69				
UNID Bird	45	1.92	19	1.09	20	1.24	17	2.38	9	0.33	12	0.66			5	0.43
LAND MAMMALS																
Mule Deer			1	0.53					6	11.18					1	1.53
Island Fox			7	0.26	1	0.59										
Island Spotted Skunk									1	0.76						
UNID Small Rodent	13	0.16			5	0.05	2	0.06			5	0.02			2	0.04
UNID Small Mammal	6	0.89	2	0.14	13	1	3	0.45	33	3.29	19	2.33	1	0.72	16	1.41
UNID Medium Mammal									3	2.18						
MARINE MAMMALS																
Small Whale/Dolphin			1	0.16												
Sea Otter									3	4.7						
UNID Seal/Sea Lion	17	6.31	19	2.85	79	6.83	34	4.07	90	19.82	126	26	100	17.83	17	28.27
California Sea Lion	2	6.49			10	10.51	47	51.5	13	34.5	20	26.52	6	6.55		
Harbor Seal			10	4.86	5	1.15										
CARTILIGENOUS FISH																
UNID Sharks/Rays/Skates			1	0.01	38	2.08	13	0.3	15	1.24	33	2.64	23	0.73	9	0.35
California Bat Ray									2	0.14						
California Thornback	1	0.03	2	0.05	1	0.11					1	0.01				
Round Stingray	1	0.05							3	0.01	2	0.06				
Spiny Dogfish			2	0.08	16	0.35	23	0.65	17	0.37	18	1.46	2	0.06		
Shortfin Mako											1	0.66				
UNID Cat Sharks	1	0.39														
Soupfin Shark					9	0.9	6	2.55	11	0.23	6	1.88	4	1.87		
Leopard Shark			3	0.25	7	1.39	5	0.64	4	0.06	4	4	1	0.02	4	4.85
BONY FISH																
UNID Bony Fish	3239	71.68	1326	84.82	2328	42.95	2947	50.57	4633	58.49	4746	67.8	2446	26.73	2479	34.1
Herring/Sardine			67	0.29	214	0.88	112	0.47	82	0.67	142	0.5	27	0.15	12	0.09
Pacific Sardine			2	0.01	6	0.03	2	0.01	6	0.05	4					
Surf Perch	40	4.71	58	3.53	36	4.54	45	5.57	57	2.49	27	2.15	10	0.49	17	1.16
Pile Perch	24	0.64	11	0.46	26	0.94	60	2.99			19	0.66			11	0.3
California Moray									2	0.03						
Opaleye											2	0.17				
Rock Wrasse	83	0.63	28	0.29	14	0.22	66	0.51	56	0.44	13	0.09				
Giant Kelpfish	1	0.01	16	0.39	5	0.16	1	0.02	2	0.02			1	0.1		
Kelp Greenling	32	0.1	18	0.37	19	0.04	8	0.01	1	0.01	2	0.01				
Sculpin	11	0.05	28	0.3	3	0.01			9	0.06	1	0.05				
Halfmoon			2	0.14											1	0.2
Lingcod	1	0.73	8	3.6	3	0.75	4	1.3			1	0.09			2	0.94
Senorita							38	0.25								
Kelp Bass					2	0.08	2	0.2	2	5.3						
Midshipman									1	0.4						
Rockfish	159	24.21	114	10.96	44	4.6	74	3.37	34	2.85	35	4.42	29	12.64	20	2.9
Cabezon	28	2.68	9	2.57			17	1.31	6	1.48	1	0.04				
California Sheephead	5	0.74	41	8.18	23	3.51	14	7.83	26	6.7	35	9.94	13	6.18	9	0.87
Yellowtail							1	0.21	1	0.05						
Pacific Mackerel			3	0.12	2	0.02										
Pacific Barracuda							2	0.25					1	0.45		
Jack Mackeral					3	0.06			1	0.1	2	0.17				
Total	3709	122.42	1802	126.76	2933	96.12	3544	138.9	5136	162	5280	153.8	2671	79.14	2606	78.06
Density (Total / Soil Volume)	109.09	3.60	38.34	2.70	59.86	1.96	101.26	3.97	102.72	3.24	63.61	1.85	102.73	3.04	86.87	2.60

Table C.3. MNI of all birds, mammals, and fish at the Coastal site (CA-SCRI-236) by excavation level. Mammal bone MNI considers bones recovered from both screened and floated assemblages.

	Terminal Early Period				Middle Period								Late Middle Period			
	Level 22		Level 21		Level 20		Level 19		Level 18		Level 17		Level 16		Level 15	
BIRDS	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Pelican					1	6.67										
Cormorant							1	4.76	2	9.09	1	7.14	1	20.00	1	10.00
Gull			2	10.00												
Scoter											1	7.14				
LAND MAMMALS																
Mule Deer															1	10.00
Island Fox			1	5.00	1	6.67										
Island Spotted Skunk									1	4.55						
MARINE MAMMALS																
Sea Otter									1	4.55						
California Sea Lion	1	4.76			1	6.67	1	4.76	1	4.55	1	7.14	1	20.00	1	10.00
Harbor Seal			1	5.00											1	10.00
CARTILIGENOUS FISH																
Leopard Shark															1	10.00
BONY FISH																
Pacific Sardine			2	10.00	6	40.00	2	9.52	6	27.27	4	28.57				
Surf Perch	2	9.52	2	10.00	1	6.67	4	19.05	4	18.18					2	20.00
Pile Perch															1	10.00
Rock Wrasse	5	23.81	2	10.00	1	6.67	6	28.57	1	4.55	2	14.29				
Kelp Greenling	1	4.76			1	6.67										
Lingcod			1	5.00			1	4.76								
Kelp Bass									1	4.55						
Rockfish	8	38.10	7	35.00	3	20.00	3	14.29	2	9.09	4	28.57	2	40.00	2	20.00
Cabezon	2	9.52					1	4.76	2	9.09						
California Sheephead	2	9.52	2	10.00			2	9.52	1	4.55	1	7.14				
Pacific Barracuda													1	20.00		
Total MNI	21		20		15		21		22		14		5		10	

Table C.4. Class-based comparisons at the Coastal site (CA-SCRI-236) by level. Percent NISP and percent WT (weight) represent the relative percentage of each class, derived from the bulk soil samples. Percent MNI considers all vertebrate remains identified in the screened and floated samples.

	Terminal Early Period						Middle Period												Late Middle Period					
	Level 22			Level 21			Level 20			Level 19			Level 18			Level 17			Level 16			Level 15		
	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI
Birds	1.2	1.6	0.0	1.3	1.2	10.0	0.7	12.9	6.7	0.5	2.7	4.8	0.3	2.7	9.1	0.3	1.4	14.3	0.3	5.8	20.0	0.2	1.3	11.1
Land Mammals	0.4	0.9	0.0	0.6	0.7	5.0	0.6	1.7	6.7	0.1	0.4	0.0	0.8	10.7	4.5	0.5	1.5	0.0	0.0	0.9	0.0	0.7	3.8	11.1
Marine Mammals	0.5	6.2	4.8	1.7	6.2	5.0	3.2	19.2	6.7	2.3	40.0	4.8	2.1	36.4	9.1	2.8	34.1	7.1	4.0	30.8	20.0	0.7	36.2	11.1
Cartilaginous Fish	0.1	0.4	0.0	0.4	0.3	0.0	2.4	5.0	0.0	1.3	3.0	0.0	1.0	1.3	0.0	1.2	7.0	0.0	1.1	3.4	0.0	0.5	6.7	11.1
Bony Fish	97.8	90.9	95.2	96.1	91.5	80.0	93.0	61.2	80.0	95.7	53.9	90.5	95.8	48.9	77.3	95.3	56.0	78.6	94.6	59.1	60.0	97.9	52.0	55.6

Table C.5. Weight (in grams) and MNI of all shellfish (>1/8th") identified the floated samples from the Coastal site (CA-SCRI-236).

	Terminal Early Period				Middle Period								Late Middle Period			
	Level 22		Level 21		Level 20		Level 19		Level 18		Level 17		Level 16		Level 15	
Soil Volume (liters)	34		47		49		35		50		83		26		30	
SHELLFISH	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI
Limpet	4.08		22.97		3.84		10.34		5.36		7.47		1.55		3.65	
Sessile Barnacle	118.17		326.64		155.83		178.46		349.64		323.72		44.71		70.19	
Venus Clam	1.98	3	108.14	4	1.89		3.64		0		32.57	1	0		0	
Crab	65.37		252.05		2.24		19.33		26.92		14.15		1.83		7.87	
Black Abalone	1655.14	62	485.46	36	105.56	8	64.48	1	189.34	12	225.77	14	73.6	11	120.96	6
Red Abalone	449.58	5	0		0		0		52.95	1	134.15	2	0		8.45	1
Wavy Top	6.85	1	0		0		0		0		42.38		0		0	
California Mussel	4491.94	650	8159.66	1597	4226.52	738	5436.8	1206	7679.49	1204	6253.36	1216	2807.5	512	2004.6	353
California Oyster	0		5.21	1	0		0		0		0		0		0	
Leaf Barnacle	46.5		154.46		5.59		41.68		40.91		39.08		10.94		3.57	
Chiton	121.13		250.34		10.11		12.24		27.85		45.24		5.32	4	4.84	
Platform Mussel	168.71	149	486.01	447	7.28	15	24.85	32	59.13	78	88.46	32	11.4	18	17.5	28
Sea Urchin	457.54		986.25		8.68		39.59		76.82		82.27		45.43		266.83	
Turban Snail	42.59	6	89.21	9	34.86	5	123.12	19	80.75	5	69.31	7	47.12	20	23.99	6
Pismo Clam	27.2	2	83.71	3	186.2	13	18.83	2	236.51		79.76	6	16.63	3	44.82	1
Small Gastropod	2.71		10.88		7.58		0.82		20.92		10		1.84		2.1	
Total	7659.49	878	11420.99	2044	4756.18	779	5974.18	1260	8846.59	1300	7447.69	1216	3067.87	568	2579.37	395
Density (Total / Soil Volume)	225.28	26	243.00	43	97.06	16	170.69	36	176.93	26	89.73	15	118.00	22	85.98	13

Pericoastal Site (CA-SCRI-823)

The screened (n=4) and floated (n=5) zooarchaeological samples from the Pericoastal site come from terminal Early Period, Middle Period, and late Middle Period contexts. The screened vertebrate assemblage from the Pericoastal site includes 88 identified mammal bone fragments weighing 70.62 grams (Appendix C.6). I identified another 4,659 bone fragments weighing 300.93 grams from the floated samples to at least class (Appendix C.7). Altogether 27 unique animal taxa—one bird, two land mammals, three marine mammals, five cartilaginous fish, and 16 bony fish—are represented in the vertebrate assemblage at the Pericoastal site. An additional 14 shellfish taxa, nine of which were likely food resources, are included in the invertebrate assemblage (Appendix C.10).

Terminal Early Period Samples. The vertebrate assemblage recovered in the screened sample pertaining to terminal Early Period occupation at the Pericoastal site yielded a total of 25 mammal bone specimens weighing 18 grams (Appendix C.6). Of the specimens identifiable beyond taxonomic class, marine mammals—specifically sea otter and pinniped—dominate the assemblage by percent NISP and by percent weight. The remaining fraction of mammal bones recovered from the screened sample is attributed to mule deer (represented by three long bone fragments) and an unidentifiable small terrestrial mammal (represented by two unidentifiable bone fragments). It is unlikely that the very limited contribution of identified land mammals represent exploitation of these taxa as animal food resources.

The vertebrate assemblage recovered in floated samples pertaining to terminal Early Period context is comprised of 637 bone specimens, weighing 63.89 grams, and representing a minimum of 13 individuals and 12 unique taxa (Appendix C.7 and C.8). Of the specimens identifiable to taxonomic class, fish—ten unique cartilaginous and bony fish taxa—constitute the majority of the vertebrate assemblage by percent NISP and percent MNI. However, marine mammals contribute the most by percent (Appendix C.9). Of the marine mammal specimens identifiable beyond class, I identified California sea lion remains (represented by one complete right mandible and one complete metatarsal), as well as highly fragmented pinniped bones that could not be further differentiated. Birds constitute a minor portion of the assemblage, represented by one single bone specimen in Level 6 (Appendix C.9). No land mammals were identified in the vertebrate assemblage recovered from the floated sample.

The invertebrate assemblage recovered from excavation Level 6, pertaining to terminal Early Period occupation at the Pericoastal site, yielded a shell weight of 3,701 grams, representing a minimum of 659 individuals (Appendix C.10). Of the 14 identified taxa, nine species, including California mussel, black turban snail, sea urchin, black abalone, red abalone, Pismo clam, wavy top, platform mussel, and crab were likely collected as food resources. The remaining five taxa identified are unlikely food resources and are excluded in further analysis.

Middle Period Samples. The vertebrate assemblage recovered in the screened sample from excavation Level 5 pertaining to Middle Period occupation at the Pericoastal site yielded 18 mammal bone specimens, weighing 26.32 grams (Appendix C.6). Of the specimens identifiable beyond taxonomic class, California sea lion, represented by a metatarsal and a vertebral fragment, comprises the majority of the assemblage by percent weight. The remaining fraction of the assemblage is comprised of 16 unidentifiable fragments attributed to a medium sized land mammal.

The vertebrate assemblage recovered in floated samples pertaining to Middle Period contexts is comprised of 1,757 bone specimens, weighing 62.25 grams and representing a minimum of 13 individuals and 13 unique taxa (Appendix C.7). In contrast to the mammal bone assemblage recovered from the screened sample, the density of vertebrate remains recovered from the floated samples is much higher—almost four times as much by NISP—in Middle Period context than in terminal Early Period context at this site. The density of vertebrate remains is roughly similar to the density of vertebrate remains recovered from floated samples from two Middle Period contexts at the Coastal site. Of the specimens identifiable to taxonomic class, nine cartilaginous and bony fish species dominate the vertebrate assemblage by percent NISP, percent weight, and percent MNI (Appendix C.9). Marine mammals recovered in the floated samples represent the second largest contribution to the Middle Period vertebrate assemblages by percent NISP, percent weight, and percent MNI (Appendix C.9). California sea lion, represented by a single complete astragalus, is the only marine mammal species that I was able to identify securely. The remaining 10 marine mammal bones were too fragmented to further differentiate; however, it is likely that they also are sea lion. Land mammals contribute the least to the vertebrate assemblage. None of the seven small bone fragments attributed to a small land mammal could be further identified. Birds contribute slightly more than land mammals to the Middle Period vertebrate assemblage. Although most of the avian bone was too fragmented for further attribution, I did identify a single taursometataursus bone fragment as cormorant. Some or all of the unidentifiable avian bones may also be cormorant, but the fragments are too small to attribute with any certainty.

The invertebrate assemblage recovered from excavation Level 5 pertaining to Middle Period occupation at the Pericoastal site yielded a shell weight of 5,112 grams and a minimum of 941 individuals (Appendix C.10). Of the 11 identified taxa, six species, including California mussel, black turban snail, black abalone, red abalone, platform mussel, and crab were likely collected as food resources. The remaining five taxa identified are unlikely food resources and are excluded from further analysis.

Late Middle Period Samples. The vertebrate assemblage recovered in screened assemblages from excavation Level 4 and Level 3, pertaining to late Middle Period occupation at the Pericoastal site, yielded a total of 45 mammal bone specimens, weighing 26.3 grams (Appendix C.11). Of the specimens identifiable beyond taxonomic class, marine mammals—specifically California sea lion, unidentifiable pinniped, and sea otter—dominate the assemblage by percent NISP and percent weight (Appendix C.11). The remaining fraction attributed to land mammal is represented by six unidentifiable bone fragments classified as small mammal (in Level 4), and one complete vertebra and one long bone fragment attributed to Island Fox (in Level 3).

The vertebrate assemblage recovered in floated samples from excavation Level 4, Feature 1, and Level 3 pertaining to late Middle Period contexts is comprised of 2,267 bone specimens, weighing 176.19 grams and representing a minimum of 27 individuals and 23 unique taxa (Appendix C.7 and C.8). Bone weight density and bone NISP density are also much lower in the floated samples from the Pericoastal site than from the Coastal site during this temporal period. Nonetheless, a higher number of unique animal taxa are represented in these samples relative to earlier contexts at the Pericoastal site and contemporaneous contexts at the Coastal site. Of the specimens identifiable to taxonomic class, 18 cartilaginous and bony fish taxa dominate the vertebrate assemblage calculated by percent NISP and percent MNI (Appendix C.9). Four of these taxa, black croaker, Pacific hake, barracuda, and bat ray are restricted to Feature 1 (Appendix C.7).

Marine mammals recovered in the floated samples contribute the most by percent weight and the second most by percent NISP and percent MNI (Appendix C.9). Of the specimens identifiable beyond taxonomic class in Level 4, I identified California sea lion (represented by five tarsals/metatarsals), sea otter (represented by one rib fragment), as well as 16 highly fragmented pinniped bones that could not be further classified beyond family. In the floated assemblage from Feature 1, I identified California sea lion (based on six tarsal/metatarsals) and harbor seal (based on the presence of one complete right femur). The remaining fraction of marine mammal bone from Feature 1 and all of the marine mammal bone from Level 3 were too fragmentary to identify beyond the pinniped family.

Land mammals and birds contribute more in the floated assemblages from late Middle Period contexts than in the preceding temporal periods (Appendix C.9). In Level 4 several mule deer long bone fragments, a very small, unidentified rodent vertebra, and unidentifiable small mammal bone fragments represent land mammals. In Feature 1 a single mule deer long bone fragment and unidentifiable small mammal bone fragments represent land mammals. In Level 3 a single Island fox metacarpal and thirty unidentifiable small mammal bone fragments represent land mammals. It is unclear whether any of the identified land mammal taxa were animal food resources. I identified most of the avian remains as cormorant in Level 3 and Level 4. The remaining unidentifiable bird bone fragments also are likely cormorant.

The invertebrate assemblage recovered from excavation Level 4, Feature 1, and Level 3 pertaining to late Middle Period occupation at the Pericoastal site yielded shell weights of 5,198 grams, 16,154 grams, and 4,924 grams respectively (Appendix C.10). I identified a minimum of 968 individuals in Level 4, a minimum of 2,098 individuals in Feature 1, and a minimum of 850 in Level 3. Feature 1 is notable both for the particularly high density of shellfish remains (indeed, the highest density documented in any sample included in this study) and for relative importance of taxa. Of the 13 identified taxa, eight species including California mussel, Pismo clam, black turban snail, black abalone, platform mussel, sea urchin, and crab were likely collected as food resources.

Table C.6. NISP and weight (grams) of all mammals (>1/4th") identified in screened samples from the Pericoastal site (CA-SCRI-823).

	Terminal Early Period		Middle Period		Late Middle Period			
	Level 6		Level 5		Level 4		Level 3	
Soil Volume (liters)	120		84		126		90	
LAND MAMMALS	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Mule Deer	3	2.62						
Island Fox							2	1.00
UNID Small Mammal	2	0.26			6	0.82		
UNID Medium Mammal			16	10.50				
MARINE MAMMALS								
Sea Otter	7	11.92			2	0.77		
UNID Seal/Sea Lion	13	3.2			25	11.57	8	7.49
California Sea Lion			2	15.82	2	4.65		
Total Bone	25	18	18	26.32	35	17.81	10	8.49
Density (Total / Soil Volume)	0.21	0.15	0.21	0.31	0.28	0.14	0.11	0.09

Table C.7. NISP and weight (grams) of all birds (>1/8th”) mammals (>1/8th”) and fish (>1/16”) identified in floated samples from the Pericoastal site (CA-SCRI-823).

	Terminal Early Period		Middle Period		Late Middle Period					
	Level 6		Level 5		Level 4		Feature 1		Level 3	
Soil Volume (liters)	40		28		42		60		30	
BIRDS	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Cormorant			1	1.36	7	3.66			2	3.55
UNID Bird	1	0.32	5	0.15			5	0.75	3	0.16
LAND MAMMALS										
Mule Deer					1	0.9	1	1.48		
Island Fox									1	0.09
UNID Small Rodent					7	0.05				
UNID Small Mammal			7	0.43	50	2.62	16	1.55	30	1.82
MARINE MAMMALS										
Sea Otter					1	1.25				
UNID Seal/Sea Lion	19	8.23	10	7.3	16	9.77	32	11.72	28	13.98
California Sea Lion	2	27.36	1	1.56	5	1.15	6	27.97		
Harbor Seal							1	12.05		
CARTILIGENOUS FISH										
UNID Sharks/Rays/Skates							3	0.64		
California Bat Ray							1	0.21		
Shovelnose Guitarfish					1	0.08				
Spiny Dogfish	3	0.07	1	0.01			5	0.1	6	0.07
Soupfin Shark	4	2.86			3	0.8			7	10.63
Leopard Shark	4	0.4	18	2.1	2	0.02	1	0.33	6	0.24
BONY FISH										
UNID Bony Fish	486	16.38	1499	34.47	363	15.51	455	12.75	1031	18.5
Herring/Sardine	5	0.04								
Surf Perch	54	2.61	44	3.52	18	1.05	36	4.53	11	0.38
Pile Perch	1	0.03	22	0.72			15	0.34	4	0.16
Rock Wrasse	6	0.07	4	0.03					1	0.01
Giant Kelpfish					4	0.06				
Kelp Greenling			33	0.18	3	0.01				
Sculpin	6	0.07								
Pacific Hake			1	0.06						
Lingcod					2	0.05	1	0.22	1	0.01
Rockfish	45	5.25	110	10.29	17	2.01	29	3.4	7	0.54
Black Croaker							1	1.55		
Spotfin Croaker									1	0.95
Cabezon	1	0.2								
California Sheephead			2	0.07	3	2.35	1	0.41	13	2.47
Pacific Mackerel					1	0.05				
Pacific Barracuda							2	1.24		
Total Bone	637	63.89	1757	62.25	504	41.39	611	81.24	1152	53.56
Density (Total / Soil Volume)	15.93	1.60	62.75	2.22	12.00	0.99	10.20	1.35	38.40	1.79

Table C.8. MNI of all taxa identified in floated samples at the Pericoastal site (CA-SCRI-823) by excavation level. Mammal bone MNI considers bones recovered from both screened and floated assemblages.

	Terminal Early Period		Middle Period		Late Middle Period					
	Level 6		Level 5		Level 4		Feature 1		Level 3	
BIRDS	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%
Cormorant			1	7.7	1	10.0			1	16.7
UNID Bird			1	7.7						
LAND MAMMALS										
Mule Deer	1	7.7								
Island Fox									1	16.7
UNID Small Rodent					1	10.0				
MARINE MAMMALS										
Sea Otter	1	7.7								
California Sea Lion	1	7.7	1	7.7	1	10.0	1	9.1		
Harbor Seal					1	10.0	1	9.1		
BONY FISH										
Surf Perch	2	15.4	2	15.4	2	20.0	2	18.2	1	16.7
Rock Wrasse	1	7.7								
Kelp Greenling			1	7.7						
Sculpin	2	15.4								
Lingcod					1	10.0	1	9.1		
Rockfish	4	30.8	6	46.2	1	10.0	3	27.3	1	16.7
Black Croaker							1	9.1		
Spotfin Croaker									1	16.7
Cabezon	1	7.7								
California Sheephead			1	7.7	1	10.0	1	9.1	1	16.7
Pacific Mackerel					1	10.0				
Pacific Barracuda							1	9.1		
Total MNI	13		13		10		11		6	

Table C.9. Class-based comparisons at the Pericoastal site (CA-SCRI-823) by excavation level. Percent NISP and Percent WT (weight) represent the relative percentage of each class, derived from the bulk soil samples. Percent MNI considers all vertebrate remains identified in the screened and floated samples.

	Terminal Early Period			Middle Period			Late Middle Period								
	Level 6			Level 5			Level 4			Feature 1			Level 3		
CLASS	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI	%NISP	%WT	%MNI
Birds	0.2	0.5	0.0	0.3	2.6	15.4	1.4	8.8	10.0	0.8	0.9	0.0	0.4	6.9	16.7
Land Mammals	0.0	0.0	7.7	0.4	0.7	0.0	11.5	8.6	10.0	2.8	3.7	8.3	2.7	3.6	16.7
Marine Mammals	3.3	55.7	15.4	0.6	14.2	7.7	4.4	29.4	20.0	6.4	63.7	16.7	2.4	26.1	0.0
Cartilaginous Fish	1.7	5.2	0.0	1.1	3.4	0.0	1.2	2.2	0.0	1.6	1.6	0.0	1.6	20.4	0.0
Bony Fish	94.8	38.6	76.9	97.6	79.1	76.9	81.5	51.0	60.0	88.4	30.1	75.0	92.8	43.0	66.7

Table C.10. Weight (in grams) and MNI of all shellfish (>1/8th") identified floated samples from the Pericoastal site (CA-SCRI-823).

	Terminal Early Period		Middle Period		Late Middle Period					
	Level 6		Level 5		Level 4		Feature 1		Level 3	
Soil Volume (liters)	40		28		42		60		30	
SHELLFISH	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI
Limpet	4.38		2.63		6.38		5.34		1.85	
Sessile Barnacle	162.56		226.23		137.52		334.21		205.04	
Crab	0.63	1	4.19		5.40		9.53	1	2.27	1
Black Abalone	27.21	3	107.40	7	56.63	3	394.18	22	85.61	1
Red Abalone	43.37	5	58.50	1	0.00		0.00		0.00	
Wavy Top	18.03	1	0		0.79	1	25.59	1	16.08	2
California Mussel	3303.60	628	4469.18	887	4685.31	925	9181.23	1914	4057.04	807
Leaf Barnacle	19.64		19.08		18.12		25.97		14.79	
Chiton	6.34		2.45		4.30		11.62		0.28	
Platform Mussel	7.38	8	7.80	13	14.95	25	27.70	39	9.20	17
Sea Urchin	7.17		0		3.47		8.83	11	3.04	
Turban Snail	73.86	12	208.32	33	155.84	11	289.07	35	70.78	16
Pismo Clam	25.30	1	0		105.06	3	5835.60	75	457.76	6
Small Gastropod	2.20		6.05		3.97		5.71		0.46	
Total Shell	3701.67	659	5112.47	941	5197.74	968	16154.58	2098	4924.20	850
Density (Total / Soil Volume)	92.54	16	182.59	34	123.76	23	269.24	35	164.14	28

Interior Site (CA-SCRI-568)

The screened (n=6) and floated (n=6) zooarchaeological samples the Interior site represent terminal Early Period, Middle Period, and late Middle Period contexts. The screened vertebrate assemblage from the Interior site includes 134 identified mammal bone fragments weighing 113.81 grams (Appendix C.11). I identified another 4,755 bone fragments weighing 135.8 grams recovered from the floated samples to at least class (Appendix C.12). Altogether a minimum of 36 individuals from 19 unique animal taxa—one bird, one land mammal, three marine mammals, five cartilaginous fish, and nine bony fish—are represented in the vertebrate assemblage at the Interior site. An additional 13 shellfish taxa, eight of which represent likely food resources, are included in the invertebrate assemblage. The number of unique vertebrate and invertebrate taxa identified at the Interior site is much lower than at the Coastal and Pericoastal sites.

Terminal Early Period Samples. The vertebrate assemblage recovered screened samples pertaining to terminal Early Period occupation at the Interior site yielded a total of 33 mammal bone specimens weighing 19.79 grams (Appendix C.11). This indicates a similar density of mammal bone recovered from screens from terminal Early Period contexts at both the Coastal and Pericoastal sites. Of the specimens identifiable beyond taxonomic class, marine mammals, specifically sea otter, dominate the assemblage by percent NISP and by percent weight. The remaining fraction of mammal bones recovered from the screened sample is attributed to small terrestrial mammal (represented by 12 small unidentifiable bone fragments).

The vertebrate assemblage recovered in floated samples pertaining to terminal Early Period context is comprised of 536 bone specimens weighing 34.68 grams and representing a minimum of 9 individuals and 9 unique taxa (Appendix C.12 and Appendix C.13). Of the specimens identifiable to taxonomic class, six cartilaginous and bony fish taxa constitute the majority of the vertebrate assemblage. Birds, marine mammals, and land mammals (in that order) contribute much less whether calculated by percent NISP, percent weight, or percent MNI (Appendix C.14). Among the identifiable avian bone specimens in Level 13, one vertebra and two large fragments that refit to form a complete left femur attributed to cormorant. The remaining fraction of the bird bone assemblage may also represent cormorant, but these eight small fragments lack diagnostic features. I identified sea otter (represented by two metacarpal bone fragments), as well as highly fragmented pinniped bones that could not be further differentiated. I attributed the remaining fraction of vertebrate remains recovered from terminal Early Period contexts to small, unidentified terrestrial mammal (represented by unidentifiable bone fragments).

The invertebrate assemblage recovered from excavation Level 13 and Level 12 pertaining to terminal Early Period occupation at the Interior site yielded shell weights of approximately 8,746 grams and 6,302 grams, respectively (Appendix C.15). I identified a total of 1,618 individuals in the shellfish assemblage from Level 13 and 1,304 individuals in the shellfish assemblage from Level 12. Of the 13 identified taxa, eight species, including California mussel, black abalone, crab, Pismo clam, platform mussel, black turban snail, moon snail, and sea urchin were likely collected as food resources. The remaining five taxa identified are unlikely food resources and are excluded in further analysis.

Middle Period Samples. The vertebrate assemblage recovered in screened assemblages from excavation Level 11 and Level 10 pertaining to Middle Period occupation at the Interior site yielded 40 mammal bone specimens, weighing 19.98 grams (Appendix C.11). This low mammal bone density is comparable to the low density of mammal bone recovered from terminal Early Period contexts at all three sites. Of the specimens identifiable beyond taxonomic class, marine mammals—specifically California sea lion and undifferentiated pinniped —overwhelm the assemblage by percent NISP and percent weight. The small remaining fraction of the screened assemblage is comprised of unidentifiable fragments attributed to a small-sized land mammal.

The vertebrate assemblage recovered in floated samples pertaining to Middle Period contexts is comprised of 3,813 bone specimens, weighing 60.64 grams and representing a minimum of 13 individuals and 17 unique taxa (Appendix C.12 and Appendix C.13). In contrast to the mammal bone assemblage recovered from the screened sample, the density of vertebrate remains recovered from the floated samples is higher in Middle Period contexts than in terminal Early Period contexts at this site. Of the specimens identifiable to taxonomic class, 11 cartilaginous and bony fish species—likely to represent food resources—contribute the most to the vertebrate assemblage calculated by percent NISP, percent weight, and percent MNI. I also identified blue shark, based on the recovery of one complete tooth, and swordfish, based on recovery of a section (weighing 15.85 grams) of its bill, both in Level 10. It is not clear that either of these taxa represent animal food resources. A single shark tooth could be collected on the beach much more easily than a blue shark could have been caught. Swordfish ceremonialism is well documented in the ethnographic literature, as discussed in the previous section. The presence of skull/bill elements in an archaeological deposit may be attributed to social and ideological factors rather than subsistence. As I did not document any other swordfish skeletal elements in the assemblage that might suggest consumption, I omit this species from further analysis, as the disproportionate weight of this specimen overwhelms all other variation in the data set. Nonetheless, the presence of this taxon, whether for subsistence or ideological purposes does attest to the presence of pelagic fishing during the Middle Period.

Marine mammals recovered in the floated samples represent the second largest contribution to the Middle Period vertebrate assemblages (Appendix C.14). California sea lion, represented by a complete calcaneus and metacarpal in Level 11 and by a fragment of a phalange in Level 10, is the only marine mammal that I was able to identify with certainty. All of the remaining marine mammal bones were too fragmented to differentiate further; however, it is likely that they may represent sea lion in both samples.

Similar to the preceding temporal period at the Interior site, land mammals and birds contribute very little to the Middle Period vertebrate assemblages whether calculated by percent NISP, by percent weight, or percent MNI (Appendix C.14). None of the small bone fragments attributed to a small land mammal could be identified further. Although most of the avian bone was too fragmented for further attribution, I did identify a single carpometacarpus bone fragment as cormorant from Level 10 assemblage. Some or all of the unidentifiable avian bones may also be cormorant, but they are too small to attribute with any certainty.

The invertebrate assemblage recovered from excavation Level 11 and Level 10 pertaining to Middle Period occupation at the Interior site yielded shell weights of approximately 9,940 grams and 7,723 grams, respectively (Appendix C.15). I identified a minimum of 1,386 individuals in the shellfish assemblage from Level 11 and 1,298 individuals in the shellfish assemblage from Level 10. Of the 12 identified taxa, just seven species, including California mussel, black abalone, black turban snail, Pismo clam, platform mussel, crab, and sea urchin were likely collected as food resources.

Late Middle Period Samples. The vertebrate assemblage recovered in screened assemblages from excavation Level 9 and Level 8 pertaining to late Middle Period occupation at the Interior site yielded 61 mammal bone specimens, weighing 74.04 grams (Appendix C.11). Of the specimens identifiable beyond taxonomic class, marine mammals—specifically California sea lion, harbor seal, unidentifiable pinniped, and sea otter—once again dominate, comprising the entire assemblage in Level 9 and contributing 98.36% by NISP and 98.78% by weight in Level 8. A single long bone fragment attributed to mule deer represents the remaining fraction attributed to land mammal.

The vertebrate assemblage recovered in floated samples from Level 9 and Level 10 pertaining to late Middle Period contexts is comprised of 406 bone specimens, weighing 40.48 grams and representing a minimum of 14 individuals and 13 unique taxa (Appendix C.12 and B.13). Bone weight density and bone NISP density are also much lower in the floated samples from the Interior site than in contemporaneous assemblages from the Coastal site or Pericoastal site. Of the specimens identifiable to taxonomic class, six cartilaginous and bony fish species contribute the majority of the vertebrate assemblage based on bone NISP (Appendix C.14). However, the relative contribution of fish is lower when based on bone weight or MNI. Marine mammals recovered in the floated samples comprise a larger portion of the vertebrate assemblage by percent weight. Most of the marine mammal bone was too fragmentary to identify beyond the pinniped family, with the exception of one squasmosal bone that I was able to attribute to sea otter. There is a greater density, both by bone weight and bone NISP, of marine mammal bone in late Middle Period contexts than in either of the preceding temporal periods represented at the Interior site (Appendix C.14). Land mammals—represented by 18 unidentifiable small mammal bone fragments—and birds—represented by just one cormorant tarsometataursus and one unidentifiable fragment—contribute minimally to the vertebrate assemblages from late Middle Period contexts.

The invertebrate assemblage recovered from Level 9 and Level 8 pertaining to late Middle Period occupation at the Interior site yielded shell weights of approximately 3,500 grams and 1,519 grams, respectively (Appendix C.15). I identified a minimum of 550 individuals in the shellfish assemblage from Level 9 and 397 individuals in the shellfish assemblage from Level 8.

Table C.11. NISP and weight (grams) of all mammals (>1/4th") identified in screened samples from the Interior site (CA-SCRI-568).

	Terminal Early Period				Middle Period				Late Middle Period			
	Level 13		Level 12		Level 11		Level 10		Level 9		Level 8	
Soil Volume (liters)	120		108		117		105		114		111	
LAND MAMMALS	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Mule Deer											1	0.90
UNID Small Mammal	12	0.65			3	1.29						
MARINE MAMMALS												
Sea Otter	6	7.34	5	4.44					3	1.53	2	2.15
UNID Seal/Sea Lion			10	7.35	15	6.74	15	1.35	13	4.83	27	7.35
California Sea Lion					6	9.80	1	0.8	12	33.4	2	2.05
Harbor Seal											1	21.83
Total	18	7.99	15	11.79	24	17.83	16	2.15	28	39.76	33	34.28
Density (Total/Soil Volume)	0.15	0.07	0.14	0.11	0.21	0.15	0.15	0.02	0.25	0.35	0.30	0.31

Table C.12. NISP and weight (grams) of all birds (>1/8th"), mammals (>1/8th"), and fish (>1/16th") identified in floated samples from the Interior site (CA-SCRI-568).

	Terminal Early Period				Middle Period				Late Middle Period			
	Level 13		Level 12		Level 11		Level 10		Level 9		Level 8	
Soil Volume (liters)	40		36		39		35		38		37	
BIRDS	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT	NISP	WT
Cormorant	3	8.09					1	0.19	1	0.19		
UNID Bird	8	1.8	2	0.25	5	0.32	2	0.05	1	0.21		
LAND MAMMALS												
UNID Small Mammal	12	0.65	2	0.14	4	0.48	22	0.96				
UNID Medium Mammal									18	1.87		
MARINE MAMMALS												
Sea Otter	2	3.22							1	0.13		
UNID Seal/Sea Lion	6	0.35	10	0.62	17	2.67	10	3.54	2	19.76	10	3.85
California Sea Lion					2	3.28	1	0.08				
CARTILIGENOUS FISH												
UNID Sharks/Rays/Skates					4	0.2	5	0.12				
Shovelnose Guitarfish					1	0.02						
Spiny Dogfish					1	0.02	1	0.03				
Blue Shark							1	0.24				
Soupfin Shark	1	2.39	2	0.73	8	2.49	6	2.88	1	0.01		
Leopard Shark											1	0.3
BONY FISH												
UNID Bony Fish	320	3.92	120	4.95	2561	14.66	871	7.83	317	5.44		
Herring/Sardine			6	0.01	6	0.01						
Surf Perch	4	0.11	9	0.91	4	0.37	9	0.55	4	1.26	16	2.74
Pile Perch	6	0.34	1	0.01	3	0.01	10	0.33	10	0.14		
Rock Wrasse					2	0.01						
Kelp Bass					2	0.35						
Rockfish			3	0.26	5	0.5	5	0.8	3	0.58	17	3.56
Cabezon					2	0.48						
California Sheephead	7	4.97	1	0.89	1	1.09	1	0.23	4	0.44		
Swordfish							240	15.85				
Total	369	25.84	156	8.84	2628	26.96	1185	33.68	362	30.03	44	10.45
Density (Total/Soil Volume)	9.23	0.65	4.64	0.25	67.38	0.69	33.86	0.96	9.53	0.79	1.19	0.28

Table C.13. MNI of all birds and mammals at the Interior site (CA-SCRI-568) by excavation level. Mammal bone MNI considers bones recovered from both screened and floated assemblages.

	Terminal Early Period				Middle Period				Late Middle Period			
	Level 13		Level 12		Level 11		Level 10		Level 9		Level 8	
BIRDS	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%
Cormorant	1	25.00					1	20.00	1	14.29		
MARINE MAMMALS												
Sea Otter	1	25.00	1	20.00					1	14.29	1	14.29
California Sea Lion					1	12.50	1	20.00	1	14.29	1	14.29
Harbor Seal											1	14.29
BONY FISH												
Herring/Sardine			1	20.00	1	12.50						
Surf Perch	1	25.00	1	20.00	1	12.50	1	20.00	1	14.29	2	28.57
Rock Wrasse					1	12.50						
Kelp Bass					1	12.50						
Rockfish			1	20.00	1	12.50	1	20.00	2	28.57	2	28.57
Cabezon					1	12.50						
California Sheephead	1	25.00	1	20.00	1	12.50	1	20.00	1	14.29		
Total MNI	4		5		8		5		7		7	

Table C.14. Class-based comparisons at the Interior site (CA-SCRI-568) by excavation level. Percent NISP and Percent WT (weight) represent the relative percentage of each class, derived from the bulk soil samples. Percent MNI considers all vertebrate remains identified in the screened and floated samples.

	Terminal Early Period						Middle Period						Late Middle Period					
	Level 13			Level 12			Level 11			Level 10			Level 9			Level 8		
CLASS	% NISP	% WT	% MNI	% NISP	% WT	% MNI	% NISP	% WT	% MNI	% NISP	% WT	% MNI	% NISP	% WT	% MNI	% NISP	% WT	% MNI
Birds	3.0	38.3	25.0	1.2	2.8	0.0	0.2	1.2	0.0	0.3	2.2	20.0	0.6	1.3	20.0	0.0	0.0	0.0
Land Mammals	3.3	2.5	0.0	1.2	1.6	0.0	0.2	1.8	0.0	2.3	5.3	0.0	5.0	6.2	0.0	0.0	0.0	12.5
Marine Mammals	2.2	13.8	25.0	6.0	7.0	20.0	0.7	22.1	12.5	1.2	20.1	20.0	0.8	66.2	40.0	22.7	36.8	37.5
Cartilaginous Fish	0.3	9.2	0.0	1.2	8.3	0.0	0.5	10.1	0.0	1.4	18.2	0.0	0.3	0.0	0.0	2.3	2.9	0.0
Bony Fish	91.3	36.1	50.0	90.4	80.3	80.0	98.4	64.8	87.5	94.8	54.2	60.0	93.4	26.2	40.0	75.0	60.3	50.0

Table C.15. Weight (in grams) and MNI of all shellfish (>1/8th") identified bulk soil samples from the Interior site (CA-SCRI-568).

	Terminal Early Period				Middle Period				Late Middle Period			
	Level 13		Level 12		Level 11		Level 10		Level 9		Level 8	
Soil Volume (liters)	34		47		49		35		50		83	
SHELLFISH	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI	WT	MNI
Limpet	7.68		4.98		2.59		3.42		3.05		0.84	
Sessile Barnacle	336.14		142.11		133.20		175.98		150.53		45.32	
Crab	51.31	1	0.00		9.29	1	0.49	1	0.00		0.38	
Black Abalone	148.81	2	113.49		17.53	2	50.66	3	81.39	2	20.36	1
California Mussel	8124.92	1581	6074.22	1184	9740.27	1373	7449.19	1280	3201.45	520	1348.36	243
Moon Snail	8.49	1	0.00		0		0		0		0	
Leaf Barnacle	14.13		6.48		7.10		14.21		17.85		37.68	
Chiton	0.39		0.26		1.62		1.41		1.17		5.02	
Platform Mussel	10.04	30	33.51	104	10.84	8	7.25	10	10.09	18	49.38	153
Sea Urchin	7.20		15.08		1.35		0.00		0.85		0.76	
Turban Snail	16.20	2	2.91	15	11.80	1	18.40	3	27.54	10	8.58	
Pismo Clam	18.35	1	2.04	1	3.61	1	0.80	1	1.29		0.00	
Small Gastropod	2.33		7.14		0.58		1.29		4.68		2.66	
Total	8745.99	1618	6402.22	1304	9939.77	1386	7723.10	1298	3499.89	550	1519.34	397
Density (Total/Soil Volume)	257.24	48	136.21	28	202.85	28	220.66	37	70.00	11	18.31	5