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Changes in Marine Subsistence on San Miguel Island from 8,500 to 2,400 Years Ago: Analysis of Bulk Samples from Cave of the Chimneys (CA-SMI-603)

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*We present a detailed faunal analysis of bulk samples excavated from Cave of the Chimneys, located on the northeast coast of San Miguel Island. The site contains at least six discrete cultural components in a well-stratified and well-preserved sequence spanning roughly 6,000 years, from about 8,500 to 2,400 years ago. Although species composition and shellfish richness changed over time, rocky intertidal shellfish dominate the faunal assemblage. The Early Holocene strata predominantly consist of California mussels (*Mytilus californianus*) with other species present in low numbers. The contribution of other shellfish taxa in the Middle Holocene strata greatly increases so that no single species dominates the assemblage. Fish remains are present throughout, but vary in abundance and dietary importance. We discuss these trans-Holocene patterns in the context of other San Miguel Island sites and general patterns of maritime subsistence developed for the Santa Barbara Channel region.*

ARCHAEOLOGICAL DEPOSITS IN COASTAL CAVES and rockshelters have played a major role in understanding the evolution of maritime adaptations across the globe. Human utilization of coastal caves and rockshelters extends back to the inception of our species (see Colonese et al. 2011; Erlandson 2001; Erlandson and Rick 2008; Klein et al. 2004; Kuhn and Stiner 1998; Marean et al. 2007; Singer and Wymer 1982). Although coastal regions were occupied throughout the Pleistocene, intensive use of marine resources and the creation of large coastal middens appear to have begun in earnest during the Early to Middle Holocene (Serizawa 1979; Waselkov 1987:124). Along the Pacific Coast of North America, as elsewhere, postglacial sea level rise has submerged and likely destroyed much of the evidence for early coastal sites. The protected locations of some caves and rockshelters provide unique opportunities to study these early maritime adaptations. Not only is preservation in caves generally superior to that of most open sites (Parkington 1976; Straus 1990), the shelter they provide likely lured coastal people away from now submerged shorelines (Rick et al. 2003).

Previously published research from Cave of the Chimneys has focused on Early Holocene cordage, artifacts (Vellanoweth et al. 2003), and vertebrate remains (Rick et al. 2005b). Other research focused on the analysis of faunal remains from 15-liter samples from the Middle and Late Holocene strata (Vellanoweth et

Table 1

A RADIOCARBON CHRONOLOGY FOR CAVE OF THE CHIMNEYS

Unit 1 Stratum	Lab number	Material dated	Uncorrected ^{14}C age (RYBP)	$^{13}C/^{12}C$ Adjusted	Calendar age range (cal B.P.)	Adjusted age range[2] (cal B.P.)
2	Beta-115556	Marine Shell	2,550 ± 60	2,980 ± 60	2,340 (2,440) 2,600	2,352 : 2,575
3	Beta-115557	Marine Shell	3,830 ± 70	4,270 ± 70	3,840 (4,060) 4,280	3,955 : 4,188
4	Beta-115558	Marine Shell	4,010 ± 70	4,450 ± 70	4,070 (4,320) 4,520	4,208 : 4,426
5	Beta-115559	Marine Shell	4,030 ± 60	4,80 ± 60	4,150 (4,370) 4,520	4,245 : 4,445
6	Beta-129099	Olivella bead	6,890 ± 70	7,300 ± 70	7,480 (7,560) 7,610	7,483 : 7,623
6	Beta-136695	Marine Shell	7,440 ± 60	7,300 ± 60	8,010 (8,110) 8,170	8,019 : 8,180
6	Beta-122712	Marine Shell	7,690 ± 80	8,120 ± 80	8,280 (8,350) 8,410	8,268 : 8,456
7	Beta-122713	Marine Shell	7,220 ± 70	7,650 ± 70	7,790 (7,870) 7,950	7,805 : 7,963
7	Beta-136696	Marine Shell	7,310 ± 80	7,740 ± 80	7,870 (7,950) 8,030	7,876 : 8,070

All dates compiled from Vellanoweth et al. (2002), and Vellanoweth et al. (2003). Dates were calibrated via Stuiver and Reimer's (1993, 1999) Calib 6.0.1 program and adjusted according to Hughen et al. (2004). Rounded calendar ages include intercept (in parentheses) and age range at 1 sigma.

al. 2002). In this paper we provide detailed analyses of bulk samples from Cave of the Chimneys radiocarbon dated to between ~8,500 and 2,400 cal B.P. (Table 1). We explore changes in diet and shellfish utilization through time and determine how these compare to broader regional patterns. The rich and well-preserved faunal assemblage from the site provides data for dietary reconstructions and inferences concerning foraging selectivity, local resource depressions and rebounds, and human land-use patterns. Faunal methods used include multiple modes of quantification and analysis to let us best interpret our data. Results of dietary reconstructions and resource harvesting patterns are compared with a previously analyzed sample from the same site and from other cave sites on San Miguel Island. Due to excellent preservation, these data provide an opportunity to observe changes in maritime subsistence strategies throughout 6,000 years of human occupation at a single location.

BACKGROUND

San Miguel Island, the outermost and second smallest (37 km.^{2} in area) of the Northern Channel Islands, is currently located approximately 44 km. off the California mainland coast (Fig. 1). During the Last Glacial, San Miguel was connected to the other northern islands as part of Santarosae Island, separated from the mainland by just 6–8 km. (Orr 1968). Extensive dune fields surrounded by sandy and rocky beaches dominate much of the island. San Miguel lies in the path of the colder, nutrient-rich waters of the California Current. Terrestrial flora and fauna are relatively impoverished (Schoenherr et al. 1999:7–17), and fresh water is limited primarily to seeps and springs (Grant 1978:524). However, the island's productive and diverse marine ecosystems have attracted human populations for at least the past 12,000 years (Braje 2007; Erlandson et al. 1996, 2008a, 2011b; Rick 2007). The scarcity of burrowing animals on San Miguel, along with calcareous sand dunes and soils, allows for excellent stratigraphic integrity and the preservation of archaeological remains.

With over 700 sites, San Miguel Island contains one of the longest, continuous archaeological sequences in the Americas (Erlandson et al. 2008b; Rick et al. 2001, 2005a). Evidence of shellfish harvesting from middens spans the past 12,000 years, providing a long record of human subsistence and adaptation to an island ecosystem (Erlandson et al. 2005a, 2011b). Daisy Cave (CA-SMI-261), located directly around the point from Cave of the Chimneys, contains one of the earliest (~11,500 cal B.P.) records of human occupation on the island (Erlandson et al. 1996, 2008a:2239; Rick et al. 2001). Terminal Pleistocene and Early Holocene sites on San Miguel Island consist of midden deposits dominated by rocky intertidal shellfish, suggesting a heavy reliance on these and other marine resources (Erlandson et al. 2011b; Rick et al. 2005a). Fish appear to have been a secondary resource at all Early Holocene sites except Daisy Cave (Rick et al. 2001, 2005a:185). Evidence

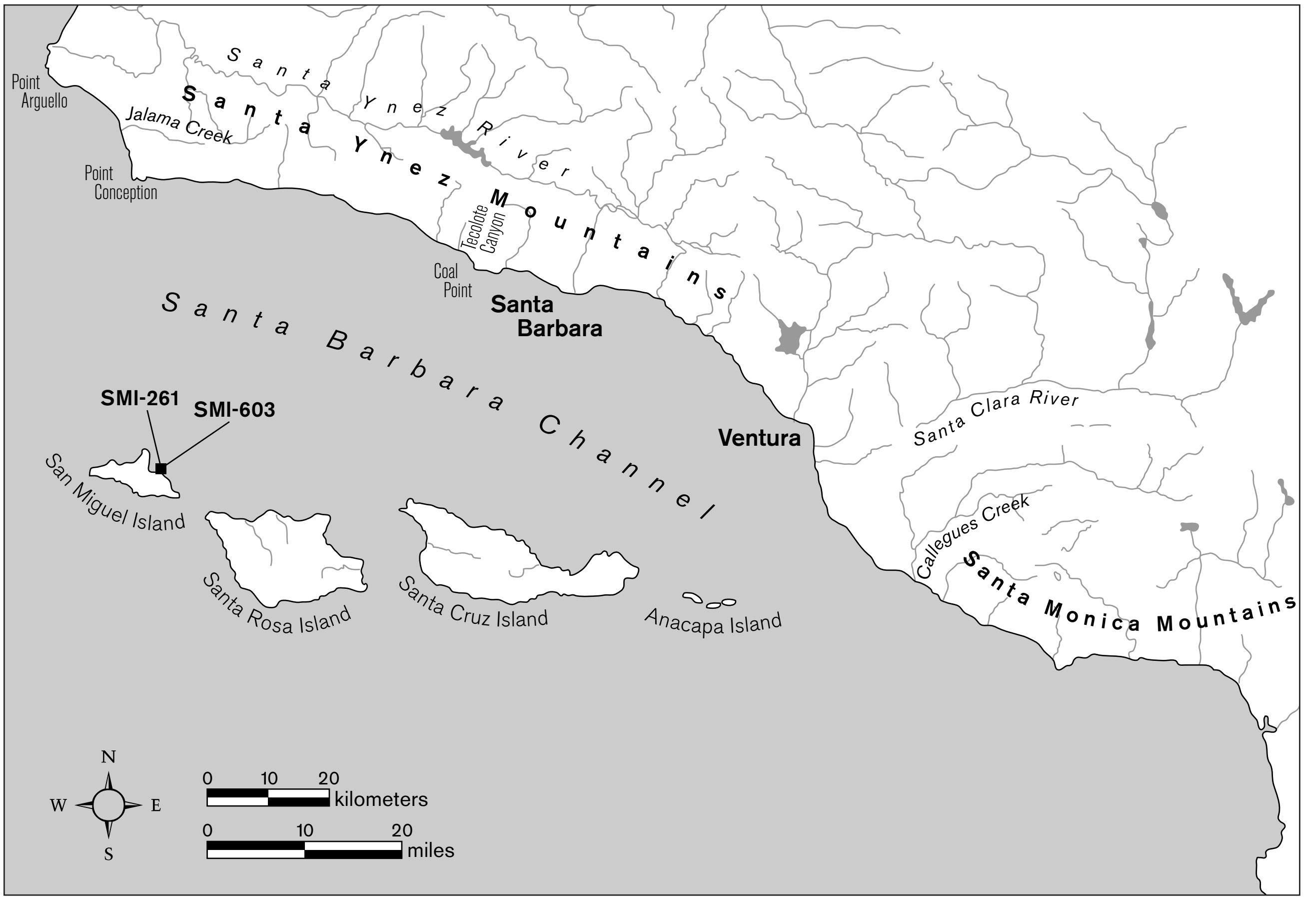

Figure 1. Map of the California coast and Northern Channel Islands.

of early technology includes chipped stone artifacts (Erlandson et al. 2005a:679), various forms of simple *Olivella* shell beads (see Rick et al. 2005a:183–184), sea grass cordage and twined basketry (Connolly et al. 1994; Norris 1996; Vellanoweth et al. 2003), and bone gorges representing early evidence for hook-and-line fishing (Erlandson 1994:265; Erlandson et al. 2005a:679; Rick et al. 2001).

Coinciding with environmental changes, the Middle Holocene marks a period of cultural transition and expansion on the Channel Islands, with evidence for more permanent settlement and intensification of resource use, as well as the development of more complex trade networks (Kennett et al. 2007; Rick et al. 2005a:187–198). Technological tool kits appear to have remained similar to those employed in the Early Holocene, with advances in fishing and hunting technology occurring near the end of the Middle Holocene (Glassow 1997, 2005a; Raab 1997; Rick et al. 2005a:189,193–194,198). Middle Holocene shell middens on San Miguel Island are relatively diverse, representing a variety of subsistence strategies despite the perceived dominance of red abalone in many middens (Glassow 1993a, 2005b; Kennett 2005; Rick et al. 2005a:196–198; Vellanoweth et al. 2006; see also Braje 2007; Braje and Erlandson 2007).

During the Late Holocene, social complexity on the Channel Islands reached its peak as populations greatly expanded, technology became more refined and elaborate, exchange networks became more extensive, sedentary villages grew, and social hierarchies increased (Kennett 2005; Rick et al. 2005a:198–215). Subsistence strategies involved an expanded use of local fisheries, including evidence for kelp bed and pelagic fishing (Bernard 2004) attributed to the development of the single-piece shell fishhook (Strudwick 1986) and the plank canoe (*tomol*) (Arnold and Bernard 2005; Gamble 2002). Cross-channel trade also increased during this time period (see Arnold 1992, 2001; Kennett 2005; Rick et al. 2005a). At the time of European contact San Miguel was

Figure 2. Entrance to Cave of the Chimneys (CA-SMI-603).

inhabited by people speaking a Chumashan language (Arnold 2001; Kennett 2005; Rick 2007), a linguistic isolate that appears to have great time depth in the Santa Barbara Channel region.

SITE DESCRIPTION

Cave of the Chimneys is located on the northeast coast of San Miguel Island at Bay Point. It currently sits approximately 12 meters above a rocky coastline and is most easily accessed by a narrow ledge at the southeast edge of the rockshelter (Fig. 2). The cave occurs in an andesitic conglomerate containing cobbles and pebbles cemented in a sandy matrix. Marine erosion and high interglacial sea levels appear to be responsible for the cave's formation during the Pleistocene. Cave of the Chimneys is roughly 10 meters deep and 12 meters wide, with a skylight measuring approximately 1.5 meters in diameter. A large east-facing entrance provides adequate lighting within the shelter and protection from the predominant northwesterly winds that buffet San Miguel Island for much of the year (Johnson 1972:63). Sediments fill the cave to within one meter or less of the ceiling in the back portion of the shelter. Substantial amounts of the sloping midden deposits near the cave mouth appear to have been lost to erosion, but the extent of these losses is impossible to quantify (Vellanoweth et al. 2003). Those deposits that remain intact, however, are finely stratified and extremely well-preserved.

Figure 3. Vellanoweth excavating Unit 1, CA-SMI-603.

STRATIGRAPHY AND CHRONOLOGY

Cave of the Chimneys contains at least six distinct archaeological components, or strata, with over two meters of midden accumulation (Fig. 3). The uppermost layer, Stratum 1, consists of a weakly-developed yellowish brown (10 YR 5/4) soil with copious rock fall, naturally-deposited bone (primarily rodent and lizard), and scant cultural materials. Due to the scarcity of cultural materials, Stratum 1 is not included in this analysis. Stratum 2, approximately 20 cm. thick, is a brown (10 YR 4/3) soil containing angular rockfall and abundant faunal remains. Radiocarbon (^{14}C) dating of a well-preserved marine shell produced an adjusted age range of 2,350–2,580 cal B.P. (Vellanoweth et al. 2002:608; Table 1). Stratum 3, dated to 3,960–4,190 cal B.P., consists of a thin charcoal-rich soil (10 YR 3/2, very dark greyish brown) containing clusters of shells and other faunal remains (Vellanoweth et al. 2002:608). Stratum 3 is the only deposit from which we recovered no artifacts. Stratum 4 (10 YR 4/3, brown) is ~35 cm. thick, and is dated to between 4,210–4,430 cal B.P. The dry matrix consists mostly of extremely well-preserved sea urchin skeletal plates, along with other faunal remains, and delicate strands of sea grass (*Phyllospadix* spp.) (Vellanoweth et al. 2002:608). Stratum 5 (4,250–4,450 cal B.P.) is the thickest layer, consisting of a brown (10 YR 5/3) soil matrix dominated by shell and animal bone, as well as angular rockfall from the cave ceiling and walls. Stratum 6, dated to 7,480–8,460 cal B.P., is a powdery dark yellowish-brown (10 YR 4/4) soil matrix with numerous pieces of angular rockfall, and stone, bone, and shell artifacts (Vellanoweth et al. 2003:1163).

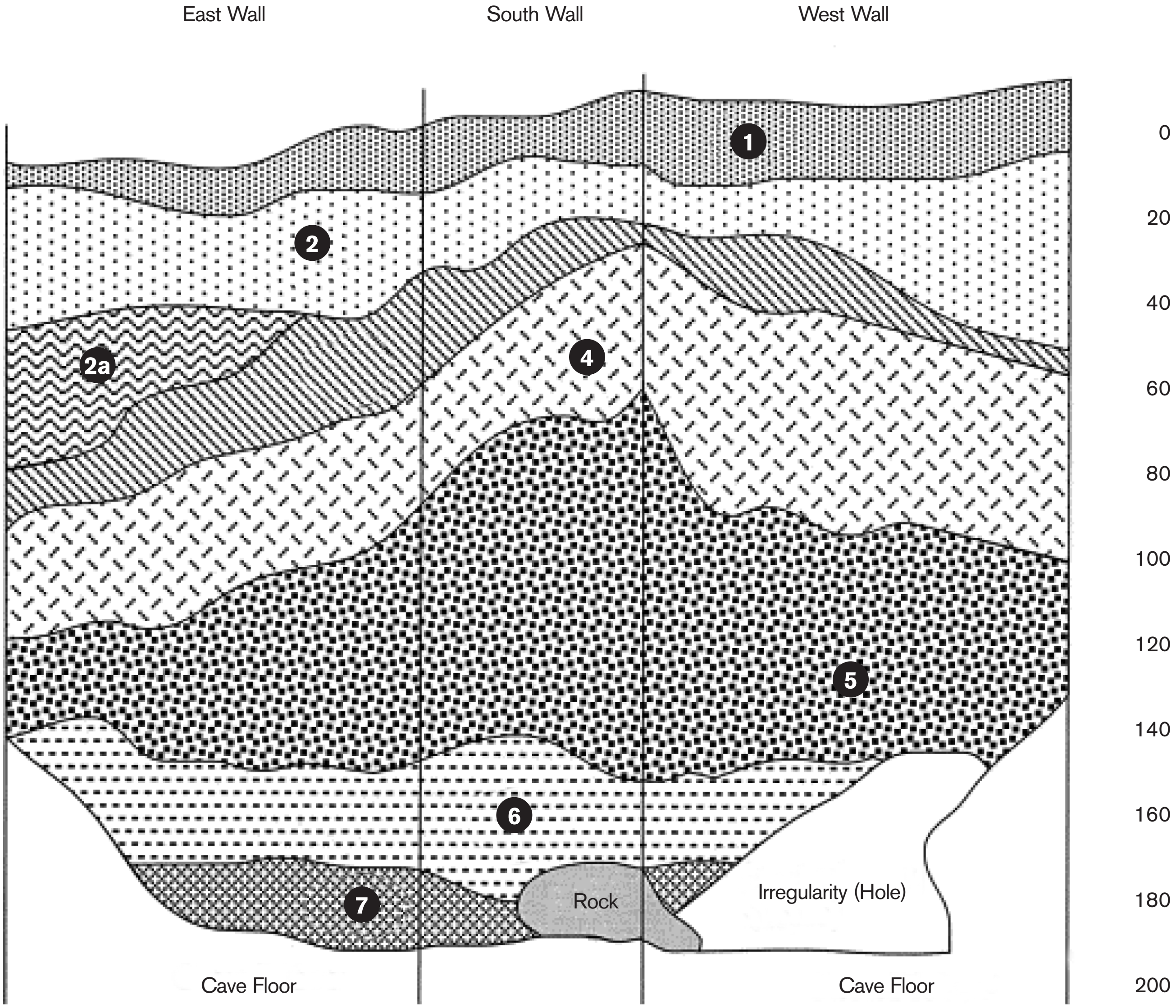

Figure 4. Stratigraphic profile of Unit 1, CA-SMI-603.

Stratum 7 (7,800–8,070 cal B.P.) contains a gritty brown (10 YR 5/3) soil matrix with abundant organic detritus and a plethora of cultural materials, including formal artifacts (Vellanoweth et al. 2003:1163). The stratigraphy and chronology of the cave's sediments suggest it was occupied by humans for about 6,000 years, from roughly 8,500 to 2,400 cal B.P. (Table 1).

METHODS

The excavation of the CA-SMI-603 bulk samples took place in 1999 after a 0.5 x 1 m. unit (Unit 1) had been excavated to a depth of approximately 2 meters (Fig. 3). Four-liter bulk samples (for a total of 36 liters) were taken from each stratum on the east wall of Unit 1, following natural stratigraphy (Fig. 4). Although the total excavated volume was relatively small, nearly 10 kg. of shellfish remains were recovered, providing a relatively large sample of shellfish remains for our analysis, and one comparable to many other studies in the region (see Braje et al. 2007; Glassow et al. 2008; Rick 2007). Excavated sediments were immediately bagged and packaged for laboratory analysis. Stratum 2 was divided into two arbitrary levels (2A and 2B), resulting in a total of 8 liters being sampled. Stratum 5 was divided into three arbitrary levels (5A, 5B, and 5C), for a total of 12 liters. Bulk samples were transported to the mainland and washed over 1/16-inch mesh screens. After air drying, the materials were sorted, quantified, and analyzed. Identifications were made using comparative collections at the University of Oregon, Humboldt State University, and California State University, Los Angeles, along with several reference manuals (Morris 1966; Morris et al. 1980; Rehder 1981). Utilizing a fine-mesh screen (1/16-inch) helps protect against screen-size bias and ensures the recovery of extremely small faunal remains and artifacts (e.g., Erlandson 1994:94).

Initial quantification included weight, number of individual specimens (NISP), and minimum number of individuals (MNI) for the faunal remains from each screen size. Weight and MNI were calculated for all materials contained in 1/16-inch mesh and higher. Due to relatively high fragmentation, a non-repetitive element (NRE) approach to MNI (utilizing hinges, apices, anterior plates, etc.) was employed. NISP was calculated for all materials contained in 1/8-inch mesh and larger. NISP was also calculated for vertebrate remains and artifacts found in the 1/16-inch mesh fraction. Meat weight conversions based on dry shell and bone weights were calculated for each stratum (Erlandson 1994; Kato and Schroeter 1985; Koloseike 1969; Moss 1989; Tartaglia 1976; Vellanoweth and Erlandson 1999). Because many of the shells were broken, ratios of NRE to shell weight were employed to compute the average size of whole shells (Glassow 2000:412). Fragmentation of the shellfish is expressed as an index of shell completeness, calculated as MNI/NISP (Kuhn and Stiner 1998:S183; Stiner et al. 2003:78; see Table 2). A ratio of 1.0 indicates complete shells, with values approaching zero as the degree of fragmentation rises (Kuhn and Stiner 1998:S183).

Testing of statistical significance was performed using variance analysis. A one-way ANOVA was calculated to determine whether these sample data provide evidence of any statistically significant differences in shellfish taxa between strata. Several statistical measures were also applied to evaluate taxonomic richness, diversity, evenness, and rank of key shellfish taxa. The Shannon-Weaver function as described by Reitz and Wing (1999:105, 235) was employed to estimate changes in taxonomic diversity through time:

$$H' = -\sum (p_i)\,(\log_e p_i)$$

where p_i is the relative abundance of each taxon per stratum in terms of meat weight contribution (as per Braje et al. 2007:743). The equitability formula as described by Reitz and Wing (1999:105,235) was utilized to investigate evenness across the whole shellfish assemblage:

$$V' = H' / \log_e S$$

where H' is the Shannon-Weaver function and S is the number of shellfish taxa per strata for which MNI was noted. An index of shellfish rank was calculated to determine the importance of the higher ranked resources (California mussel and abalone) relative to other shellfish (see Butler 2000:654; Braje et al. 2007:743):

$$\sum \textit{Mytilus} + \textit{Haliotis} \text{ estimated meat weight} / \sum \text{Total shellfish estimated meat weight.}$$

Human harvesting pressures on local shellfish beds are investigated by estimating a ratio for the average whole-shell sizes of California mussel and sea urchin (as per Glassow 2000:412).

Table 2

DEGREE OF FRAGMENTATION OF SHELLFISH EXPRESSED AS THE COMPLETENESS INDEX[1]

	Strata					
	2	3	4	5	6	7
Abalone (*Haliotis* spp.)	0.008	0.038	0.095	0.022	0.006	0.021
Limpets and Small Gastropods	0.164	0.667	0.745	0.756	0.944	0.917
Mussel (*Mytilus californianus*)	0.055	0.101	0.199	0.051	0.029	0.021
Sea urchin (*Strongylocentrotus* spp.)	0.005	0.004	0.01	0.005	0.009	0.008
Turbans (*Tegula* spp.)	0.032	0.083	0.039	0.059	0.032	0.032

[1] The completeness index is calculated as the minimum number of individuals divided by the number of identified shell fragments, or MNI/NISP (see Stiner 1999; Stiner et al. 2003).

RESULTS

Overall, the deposits at Cave of the Chimneys contain a diverse faunal sequence dominated by largely rocky intertidal and kelp forest plants and animals. Rockfall, stone, shell, and bone artifacts, and the remains of terrestrial animals such as mice and lizards make up the rest. Shellfish remains dominate by weight in every stratum (~97–99%) and include rocky-shore species that require limited technology to extract and process. The taxonomic richness of shellfish appears to wax and wane through time, hitting its peak in the earliest Middle Holocene deposit (Stratum 5) (Fig. 5). The index of shell completeness (Table 2) speaks to the highly fragmented nature of the sample. In general, sea urchins are the most fragmented, followed by abalones, turbans, and mussels. Small limpets and snails not processed for consumption are the least fragmented and act as indirect evidence for kelp and sea grass harvesting. The index of shell completeness is somewhat misleading for fragile sea urchin tests since they were relatively whole when first uncovered, but many broke during excavation, transport, and handling. Due to the robust nature of turban shells, the high fragmentation of these species is likely due to human processing with a hammer and anvil. A sandstone anvil found in Stratum 7 during the excavation of Unit 1 provides evidence for this type of processing. While bone constitutes only a small fraction of the total assemblage, it is important to note that the degree of preservation of bone is excellent in all strata, minimizing a preservation bias towards shellfish (Glassow 1993b:82).

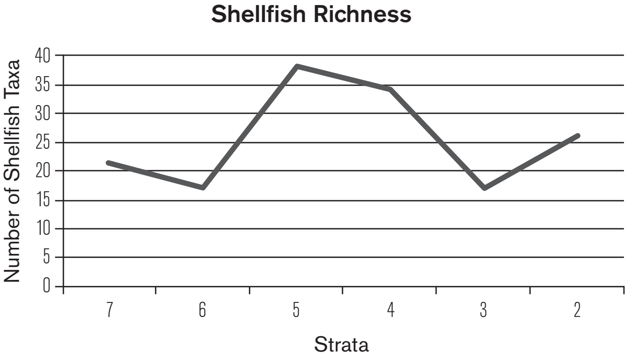

Figure 5. Changes in taxonomic richness of shellfish through time.

An analysis of variance using a one-way ANOVA was computed to test the statistical significance of differences. The dependent variable is MNI of key shellfish taxa (*Haliotis* spp., *Mytilus californianus*, *Strongylocentrotus* spp., *Tegula* spp.) in each stratum. The F value we obtained (F=4.25, df=5, 18) is in the critical region (α=.01=4.25) and thus highly significant. It is extremely unlikely (p=.01) that we would obtain a value this large if there was no significant difference. Therefore, we reject the null hypothesis of no difference between means and accept the alternative hypothesis that the means are different from each other. We conclude that there is a statistically significant difference in MNI of key shellfish taxa between strata.

Shellfish

A total of 9.74 kg. of shell comprises 95% of the total sample (minus rockfall; Table 3) and represents a minimum of 1,623 individuals from 41 taxa. Although 41 invertebrate taxa were identified, for space considerations we present only 21 here (Table 4). The most abundant shellfish taxa by weight for all strata include California mussel (*Mytilus californianus*; 31%), sea urchin (*Strongylocentrotus* spp.; 24%), red abalone (*Haliotis rufescens*; 14%), black abalone (*H. cracherodii*; 9.7%), and two species of turban shells (*Tegula* spp.; 10%). Chitons, limpets, small gastropods, and other species are all represented in smaller numbers. When employing MNI, California mussel dominates the assemblage at approximately 31% of all shellfish, with sea urchin following at roughly 19%.

Vertebrate Remains

A total of 14,898 pieces of bone weighing 157.71 g. but comprising only 0.84% of the sample (minus rockfall) was recovered (Table 5). NISP is high due to the inclusion of residuals retained in 1/16-inch mesh screen and the abundance of small rodent and lizard bones. Fish bone, with a NISP of 5,786, makes up the majority of the vertebrates by weight (96.02 g.). Readily identifiable species include surfperches (Embiotocidae), greenlings (Hexigrammidae), rockfishes (*Sebastes* spp.), and California sheephead (*Semicossyphus pulcher*). With 73 pieces weighing 1.42 g., marine mammal accounts for less than 1% of the vertebrate assemblage. Bird bone has a combined weight of 9.39 g., represented by

Table 3

WEIGHT OF TOTAL CONSTITUENTS FROM CA-SMI-603 BULK SAMPLES[1]

	Stratum 2(8L)		Stratum 3(4L)		Stratum 4(4L)		Stratum 5(12L)		Stratum 6(4L)		Stratum 7(4L)		**Total**	
	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	**Weight (g)**	**%**
INVERTEBRATES														
Abalone														
Haliotis cracherodii/Black Abalone	47.35	5.42	327.53	28.08	1.12	0.05	473.02	10.93	12.95	2.64	85.28	12.12	**947.25**	**9.73**
Haliotis rufescens/Red Abalone	56.61	6.48	392.37	33.64	261.12	12.01	632.22	14.61	4.67	0.95	0.56	0.08	**1347.55**	**13.84**
Haliotis spp.	16.23	1.86	50.01	4.29	46.75	2.15	76.43	1.77	6.93	1.41	14.52	2.06	**210.87**	**2.17**
Algae														
Corallinaceae/Coralline Algae	6.01	0.69	1.39	0.12	33.54	1.54	8.41	0.19	0.19	0.04	0.12	0.02	**49.66**	**0.51**
Melobesia mediocris/ Encrusting Algae	0.57	0.07	0.15	0.01	2.02	0.09	1.28	0.03	–	–	0.11	0.02	**4.13**	**0.04**
Barnacle														
Balanus spp./Acorn Barnacle	14.73	1.69	15.06	1.29	13.17	0.61	77.15	1.78	13.46	2.75	22.19	3.15	**155.76**	**1.60**
Pollicipes polymerus/ Gooseneck Barnacle	3.74	0.43	0.08	0.01	2.19	0.10	16.12	0.37	1.5	0.31	3.26	0.46	**26.89**	**0.28**
Bivalves misc.														
Anomia peruviana/Jingle Shell	–	–	0.01	0.00	–	–	–	–	–	–	–	–	**0.01**	**0.00**
Veneridae/Venus Clam	–	–	–	–	0.14	0.01	1.03	0.02	0.01	0.00	0.07	0.01	**1.25**	**0.01**
Chiton														
Cryptochiton stelleri/Giant Chiton	1.05	0.12	–	–	3.63	0.17	6.92	0.16	–	–	0.91	0.13	**12.51**	**0.13**
Chiton undif.	10.01	1.15	1.37	0.12	40.28	1.85	8.45	0.20	0.45	0.09	0.15	0.02	**60.71**	**0.62**
Crab spp.	3.75	0.43	2.37	0.20	11.52	0.53	23.65	0.55	1.54	0.31	0.43	0.06	**43.26**	**0.44**
Fossil Shell							0.64	0.01					**0.64**	**0.01**
Gastropods undif.	0.28	0.03	–	–	1.49	0.07	1.07	0.02	0.04	0.01	0.07	0.01	**2.95**	**0.03**
Land Snail undif.	24.51	2.81	0.63	0.05	0.78	0.04	41.67	0.96	1.14	0.23	0.43	0.06	**69.16**	**0.71**
Limpets and slipper shells														
Collisella limatula/File Limpet	0.08	0.01	0.83	0.07	7.14	0.33	1.18	0.03	0.08	0.02	0.04	0.01	**9.35**	**0.10**
Lottia gigantea/Owl Limpet	0.83	0.10	–	–	3.72	0.17	60.99	1.41	0.04	0.01	–	–	**65.58**	**0.67**
Limpets and Slipper Shells undif.	1.83	0.21	0.42	0.04	6.86	0.32	11.83	0.27	0.62	0.13	0.34	0.05	**21.90**	**0.22**
Mussel														
Mytilus californianus/ California mussel	311.58	35.68	181.95	15.60	507.2	23.33	1108.19	25.60	396.24	80.85	512.81	72.85	**3017.97**	**31.00**
Septifer bifurcatus/Platform Mussel	8.31	0.95	4.72	0.40	48.27	2.22	1.83	0.04	0.13	0.03	0.38	0.05	**63.64**	**0.65**
Mussel Skin	2.4	0.27	0.71	0.06	2.69	0.12	0.78	0.02	0.09	0.02	0.15	0.02	**6.82**	**0.07**
Dendraster sp./Sand Dollar	–	–	–	–	–	–	0.01	0.00	–	–	–	–	**0.01**	**0.00**
Serpulorbis squamigerus/ Scaled Worm Shell	1.01	0.12	2.17	0.19	0.75	0.03	6.23	0.14	0.27	0.06	0.08	0.01	**10.51**	**0.11**
Sponges	–	–	–	–	–	–	–	–	–	–	0.18	0.03	**0.18**	**0.00**
Strongylocentrotus spp./Sea Urchin	274.56	31.44	138.35	11.86	774.03	35.60	1126.65	26.03	12.83	2.62	11.64	1.65	**2338.06**	**24.01**
Turban Shells														
Tegula brunnea/Brown Turban	24.87	2.85	18.49	1.59	259.51	11.94	21.79	0.50	1.48	0.30	5.08	0.72	**331.22**	**3.40**
Tegula funebralis/Black Turban	33.16	3.80	12.37	1.06	102.41	4.71	450.98	10.42	11.86	2.42	24.05	3.42	**634.83**	**6.52**
Tegula spp./Turban Shell	0.96	0.11	0.38	0.03	0.09	0.00	0.09	0.00	–	–	–	–	**1.52**	**0.02**
Marine Shell Unid.	13.12	1.50	1.26	0.11	18.08	0.83	62.29	1.44	13.69	2.79	5.68	0.81	**114.12**	**1.17**
Marine Shell Nacre Unid.	15.79	1.81	13.68	1.17	25.65	1.18	107.78	2.49	9.9	2.02	15.35	2.18	**188.15**	**1.93**
Invertebrates subtotal	**873.34**	**100.00**	**1166.3**	**100.00**	**2174.15**	**100.00**	**4328.68**	**100.00**	**490.11**	**100.00**	**703.88**	**100.00**	**9736.46**	**100.00**

Table 3 (Continued)

WEIGHT OF TOTAL CONSTITUENTS FROM CA-SMI-603 BULK SAMPLES[1]

	Stratum 2(8L)		Stratum 3(4L)		Stratum 4(4L)		Stratum 5(12L)		Stratum 6(4L)		Stratum 7(4L)		**Total**	
	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	**Weight (g)**	**%**
VERTEBRATES														
Bird	0.76	3.97	0.68	9.91	0.12	0.91	5.14	5.08	0.32	5.47	2.37	20.73	**9.39**	**5.95**
Fish	12.36	64.61	4.07	59.33	10.36	78.60	63.26	62.47	1.27	21.71	4.7	41.12	**96.02**	**60.88**
Fish Scales	0.06	0.31	0.07	1.02	–	–	0.11	0.11	–	–	–	–	**0.24**	**0.15**
Otolith	–	–	–	–	0.25	1.90	0.13	0.13	–	–	–	–	**0.38**	**0.24**
Lizard	1.22	6.38	0.06	0.87	0.2	1.52	6.99	6.90	0.26	4.44	0.16	1.40	**8.89**	**5.64**
Peromyscus maniculatus/Deermouse	4	20.91	1.87	27.26	2.21	16.77	23.45	23.16	3.86	65.98	4.18	36.57	**39.57**	**25.09**
Peromyscus nesodytes/Giant Mouse	0.17	0.89	0.1	1.46	–	–	0.56	0.55	0.06	1.03	–	–	**0.89**	**0.56**
Sea Mammal	0.31	1.62	–	–	–	–	1.05	1.04	0.04	0.68	0.02	0.17	**1.42**	**0.90**
Sorex ornatus/Ornate Shrew	–	–	0.01	0.15	0.01	0.08	0.16	0.16	–	–	–	–	**0.18**	**0.11**
Urocyon littoralis/Island Fox	–	–	–	–	0.03	0.23	0.05	0.05	–	–	–	–	**0.08**	**0.05**
Unid. Bone	0.25	1.31	–	–	–	–	0.36	0.36	0.04	0.68	–	–	**0.65**	**0.41**
Vertebrates subtotal	**19.13**	**100.00**	**6.86**	**100.00**	**13.18**	**100.00**	**101.26**	**100.00**	**5.85**	**100.00**	**11.43**	**100.00**	**157.71**	**100.00**
ARTIFACTS														
Asphaltum with impression	–	–	–	–	–	–	–	–	–	–	0.01	0.74	**0.01**	**0.23**
Cordage	–	–	–	–	–	–	–	–	0.05	7.58	0.55	40.44	**0.60**	**13.64**
Unraveled Cordage	–	–	–	–	–	–	–	–	0.02	3.03	–	–	**0.02**	**0.45**
Mussle hinge with asphaltum	–	–	–	–	–	–	0.02	0.90	–	–	–	–	**0.02**	**0.45**
Olivella bead, spire-lopped	–	–	–	–	–	–	–	–	0.47	71.21	0.63	46.32	**1.10**	**25.00**
Olivella detritus	0.06	100.00	–	–	0.11	100.00	0.09	4.07	0.12	18.18	0.17	12.50	**0.55**	**12.50**
Olivella whole	–	–	–	–	–	–	2.1	95.02	–	–	–	–	**2.10**	**47.73**
Artifacts subtotal	**0.06**	**100.00**	**–**	**–**	**0.11**	**100.00**	**2.21**	**100.00**	**0.66**	**100.00**	**1.36**	**100.00**	**4.40**	**100.00**
LITHICS														
Chert Broken Flake	7.74	51.33	–	–	–	–	10.24	8.02	–	–	–	–	**17.98**	**2.79**
Chert Flakes	–	–	–	–	–	–	66.16	51.80	–	–	–	–	**66.16**	**10.26**
Chert Shatter	0.01	0.07	–	–	0.22	100.00	1.84	1.44	0.18	100.00	0.4	20.73	**2.65**	**0.41**
Metasedimentary Shatter	–	–	–	–	–	–	–	–	–	–	0.28	14.51	**0.28**	**0.04**
Quartzite Broken Flake	–	–	–	–	–	–	32.55	25.48	–	–	–	–	**32.55**	**5.05**
Quartzite Flake	–	–	–	–	–	–	16.94	13.26	–	–	–	–	**16.94**	**2.63**
Silicious Shale Shatter	7.33	48.61	–	–	–	–	–	–	–	–	1.25	64.77	**8.58**	**1.33**
Lithics subtotal	**15.08**	**100.00**	**–**	**–**	**0.22**	**100.00**	**127.73**	**100.00**	**0.18**	**100.00**	**1.93**	**100.00**	**645.14**	**22.50**
MISCELLANEOUS														
Abalone Pearl	0.01	0.00	–	–	–	–	–	–	–	–	–	–	**0.01**	**0.00**
Asphaltum	5	0.24	21.57	2.06	–	–	0.21	0.01	0.04	0.00	0.49	0.05	**27.31**	**0.29**
Caliche	0.68	0.03	–	–	0.84	0.22	1.12	0.04	0.34	0.02	0.93	0.10	**3.91**	**0.04**
Charcoal	23.05	1.08	3.6	0.34	24.38	6.52	113.46	3.94	13.17	0.89	21.49	2.36	**199.15**	**2.11**
Miscellaneous	1.23	0.06	0.02	0.00	–	–	0.24	0.01	0.04	0.00	2	0.22	**3.53**	**0.04**
Pebble	–	–	–	–	–	–	2.21	0.08	–	–	–	–	**2.21**	**0.02**
Phyllospadix sp./Sea Grass	0.23	0.01	0.12	0.01	1.02	0.27	0.53	0.02	0.12	0.01	0.24	0.03	**2.26**	**0.02**
Red Ochre	0.01	0.00	–	–	–	–	1.72	0.06	0.12	0.01	0.35	0.04	**2.20**	**0.02**
Rockfall	2,096.89	98.58	1,021.08	97.58	347.57	92.98	2,757.42	95.85	1,468.24	99.07	885.17	97.20	**8,576.37**	**91.07**
Miscellaneous subtotal	**2,127.10**	**100.00**	**1,046.39**	**100.00**	**373.81**	**100.00**	**2,876.91**	**100.00**	**1,482.07**	**100.00**	**910.67**	**100.00**	**9,416.95**	**93.63**
TOTAL STRATUM CONSTITUENTS	**3,034.71**		**2,219.55**		**2,561.47**		**7,436.79**		**1,978.87**		**1,629.27**		**18,860.66**	

[1] Includes weight for all Bulk Sample materials from 1/16 inch mesh.

Table 4

MNI OF INVERTEBRATES FROM CA-SMI-603, BULK SAMPLES[1]

	Stratum 2(8L)		Stratum 3(4L)		Stratum 4(4L)		Stratum 5(12L)		Stratum 6(4L)		Stratum 7(4L)		**Total**	
	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	**MNI**	**%**
INVERTEBRATES														
Abalone														
Haliotis cracherodii/Black Abalone	3	1.92	5	7.46	1	0.17	21	3.52	1	1.54	2	2.04	**33**	**2.12**
Haliotis rufescens/Red Abalone	1	0.64	8	11.94	14	2.45	9	1.51	1	1.54	1	1.02	**34**	**2.19**
Bivalves misc.														
Anomia peruviana/Jingle Shell	–	–	1	1.49	–	–	–	–	–	–	–	–	**1**	**0.06**
Veneridae/Venus Clam	1	0.64	–	–	–	–	–	–	–	–	–	–	**1**	**0.06**
Chiton														
Cryptochiton stelleri/Giant Chiton	1	0.64	–	–	1	0.17	1	0.17	–	–	1	1.02	**4**	**0.26**
Chiton undif.	5	3.21	3	4.48	15	2.62	3	0.50	2	3.08	2	2.04	**30**	**1.93**
Gastropods undif.	4	2.56	–	–	45	7.87	20	3.35	1	1.54	3	3.06	**73**	**4.69**
Limpets														
Collisella limatula/File Limpet	–	–	1	1.49	16	2.80	27	4.52	7	10.77	8	8.16	**59**	**3.79**
Lottia gigantea/Owl Limpet	1	0.64	–	–	2	0.35	15	2.51	1	1.54	–	–	**19**	**1.22**
Limpet undif.	8	5.13	4	5.97	48	8.39	136	22.78	8	12.31	22	22.45	**226**	**14.53**
Mussel														
Mytilus californianus/ California Mussel	65	41.67	24	35.82	140	24.48	167	27.97	37	56.92	41	41.84	**474**	**30.48**
Septifer bifurcatus/Platform Mussel	13	8.33	6	8.96	80	13.99	3	0.50	1	1.54	2	2.04	**105**	**6.75**
Dendraster sp./Sand Dollar	–	–	–	–	–	–	1	0.17	–	–	–	–	**1**	**0.06**
Strongylocentrotus spp./Sea Urchin	43	27.56	9	13.43	158	27.62	84	14.07	2	3.08	2	2.04	**298**	**19.16**
Turban Shells														
Tegula brunnea/Brown Turban	2	1.28	2	2.99	30	5.24	11	1.84	2	3.08	3	3.06	**50**	**3.22**
Tegula funebralis/Black Turban	9	5.77	4	5.97	21	3.67	99	16.58	2	3.08	11	11.22	**146**	**9.39**
Tegula spp./Turban Shell	–	–	–	–	1	0.17	–	–	–	–	–	–	**1**	**0.06**
Invertebrates subtotal	**156**	**100.00**	**67**	**100.00**	**572**	**100.00**	**597**	**100.00**	**65**	**100.00**	**98**	**100.00**	**1555**	**100.00**

[1] Includes MNI for all Bulk Sample materials from 1/16 inch mesh.

473 fragments. Marine mammal and bird bones may be underrepresented at the site because of small sample size, off-site butchering, and the use of bone as a raw material for making tools and ornaments.

Although relatively abundant, the remains of several small terrestrial animals seem likely to be of natural rather than cultural origin. These include two species of mice (*Peromyscus maniculatus* and *P. nesodytes*) and one shrew (*Sorex ornatus*), which contribute 6,928 specimens weighing 40.64 g. Undifferentiated lizard (probably *Sceloporus occidentalis becki* and *Elgaria multicarinatus*) bones (1,285 specimens weighing 8.89 g.) are also numerous. The remains of these small animals were probably part of a natural death assemblage or deposited by owls or other predatory birds.

Artifacts

The bulk samples from Strata 6 and 7 yielded spire-lopped *Olivella* beads (Bennyhoff and Hughes 1987; n=3) and *Olivella* bead detritus (n=9). The presence of *Olivella* beads in these deposits is consistent with beads found in Unit 1 (Vellanoweth et al. 2003). *Olivella* bead detritus was also identified in Stratum 2 (n=4), Stratum 4 (n=1), and Stratum 5 (n=2). Strata 6 and 7 also yielded sea grass cordage fragments and knots (n=22), as well as unraveled cordage (n=6), consistent with materials from Unit 1 (Vellanoweth et al. 2003). No bone artifacts were recovered from the bulk samples, although a bone gorge was found in Stratum 7, Unit 1 (Vellanoweth et al. 2003:1168). Small numbers of chipped stone artifacts were recovered from all strata except Stratum 3. Stone

Table 5

NISP OF TOTAL CONSTITUENTS FROM CA-SMI-603, BULK SAMPLES[1]

	Stratum 2(8L)		Stratum 3(4L)		Stratum 4(4L)		Stratum 5(12L)		Stratum 6(4L)		Stratum 7(4L)		**Total**	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
INVERTEBRATES														
Abalone														
Haliotis cracherodii/Black Abalone	178	1.41	91	2.90	2	0.01	552	2.14	90	4.18	86	2.66	**999.00**	**1.50**
Haliotis rufescens/Red Abalone	307	2.43	253	8.07	146	0.74	793	3.07	79	3.67	10	0.31	**1,588.00**	**2.38**
Algae														
Corallinaceae/Coralline Algae	274	2.16	48	1.53	366	1.87	30	0.12	1	0.05	–	–	**719.00**	**1.08**
Melobesia mediocris/ Encrusting Algae	17	0.13	2	0.06	10	0.05	15	0.06	–	–	–	–	**44.00**	**0.07**
Barnacle														
Balanus spp./Acorn Barnacle	278	2.20	107	3.41	252	1.28	874	3.38	186	8.63	368	11.38	**2,065.00**	**3.10**
Pollicipes polymerus/ Gooseneck Barnacle	84	0.66	–	–	16	0.08	155	0.60	15	0.70	34	1.05	**304.00**	**0.46**
Bivalves.														
Anomia peruviana/Jingle Shell	–	–	1	0.03	–	–	–	–	–	–	–	–	**1.00**	**0.00**
Veneridae/Venus Clam	–	–	1	0.03	–	–	–	–	–	–	–	–	**1.00**	**0.00**
Chiton														
Cryptochiton stelleri/Giant Chiton	4	0.03	–	–	4	0.02	10	0.04	–	–	1	0.03	**19.00**	**0.03**
Chiton undif.	116	0.92	15	0.48	238	1.21	46	0.18	2	0.09	5	0.15	**422.00**	**0.63**
Crab spp.	121	0.96	21	0.67	134	0.68	268	1.04	10	0.46	10	0.31	**564.00**	**0.85**
Gastropods undif.	11	0.09			51	0.26	19	0.07	1	0.05	4	0.12	**86.00**	**0.13**
Land Snail undif.	720	5.69	19	0.61	12	0.06	749	2.90	20	0.93	10	0.31	**1,530.00**	**2.30**
Limpets and slipper shells														
Collisella limatula/File Limpet	4	0.03	1	0.03	16	0.08	27	0.10	7	0.32	8	0.25	**63.00**	**0.09**
Lottia gigantea/Owl Limpet	1	0.01	–	–	2	0.01	33	0.13	1	0.05	–	–	**37.00**	**0.06**
Limpet undif.	57	0.45	5	0.16	80	0.41	183	0.71	9	0.42	24	0.74	**358.00**	**0.54**
Mussel														
Mytilus californianus/ California Mussel	1187	9.38	211	6.73	687	3.50	2,844.00	11.00	1,263.00	58.61	1,747.00	54.04	**7,939.00**	**11.91**
Septifer bifurcatus/l Platform Mussel	72	0.57	26	0.83	201	1.02	5.00	0.02	3.00	0.14	9	0.28	**316.00**	**0.47**
Dendraster sp./Sand Dollar	–	–	–	–	–	–	1.00	0.00	–	–	–	–	**1.00**	**0.00**
Serpulorbis squamigerus/ Scaled Worm Shell	26	0.21	1	0.03	12	0.06	29.00	0.11	1.00	0.05	2	0.06	**71.00**	**0.11**
Strongylocentrotus spp./ Sea Urchin	8,649.00	68.33	2,235.00	71.31	15,735.00	80.20	16,876.00	65.30	220.00	10.21	260	8.04	**43,975.00**	**65.98**
Turban Shells														
Tegula brunnea/Brown Turban	120	0.95	29	0.93	809.00	4.12	132.00	0.51	10.00	0.46	22	0.68	**1,122.00**	**1.68**
Tegula funebralis/Black Turban	178	1.41	37	1.18	530.00	2.70	1,729.00	6.69	117.00	5.43	417	12.90	**3,008.00**	**4.51**
Tegula spp./Turban Shell	47	0.37	6	0.19	1.00	0.01	–	–	–	–	–	–	**54.00**	**0.08**
Marine Shell Unid.	206	1.63	26	0.83	316.00	1.61	473.00	1.83	120.00	5.57	216	6.68	**1,357.00**	**2.04**
Invertebrates subtotal	**12,657.00**	**100.00**	**3,134.00**	**100.00**	**19,620.00**	**100.00**	**25,845.00**	**100.00**	**2,155.00**	**100.00**	**3,233.00**	**100.00**	**66,644.00**	**100.00**

Table 5 (Continued)

NISP OF TOTAL CONSTITUENTS FROM CA-SMI-603, BULK SAMPLES[1]

	Stratum 2(8L)		Stratum 3(4L)		Stratum 4(4L)		Stratum 5(12L)		Stratum 6(4L)		Stratum 7(4L)		Total	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
VERTEBRATES														
Bird	27.00	0.97	19.00	5.40	13.00	1.06	350.00	4.33	18.00	1.63	46.00	3.40	**473.00**	**3.17**
Fish	1,761.00	63.44	117.00	33.24	745.00	60.82	2,580.00	31.90	126.00	11.41	457.00	33.80	**5,786.00**	**38.84**
Otolith	–	–	–	–	1.00	0.08	2.00	0.02	–	–	–	–	**3.00**	**0.02**
Lizard	181.00	6.52	3.00	0.85	26.00	2.12	994.00	12.29	57.00	5.16	24.00	1.78	**1,285.00**	**8.63**
Peromyscus maniculatus/Deermouse	679.00	24.46	208.00	59.09	437.00	35.67	3,817.00	47.19	877.00	79.44	824.00	60.95	**6,842.00**	**45.93**
Peromyscus nesodytes/Giant Mouse	19.00	0.68	4.00	1.14	–	–	42.00	0.52	5.00	0.45	–	–	**70.00**	**0.47**
Sea Mammal	4.00	0.14	–	–	–	–	62.00	0.77	6.00	0.54	1.00	0.07	**73.00**	**0.49**
Sorex ornatus/Ornate Shrew	–	–	1.00	0.28	1.00	0.08	14.00	0.17	–	–	–	–	**16.00**	**0.11**
Urocyon littoralis/Island Fox	–	–	–	–	2.00	0.16	2.00	0.02	–	–	–	–	**4.00**	**0.03**
Unid. Bone	105.00	3.78	–	–	–	–	226.00	2.79	15.00	1.36	–	–	**346.00**	**2.32**
Vertebrates subtotal	**2,776.00**	**100.00**	**352.00**	**100.00**	**1,225.00**	**100.00**	**8,089.00**	**100.00**	**1,104.00**	**100.00**	**1,352.00**	**100.00**	**14,898.00**	**100.00**
ARTIFACTS														
Asphaltum with impression	–	–	–	–	–	–	–	–	–	–	1.00	3.70	**1.00**	**2.00**
Cordage	–	–	–	–	–	–	–	–	5.00	35.71	17.00	62.96	**22.00**	**44.00**
unraveled cordage	–	–	–	–	–	–	–	–	6.00	42.86	–	–	**6.00**	**12.00**
Mussle Hinge with Asphaltum	–	–	–	–	–	–	1.00	25.00	–	–	–	–	**1.00**	**2.00**
Olivella bead, spire-lopped	–	–	–	–	–	–	–	–	1.00	7.14	2.00	7.41	**3.00**	**6.00**
Olivella detritus	4.00	100.00	–	–	1.00	100.00	2.00	50.00	2.00	14.29	7.00	25.93	**16.00**	**32.00**
Olivella whole	–	–	–	–	–	–	1.00	25.00	–	–	–	–	**1.00**	**2.00**
Artifacts subtotal	**4.00**	**100.00**	**–**	**–**	**1.00**	**100.00**	**4.00**	**100.00**	**14.00**	**100.00**	**27.00**	**100.00**	**50.00**	**100.00**
LITHICS														
Chert Broken Flake	2.00	33.33	–	–	–	–	4.00	7.84	–	–	–	–	**6.00**	**6.67**
Chert Flake	–	–	–	–	–	–	1.00	1.96	–	–	–	–	**1.00**	**1.11**
Chert Shatter	1.00	16.67	–	–	3.00	100.00	44.00	86.27	4.00	100.00	23.00	88.46	**75.00**	**83.33**
Metasedimentary Shatter	–	–	–	–	–	–	–	–	–	–	1.00	3.85	**1.00**	**1.11**
Quartzite Broken Flake	–	–	–	–	–	–	1.00	1.96	–	–	–	–	**1.00**	**1.11**
Quartzite Flake	–	–	–	–	–	–	1.00	1.96	–	–	–	–	**1.00**	**1.11**
Silicious Shale Shatter	3.00	50.00	–	–	–	–	–	–	–	–	2.00	7.69	**5.00**	**5.56**
Lithics subtotal	**6.00**	**100.00**	**–**	**–**	**3.00**	**100.00**	**51.00**	**100.00**	**4.00**	**100.00**	**26.00**	**100.00**	**90.00**	**100.00**
MISCELLANEOUS														
Abalone Pearl	1.00	0.07	–	–	–	–	–	–	–	–	–	–	**1.00**	**0.02**
Asphaltum	3.00	0.22	1.00	0.53	–	–	5.00	0.22	–	–	8.00	0.67	**17.00**	**0.26**
Caliche	32.00	2.34	–	–	55.00	5.04	5.00	0.22	7.00	1.43	22.00	1.83	**121.00**	**1.83**
Charcoal	1,056.00	77.31	124.00	66.31	694.00	63.55	1,979.00	87.14	443.00	90.22	918.00	76.56	**5,214.00**	**78.93**
Miscellaneous	132.00	9.66	1.00	0.53	–	–	7.00	0.31	3.00	0.61	6.00	0.50	**149.00**	**2.26**
Pebble	–	–	–	–	–	–	1.00	0.04	–	–	–	–	**1.00**	**0.02**
Phyllospadix sp./Sea Grass	140.00	10.25	61.00	32.62	342.00	31.32	177.00	7.79	26.00	5.30	214.00	17.85	**960.00**	**14.53**
Phyllospadix sp./Sea Grass clump	–	–	–	–	1.00	0.09	–	–	–	–	–	–	**1.00**	**0.02**
Red Ochre	2.00	0.15	–	–	–	–	97.00	4.27	12.00	2.44	31.00	2.59	**142.00**	**2.15**
Miscellaneous subtotal	**1,366.00**	**100.00**	**187.00**	**100.00**	**1,092.00**	**100.00**	**2,271.00**	**100.00**	**491.00**	**100.00**	**1,199.00**	**100.00**	**6,606.00**	**100.00**
TOTAL STRATUM CONSTITUENTS	**16,809.00**		**3,673.00**		**21,941.00**		**36,260.00**		**3,768.00**		**5,837.00**		**88,288.00**	

[1] Includes NISP for all Bulk Sample materials from 1/8 inch mesh.

material types include chert (n=82), siliceous shale (n=5), quartzite (n=2), and metasedimentary (n=1), all of which appear to be of local origin.

TRANS-HOLOCENE SHELLFISH PATTERNS

Due to the fragmentary nature of the samples, the measurement of whole shells was not possible. Rather, following Glassow (2000:412), a ratio of NRE to shell weight was employed to infer average whole shell size for sea urchin and California mussel (Fig. 6). As the numbers presented here represent a ratio, larger numbers indicate smaller shell size, while smaller numbers indicate larger shell size. Mussel umbos and pyramids of the sea urchin lantern (10 hemipyramids=5 pyramids=1 NRE) were used to calculate MNI. Our results indicate that average shell size for mussel and sea urchin fluctuated through time. Mean mussel shell size generally declines from the Early to Late Holocene, but sea urchin size fluctuated throughout. Smaller urchins during the Early Holocene might reflect the increased presence of other predators such as sea otter, California sheephead, and spiny lobster, or some unidentified environmental factor. Middle Holocene components (Strata 3–5) reveal corresponding increases and decreases in average shell size for both taxa represented here. Stratum 5 shows relatively larger urchins and mussels, both of which decrease in similar proportions in Stratum 4 and then increase in Stratum 3. The Late Holocene sample demonstrates a slightly smaller decrease in size of both taxa. Possible explanations for these fluctuations include intensification-related resource depressions and rebounds in the site vicinity, and/or climatic and other environmental changes.

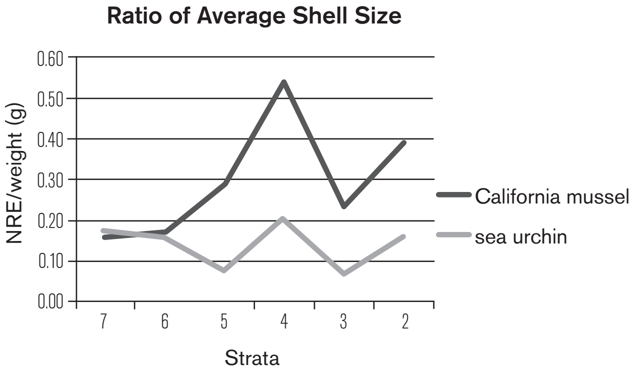

Figure 6. Ratio of average shell size for California mussel and sea urchin. Higher values on the vertical axis signify smaller average shell size and vice versa..

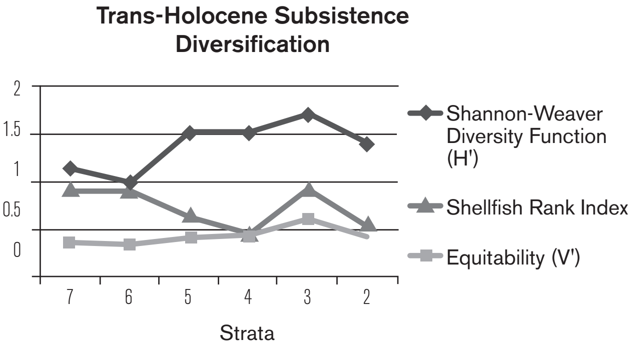

Figure 7. Trans-Holocene subsistence diversification. Measures of shellfish diverstiy, equitability and overall rank, described by the Shannon-Weaver Diversity Function (H'), Equitability Formula (V'), and a prey rank index (Butler 2000; Braje 2007; Reitz and Wing 1999).

Measures of taxonomic diversity and evenness (Fig. 7) demonstrate an overall increase in diversity of primary shellfish taxa through time. Although diversity in the Early Holocene deposits is relatively low (H'=1), it increases to relatively high levels in the Middle Holocene (H'=1.5–1.8). The equitability function indicates moderate to high levels of evenness (V'=0.38–0.6) throughout the deposits. Low diversity in the Early Holocene is likely due to the dominance of mussel in Strata 6 and 7, while high diversity in the Middle Holocene reflects increasing diet breadth. High equitability reflects taxonomic evenness through time, a product of the distribution of similar MNI per taxa within and across strata. The index of shellfish rank supports these conclusions by demonstrating a decrease in the rank of mussel and abalone alongside an increase in diversity of key taxa during the Middle Holocene.

Early Holocene Strata 6 and 7

In Strata 6 and 7, California mussel, followed by abalone and urchin, comprises the majority of the sample when quantified by weight, NISP, and MNI. In Stratum 7, mussel dominates the assemblage (73%) by dry weight with black abalone comprising about 12%, black turban snail 3.4%, urchin 1.7%, and red abalone less than 1%. Mussel in Stratum 6 makes up 81% of the sample, while black abalone makes up only 2.6% and red abalone less than 1%. Sea urchin increases slightly, making up 2.6% of the sample, with black turbans contributing 2.4%.

Middle Holocene Strata 3, 4, and 5

The samples from Strata 3, 4, and 5 suggest that Middle Holocene resources varied considerably through time, most notably the relative importance of abalone, mussel, and sea urchin. In Stratum 5 the percentage of black abalone is similar to that of the Early Holocene strata, but the amount of red abalone greatly increases, a pattern seen in many Middle Holocene sites on the Channel Islands (Braje 2007; Braje et al. 2009; Glassow 1997; Vellanoweth et al. 2006). Most of the sample consists of sea urchin and California mussel, each comprising ~26% by weight. Black turban snail, which make up over 10% of the shell weight, also increases. When employing MNI, California mussel dominates the assemblage at 28%, followed by black turban snail (17%) and sea urchin (14%). Tiny limpets (~23%) make up a high percentage of MNI but were accidental inclusions and not of dietary value. In Stratum 4, abalone plunges dramatically, red abalone to 0.05% and black abalone to 12%. Sea urchin contributes most of the sample weight at 36%, with California mussel at 23%. Brown turban (12%) also makes up a large proportion of this stratum, replacing the black turban that made up a significant portion of Stratum 5. When looking at MNI, sea urchin and California mussel contribute approximately 28% and 24%, respectively. In Stratum 3, abalone is by far the most abundant species by weight; red abalone makes up 34% of the stratum and black abalone 28%. California mussel (15%) and sea urchin (12%) also contribute significantly. However, when MNI is used for quantification, mussel clearly dominates the assemblage at 36%, while abalone drops to a combined total of 19% and sea urchin makes up roughly 13%.

Late Holocene Stratum 2

By weight, California mussel (36%) and sea urchin (32%) dominate the Stratum 2 shellfish assemblage. Abalone is the third most abundant taxa by weight, with red and black varieties present at 6.5% and 5.4%, respectively. Black turban (3.8%), brown turban (2.9%), and barnacles (2.1%) are the only other taxa that constitute over 1% of the stratum's total shell weight. Based on MNI, California mussel continues to dominate with ~42%, and sea urchin follows with ~28% of all shellfish individuals.

DIETARY RECONSTRUCTIONS

Dietary reconstructions using meat weight conversions have several problems (Erlandson 1994; Mason et al. 1998; Moss 1989), but provide another perspective on the relative nutritional importance of various animals. Unlike MNI, NISP, and raw weight measures, meat weights allow a comparison of different faunal classes (fish, shellfish, bird, mammal, etc.) by helping normalize biases in other measures. Although fish bone makes up less than 1% of the recovered faunal remains, for instance, dietary conversions suggest that fish comprise approximately one third of the estimated meat yields for the overall sample (see Table 6). Shellfish make up the other two-thirds of the meat weight estimates, despite contributing ~98% of the dry weight of faunal remains. Bird and mammal bone is present in trace amounts. No one shellfish species is represented by more than 25%. Red abalone is the predominant shellfish taxa, making up 21% of the total meat weight estimate; sea urchin follows at 16%, and California mussel and black abalone contribute ~10% each. Following the general pattern for Channel Islands coastal sites, black abalone holds higher percentages in the Early Holocene strata and is superseded in importance by red abalone in the Middle and Late Holocene strata.

Trends of dietary reconstructions for Cave of the Chimneys reveal a distinct change in the degree to which various shellfish species were harvested throughout the Holocene. When meat weight estimates are viewed by strata through time, California mussel peaks in the Early Holocene, with fish also making up an important part of the diet (Figs. 8 and 9). The most pronounced difference between the two Early Holocene strata is the much larger proportion of black abalone in Stratum 7 (18%) compared to Stratum 6 (6%). Other shellfish complement the diet in similar amounts in these early strata. Also apparent in the Early Holocene strata is the relatively high proportion of bird bone when compared to other strata. In fact, bird bone is highest in Stratum 7 at 8.15% and decreases in representation through time.

During the Middle Holocene (Strata 3–5), dietary patterns fluctuate, with fish declining over time (Fig. 8). Estimated meat yields for Stratum 5 reveal an emphasis on abalone, which makes up 30% of the total meat. Urchin and California mussel are also significant

Table 6

MEAT YIELDS FOR CA-SMI-603 BULK SAMPLES

	Stratum 2		Stratum 3		Stratum 4		Stratum 5		Stratum 6		Stratum 7		**Totals**	
	Meat Weight (g)	%	Meat Weight (g)	%	Meat Weight (g)	%	Meat Weight (g)	%	Meat Weight (g)	%	Meat Weight (g)	%	**Meat Weight (g)**	**%**
Black Abalone (.944)	44.70	5.64	309.19	26.36	1.06	0.07	446.53	9.90	12.23	6.16	80.50	18.46	**894.21**	**10.38**
Red Abalone (1.36)	76.99	9.71	533.62	45.50	355.12	23.57	859.82	19.06	6.35	3.20	0.76	0.17	**1,832.66**	**21.27**
Abalone (1.15)	18.67	2.35	57.51	4.90	53.76	3.57	87.90	1.95	7.97	4.01	16.70	3.83	**242.51**	**2.81**
Chiton (1.15)	12.72	1.60	1.58	0.13	50.50	3.35	17.68	0.39	0.52	0.26	1.54	0.35	**84.54**	**0.98**
Owl Limpet (1.36)	1.13	0.14	–	–	5.06	0.34	82.95	1.84	0.05	0.03	–	–	**89.19**	**1.04**
California Mussel (.298)	92.85	11.71	54.22	4.62	151.15	10.03	330.24	7.32	118.08	59.47	152.82	35.04	**899.36**	**10.44**
Platform Mussel (.364)	3.03	0.38	1.72	0.15	17.57	1.17	0.67	0.01	0.05	0.03	0.14	0.03	**23.18**	**0.27**
Sea Urchin (.583)	160.07	20.19	80.66	6.88	451.26	29.96	656.84	14.56	7.48	3.77	6.79	1.56	**1,363.10**	**15.82**
Turban Shell (.365)	21.53	2.72	11.40	0.97	132.13	8.77	172.59	3.83	4.87	2.45	10.63	2.44	**353.15**	**4.10**
Shellfish subtotal	**431.69**	**54.44**	**1,049.90**	**89.52**	**1,217.61**	**80.83**	**2,655.22**	**58.87**	**157.60**	**79.38**	**269.88**	**61.88**	**5,781.90**	**67.10**
Bird (15.0)	11.40	1.44	10.20	0.87	1.80	0.12	77.10	1.71	4.80	2.42	35.55	8.15	**140.85**	**1.63**
Fish (27.7)	342.37	43.18	112.74	9.61	286.97	19.05	1,752.30	38.85	35.18	17.72	130.19	29.85	**2,659.75**	**30.87**
Sea Mammal (24.2)	7.50	0.95	–	–	–	–	25.41	0.56	0.97	0.49	0.48	0.11	**34.36**	**0.40**
Vertebrate subtotal	**361.27**	**45.56**	**122.94**	**10.48**	**288.77**	**19.17**	**1,854.81**	**41.13**	**40.95**	**20.62**	**166.22**	**38.12**	**2,834.96**	**32.90**
TOTAL	**792.96**	**100.00**	**1,172.84**	**100.00**	**1,506.38**	**100.00**	**4,510.03**	**100.00**	**198.55**	**100.00**	**436.10**	**100.00**	**8,616.86**	**100.00**

Meat weight conversions based on Erlandson (1994); Kato and Schroeter (1985); Koloseike (1969); Moss (1989); Tartaglia (1976); Vellanoweth and Erlandson (1999).
Meat multipliers are indicated in parentheses next to common name.

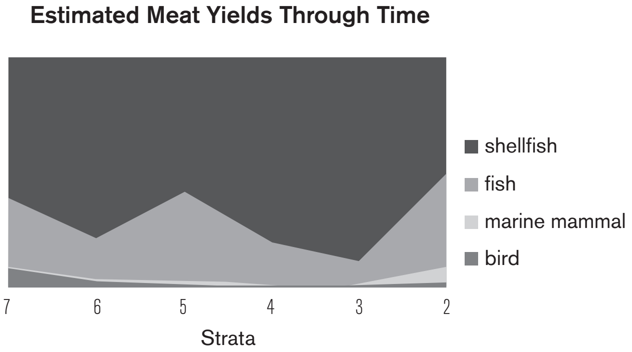

Figure 8. Trans-Holocene trend in estimated meat yields for shellfish, fish, marine mammal, and bird. This graph emphasizes differences between faunal categories through time. Shaded areas represent relative percentages of the various categories.

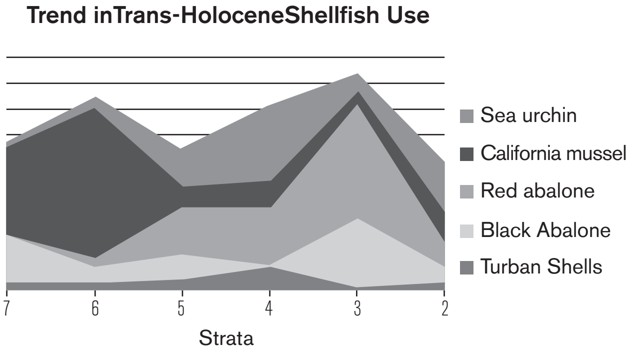

Figure 9. Trans-Holocene trend in estimated meat yields for key shellfish taxa. This graph emphasizes differences within the shellfish assemblage through time. Shaded areas represent relative percentages of the various taxa.

contributors, with turban snails supplementing the diet. Stratum 4 demonstrates the widest diet breadth as sea urchin dominates the edible meat, followed by abalone and mussel, with turban snails and chitons also reaching their highest numbers. In Stratum 3, abalone increases compared to other strata, making up a combined total of 73% of the estimated edible meat yield; sea urchin and mussel supplement the diet, and other low-ranking taxa are barely present. Stratum 2, dating to the Late Holocene, reveals a more balanced economy, with shellfish contributing roughly 55% of the edible meat represented and fish approximately 44%. Among the shellfish, sea urchin makes up the largest percentage of edible meat with 20%; abalone (black and red combined) and California mussel are also significant contributors, and turban snails and chitons round out the assemblage.

DISCUSSION

The faunal analysis and dietary reconstructions presented here suggest that the occupants of Cave of the Chimneys relied heavily on marine resources throughout the Holocene. Overall, shellfish dominate the assemblage in dry weight, MNI, and meat yield estimates. Shellfish, particularly abalone, mussel, and urchin, were the primary sources of meat consumed, accounting for anywhere from 55–91% of the total meat represented in any given strata. Fish were the second most important source of meat, contributing between about 9 and 45% of the estimated meat yields for the different strata. Birds and marine mammals do not appear to have been a major component of the diet, although they are likely to be underrepresented in the small bulk samples from the site. Bird and marine mammal bones were also made into tools. While birds were not generally large contributors to the overall diet, ethnographic and archaeological data for the region suggest that feathers and bones were utilized in the construction of various artifacts (see Wake 2001). This is consistent with the presence of a bird-bone tool in the Early Holocene strata of Unit 1 (Vellanoweth et al. 2003).

A cyclical pattern of decline and rebound becomes evident when examining meat weight conversions for fish bone, indicating that the dietary reliance on fish appears to have waxed and waned at this site. Stratum 7 reveals approximately 30% of edible meat from fish, Stratum 6 about 18%, and Stratum 5 about 39%, before declining in Strata 4 and 3 (~19% and 10%), and then rebounding again in Stratum 2 (43%). This cyclical pattern of decline and rebound seems to be confirmed by previously analyzed 15-liter samples from three of the strata at Cave of the Chimneys (Table 7; see Vellanoweth et al. 2002), and it follows a general upward trend of an overall increase in the importance of fish to the diet. These patterns could be indicative of a shifting focus on fish relative to shellfish, the availability of key shellfish taxa in the site vicinity, short-term adaptive adjustments by site occupants, seasonality of occupation, or horizontal variability in deposited materials.

When comparing the bulk samples to previously analyzed 15-liter samples from Strata 2, 3, and 4 (Vellanoweth et al. 2002), differences in the relative importance of shellfish taxa are evident. These differences are likely due to both horizontal and spatial variability within the midden constituents, as well as to the smaller size of the bulk samples. For instance, the top three shellfish taxa are sea urchin, red abalone, and California mussel in Strata 3 and 4 of the 15-liter samples. In the bulk samples, the same top three taxa are present in Stratum 4 but their order of importance varies. In Stratum 3 of the bulk sample, black abalone replaces sea urchin as one of the top three taxa. Some horizontal consistency is evident between the samples for Stratum 2, where the order of importance of the top three taxa are the same.

Table 7

COMPARISON OF MEAT YIELD ESTIMATES FOR CA-SMI-603

	Stratum 2		Stratum 3		Stratum 4	
Sample size:	(15L.)* % Meat	(8 L.) % Meat	(15L.)* % Meat	(4 L.) % Meat	(15L.)* % Meat	(4 L.) % Meat
Bird	8.60	1.44	0.80	0.87	0.40	0.12
Fish	51.90	43.18	8.60	9.61	16.90	19.05
Sea mammal	14.70	0.95	32.60	0	<.1	0
Shellfish	24.70	54.44	58.20	89.52	82.70	80.83

*Data compiled from Vellanoweth et al. (2002)

Overall, the Middle Holocene components at this site (Strata 3–5) follow the general pattern observed on the Channel Islands during this time period, including an overall reliance on shellfish, with considerable diversity in the species represented (see Erlandson 1997; Rick et al. 2005a). Although the radiocarbon dates for these three distinct strata are extremely close and even overlap, the constituents are very different, demonstrating that people utilized a variety of different habitats and combined certain taxa for meals, resulting in discrete dumping episodes (deposits). Compositional differences between strata might reflect specific human tasks and associated dumping episodes, such as mussel harvesting vs. snail (*Tegula* spp.) processing, resulting in localized depositional differences and horizontal variability within and between strata. The constituents of these events would not necessarily be representative of the available resources in the site vicinity but rather of the chosen and targeted taxa. Variation among midden constituents could also be the result of seasonal differences in the availability or accessibility of certain plant or animal species, environmental forcing agents such as El Niño/La Niña southern oscillation events, storm frequency and intensity, eustatic sea level fluctuations, and changes in site use and function over time.

At Cave of the Chimneys, a diversification of the shellfish taxa harvested and the cyclical patterns of use began in earnest during the Middle Holocene occupation, represented by Stratum 5. California mussel dominates the Early Holocene strata (6 and 7), but there is a clear expansion of targeted taxa and an increased use of multiple species beginning in Stratum 5 and continuing through Stratum 2. Erlandson et al. (2008b, 2011a) have presented evidence for probable human impacts on San Miguel Island shellfish populations (see also Braje 2009). By the Middle Holocene, the reduced size and abundance of mussels, abalones, and large limpets may have contributed to an increasing focus of intertidal foragers on alternative species.

Evidence for diet breadth expansion during the Middle Holocene is seen in the large percentage of edible meat from urchin compared to earlier strata. Middle Holocene constituents demonstrate an expanding diet breadth as mussel drops in abundance, while abalone (particularly red abalone) increases and urchin and turban snails also become important constituents. This is particularly evident in Stratum 4, where urchin dominates the harvested shellfish by dry shell weight and estimated meat yield. Another pattern that might indicate diet and/or site catchment expansion is the significant increase of brown turban snails in Stratum 4; black turban snails are major contributors in Stratum 5 but are then replaced by brown turbans in Stratum 4. This is significant because black turbans are found in the high intertidal zone while brown turbans live mostly on the tops of giant kelp or in the low intertidal zone. The addition of brown turbans to the menu demonstrates an expanded foraging area or an increase in kelp harvesting. Increased use of lower-ranked shellfish taxa (such as urchin and turban snails; Braje et al. 2007:740) in the Middle Holocene might also be indicative of local resource depressions (see Butler 2000) and harvesting pressure on local intertidal communities. The Late Holocene component represented in Stratum 2 presents a more balanced economy, with fish and shellfish contributing close to equal portions of meat to the inhabitants' diet — approximately 44% and 55%, respectively. Stratum 2 dates to approximately 2,350 cal B.P., after the invention of the circular shell fishhook enhanced fishing capabilities (Rick et al. 2005a; Strudwick 1986).

In some respects, the faunal remains from Cave of the Chimneys follow the general trends for the region but deviate in others. Nearby Daisy Cave is an exception to trans-Holocene patterns for the region as it contains a much higher percentage of fish remains when compared to other early coastal sites (Rick et al. 2001). Interestingly, radiocarbon dates indicate that Cave of the Chimneys and Daisy Cave were occupied in alternating periods, suggesting that while one cave was in use the other was not. When comparing the Early Holocene deposits to those from Seal Cave (CA-SMI-604), dated to approximately 10,200–9,200 cal B.P., similarities are seen in overall percentages of shellfish weight (Erlandson et al. 2009). Both sites reveal a heavy reliance on California mussel, accounting for over 90% in Seal Cave (see Erlandson et al. 2009) and approximately 73–81% in the Early Holocene layers at Cave of the Chimneys. Excavated materials from several Middle Holocene occupations at Otter Cave (CA-SMI-605; Erlandson et al. 2005b) display a similar pattern to that observed in the Middle Holocene strata at Cave of the Chimneys. Meat yield estimates for Otter Cave reveal an overall emphasis on shellfish, with fish providing approximately 25% of the edible meat consumed (Erlandson et al. 2005b). The relatively high percentage of edible meat from fish in the Early and Middle Holocene deposits at Cave of the Chimneys, Otter Cave, and especially Daisy Cave, is in contrast to open-air sites with red abalone middens, such as nearby Otter Point (CA-SMI-481), where fish remains account for just over 2% of the edible meat (Vellanoweth et al. 2006). CA-SRI-191 (Rick et al. 2007), CA-SRI-667 (Wolff et al. 2007), and CA-SRI-147 (Braje et al. 2007) on Santa Rosa Island also contain limited but variable amounts of fish bones in Middle Holocene deposits. Fish are also relatively limited in Early and Middle Holocene deposits at Punta Arena on Santa Cruz Island, but fish increase during the Late Holocene and dolphins are an important food source during parts of the Middle Holocene (Glassow 2005a; Glassow 2005b; Glassow et al. 2008).

CONCLUSIONS

In most regards, the faunal analysis and dietary reconstructions presented here are consistent with trans-Holocene trends for the Channel Islands and southern

California coast. The broad Santa Barbara Channel pattern suggests an overall decline in the dietary importance of shellfish and an increase in the use of fish through time, especially during the Late Holocene. The Early Holocene inhabitants of Cave of the Chimneys utilized shellfish, particularly mussel, abalone, and sea urchin, as economic staples, with fish and birds rounding out the diet. Middle Holocene components reveal an increase in diet breadth, with varying proportions of harvested shellfish taxa in each stratum, but a decline in fish meat yields from Stratum 5 to Stratum 3. Fish become more important in the Late Holocene (Stratum 2), replacing shellfish to some extent (see also Vellanoweth et al. 2002). The dominance of fish is seen in other Late Holocene San Miguel Island sites, especially during the last 1,500 years of island occupation (Kennett 2005; Rick 2007).

Stratified and well-preserved deposits such as those at Cave of the Chimneys demonstrate the nature of resource diversification and changes in harvesting patterns through time along the northeast coast of San Miguel Island. These dietary reconstructions provide detailed information on the subsistence economies of people on the Northern Channel Islands, with Late Holocene increases in fish possibly related to the growing population densities and changes in social complexity observed elsewhere on the Northern Channel Islands (see Kennett 2005; Rick 2007). While data from Cave of the Chimneys contribute to regional patterns, it is important to bear in mind that cave and rockshelter sites may not fully represent regional economic patterns, as they comprise a unique site type and were often occupied seasonally or for shorter periods of time in comparison to open-air sites. On the other hand, deposits from caves and shelters are often well preserved, providing a glimpse of cultural deposits little disturbed by the strong winds and erosion that deflate and degrade some open-air sites on the Channel Islands.

Diachronic perspectives viewed in the context of site-specific historical ecology allow archaeologists to understand localized resource depressions and rebounds and short-term adaptive adjustments by humans. Focusing on sites and site clusters has the potential to reveal the diversity of past subsistence patterns by exposing nuances within general trends visible at the regional scale. Our study exemplifies the importance of understanding long-term adaptive responses by focusing on a single location and revealing short-term cyclical harvesting patterns at Bay Point, patterns which are not visible in some broader scales of analysis.

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