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REPORTS

Geographic and Temporal Variability of Middle Holocene Red Abalone Middens on San Miguel Island, California

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For at least the last half-century, Middle Holocene "red abalone middens" have been of interest to a variety of scientists working on the Channel Islands of California. Paleoclimatologists, oceanographers, ecologists, and archaeologists have all offered hypotheses to explain their widespread occurrence; however, quantification of their midden constituents has generally been insufficient to explain both their temporal and spatial variability. Detailed zooarchaeological analysis is a key component in understanding why these middens appeared at about 7,500 cal B.P. and disappeared at about 3,300 cal B.P. Faunal data from three radiocarbon (^{14}C) dated red abalone middens on San Miguel Island are presented. The analysis demonstrates both the geographic and temporal variability inherent within these sites, and suggests that our models for explaining their presence must account for this complexity.

The first rigorous scientific investigations of Middle Holocene "red abalone middens" were undertaken by oceanographer Carl Hubbs in the 1950s and geologist/archaeologist Phil Orr in the 1960s while investigating sites on the northwest coast of Santa Rosa Island, the second largest of the northern Channel Islands (Figure 1). Orr (1968) characterized these "red abalone middens" as shell middens dominated by dense concentrations or

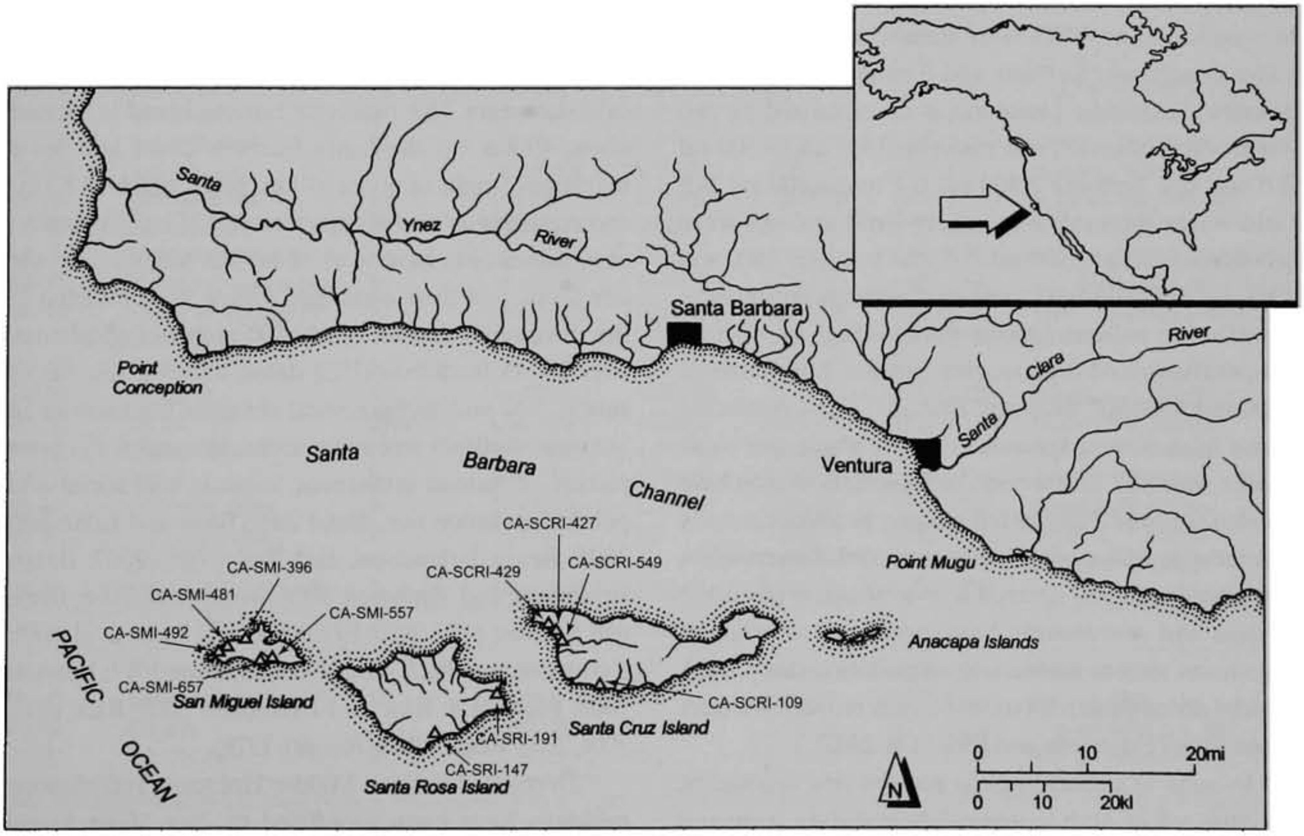

Figure 1. Map of the southern California Bight and the northern Channel Islands with locations of the red abalone sites discussed in the text.

pavements of relatively large red abalone shells. Hubbs (1967) and Orr (1968:97) agreed that these sites resulted from episodes of sea-surface temperature (SST) cooling during the Middle Holocene that allowed red abalones to migrate from subtidal or lower intertidal habitats into an upper intertidal habitat and replace black abalone, a common midden constitutent of Early Holocene sites (e.g., Erlandson 1994; Erlandson et al. 1999; Erlandson and Braje et al. 2005; Rick et al. 2005). Modern abalone distribution studies by Ault (1985) from the central California coast and Pisias' (1978, 1979) SST curve from the Santa Barbara Basin seemed to support these conclusions and were employed by Glassow (1993) to implicate SST cooling and corroborate Hubbs' (1967) and Orr's (1968) conclusions. Glassow (1993) suggested that red abalone became a more cost-efficient resource during the Middle Holocene when their intertidal location made them more accessible.

A new trans-Holocene record of SST developed from varved sediments from the Santa Barbara Basin (Kennett 2005; Kennett and Kennett 2000) suggests that the chronology of red abalone middens corresponds to a period when SSTs were dominated by relatively warm conditions. Kennett and Kennett (2000:65–66) describe the Middle Holocene as characterized by two warm-water intervals, one between 7,500 and 6,300 cal B.P. and one between 5,900 cal B.P. and 3,800 cal B.P. Cold-water intervals were short-lived and occurred between 6,300 and 5,900 cal B.P., and between 3,800 and 3,500 cal B.P. The new paleo-water-temperature data, however, do indicate "cooler than average sea-surface temperatures and high marine productivity between 6,400 and 5,800 B.P." (Kennett 2005:147). These results are drawn from 50-year running averages, which may mask smaller scale SST fluctuations. Such oscillations may have affected the availability of red abalone at scales currently undetectable with available climatic records. Nevertheless, this complexity has spurred a re-evaluation of earlier models and researchers have proposed alternative hypotheses, such as human over-exploitation (Salls 1992), subtidal diving (Sharp 2000), and locally reduced sea otter populations (Erlandson and Rick et al. 2005).

In order to effectively build and test new hypotheses, a robust set of archaeological faunal data from red abalone middens is required from a variety of temporal and geographic settings. The only published data presently available are from four sites on Santa Cruz Island (Glassow 2005; Sharp 2000), two sites on Santa Rosa Island (Braje and Kennett et al. 2007; Rick et al. 2006), and one site on San Miguel Island (Vellanoweth et al. 2006). In this paper, I present faunal data from three well-preserved Middle Holocene red abalone middens on San Miguel Island, one from the north coast and two from the south coast. I examine the temporal and spatial differences in the abundance of red abalone shell in these Middle Holocene red abalone middens. My analysis suggests that the importance of red abalone for the site inhabitants varied across space and time. When compared with similar data from other sites on Santa Cruz, Santa Rosa, and San Miguel, a complex picture of red abalone foraging during the Middle Holocene emerges—one that requires a great deal more data to explain adequately.

ARCHAEOLOGY OF SAN MIGUEL ISLAND RED ABALONE MIDDENS

San Miguel Island is the westernmost of California's northern Channel Islands and contains hundreds of archaeological sites and a nearly continuous record of human occupation spanning at least the last 11,500 calendar years. This relatively remote island is located about 40 km. off the Santa Barbara Coast and has a maximum length of about 17 km. and a width of 8 km., encompassing an area of approximately 37 km^2. A number of archaeologists have worked on San Miguel since the late 1800s, and their combined efforts have resulted in the documentation of nearly 700 archaeological sites, over 100 radiocarbon (^{14}C) dates, detailed records of subsistence and technological changes, fluctuations in average shellfish size measurements, and a dynamic picture of human settlement, impacts, and social and political evolution (e.g., Braje 2007; Braje and Erlandson 2005; Braje, Erlandson, and Rick 2005, 2007; Braje, Erlandson, and Timbrook 2005; Braje et al. 2006; Braje and Kennett et al. 2007; Erlandson and Braje et al. 2005; Erlandson and Rick et al. 2005; Glassow 1977; Kennett 2005; Rick 2004; Rick and Erlandson 2003; Rick et al. 2001, 2005; Rogers 1929; Rozaire 1978).

Thirteen ^{14}C dated Middle Holocene red abalone middens have been identified on San Miguel, and published faunal data are available from one site, CA-SMI-481 (see Vellanoweth et al. 2006; however,

Table 1

RADIOCARBON CHRONOLOGY OF MIDDLE HOLOCENE RED ABALONE MIDDENS DISCUSSED IN TEXT

Site CA-	Provenience	Material[1]	Lab #	Measured ^{14}C age	Conventional ^{14}C age	Age range (cal BP)[2]	Source
				Santa Cruz Island			
SCRI-109	North Unit, Strat. 15	Charcoal	Beta-119186	5,520±70	6,300±70	6,395 - 6,280	Glassow 2005:25
SCRI-109	North Unit, Strat. 15	*Lu*	Beta-119185	5,600±80	5,730±80	5,865 - 5,635	Glassow 2005:25
SCRI-109	North Unit, Strat. 10	*Mc*	Beta-119184	5,580±60	5,710±60	5,795 - 5,635	Glassow 2005:25
SCRI-109	North Unit, Strat. 10	Charcoal	UCR-0201	4,790±150	5,510±150	5,680 - 5,320	Glassow 2005:25
SCRI-109	North Unit, Strat. 10	*Hc*	UCR-0209	5,030±150	5,040±150	5,290 - 4,840	Glassow 2005:25
SCRI-109	South Unit, Strat. 15	*Ts*	Beta-122001	7,370±60	7,560±60	7,625 - 7,515	Glassow 2005:25
SCRI-109	South Unit, Strat. 15	*Mc*	Beta-119191	5,940±80	6,145±80	6,225 - 6,000	Glassow 2005:25
SCRI-109	South Unit, Strat. 11	*Mc*	Beta-119190	5,740±70	5,900±70	5,960 - 5,835	Glassow 2005:25
SCRI-109	South Unit, Strat. 2	*Hc*	Beta-119189	5,210±70	5,305±70	5,430 - 5,250	Glassow 2005:25
SCRI-549	Col. 1, Strat. 7	*Hc*	Beta-122007	6,560±60	6,785±60	6,865 - 6,715	Glassow 2005:25
SCRI-549	Col 1. Strat. 2	*Hr*	Beta-122008	5,240±70	5,325±70	5,455 - 5,275	Glassow 2005:25
SCRI-429[3]	Midden	*Hr*	UCR-1837	7,205±130	7,420±130	7,540 - 7,320	Glassow 2005:25
SCRI-429	Col. 2, midden	*Mc*	Beta-122005	6,210±70	6,395±70	6,470 - 6,305	Glassow 2005:25
SCRI-427	Col., Strat. 1	*Hr*	Beta-122002	5,580±70	5,710±70	5,835 - 5,625	Glassow 2005:25
SCRI-427	Col., Strat. 2B	*Hs*	Beta-122003	5,840±70	5,985±70	6,115 - 5,910	Glassow 2005:25
SCRI-427	Col., Strat. 2A	*Mc*	Beta-128111	5,900±60	6,095±60	6,170 - 5,980	Glassow 2005:25
SCRI-427	Midden	*Hr*	UCR-1835	5,420±100	5,570±100	5,650 - 5,550	Glassow 2005:25
				San Miguel Island			
SMI-657	Southern loci	Ms	Beta-195745	6,240±80	6,670±80	7,060 - ,6820	Braje, Erlandson, and Rick 2005
SMI-657	Northern loci, Bulk Sample 1	*Hc*	Beta-217110	5,460±90	5,900±90	6,190 - ,5970	Braje, Erlandson, and Rick 2005
SMI-657	Unit 1, Level 2	*Hm*	OS-56706	N/A	5,920±40	6,180 - ,6020	Braje 2007
SMI-528	A3, Str. III	*Hr*	Beta-114036	5,210±70	5,670±70	5,900 - ,5720	Kennett 2005
SMI-557	5 m below surface	*Hr*	UCR-1831	5,525±130	5,955±130	6,270 - 5,980	Glassow 1982
SMI-557	Bulk Sample 1	*Hr*	OS-44640	N/A	6,310±35	6,580 - 6,440	Braje, Erlandson, and Rick 2005
SMI-557	Bulk Sample 2	*Hr*	Beta-213143	5,710±60	6,140±60	6,400 - 6,265	Braje, Erlandson, and Rick 2005
SMI-520	Surface NE area	*Hc*	OS-37736	N/A	3,630±25	3,330 - 3,220	Channel Is. ^{14}C Database
SMI-520	Surface NE area	*Hr*	Beta-171805	5,250±80	5,680±80	5,920 - 5,720	Channel Is. ^{14}C Database
SMI-492	North Profile, Strat. 4	*Mc*	Beta-5807	4,920±80	5,350±80	5,580 - 5,420	Walker and Snethkamp 1984
SMI-481	Red Abalone lens	*Hr*	Beta-145317	5,430±70	5,870±70	6,160 - 5,930	Vellanoweth et al. 2006
SMI-396	Abalone soil, western area	*Hc*	Beta-181392	4,220±70	4,650±70	4,765 - 4,490	Braje, Erlandson, and Timbrook 2005
SMI-396	Abalone soil, northeast area	Ms	Beta-194508	4,240±70	4,650±70	4,765 - 4,490	Braje, Erlandson, and Timbrook 2005
SMI-396	Abalone soil, southeast area	Ms	Beta-194509	4,580±50	4,990±50	5,130 - 4,900	Braje, Erlandson, and Timbrook 2005
SMI-388NW	20 cm deep	*Hr*	I-04587	6,450±130	6,880±130	7,310 - 7,010	Kennett 2005
SMI-261	Col. E-6, Str. C	*Hc*	Beta-15620	5,940±110	6,380±110	6,720 - 440	Erlandson et al. 1996:361
SMI-261	Col. E-6, Str. C	*Mc*	Beta-52359	6,090±80	6,500±80	6,800 - 6,630	Erlandson et al. 1996:361
SMI-261	Col. E-6, Str. C	Charred Twig	CAMS-8862	6,000±70	6,000±70	6,900 - 6,730	Erlandson et al. 1996:361
SMI-212	Gully wall exposure	*Hc*	Beta-213140	6,220±60	6,640±60	6,980 - 6,720	Channel Is. ^{14}C Database
SMI-212	Surface	*Hr*	Beta-213141	6,400±60	6,800±60	7,200 - 6,990	Channel Is. ^{14}C Database
SMI-172	Red Abalone midden	*Hr*	Beta-42606	5,730±90	6,160±90	6,440 - 6,270	Channel Is. ^{14}C Database
SMI-161	Unit 1 14 -16 cmbs	*Hr*	OS-51579	N/A	4,490±35	4,440 - 4,290	Channel Is. ^{14}C Database
SMI-161	Unit 2 12 -15 cmbs	*Hr*	OS-51580	N/A	4,520±35	4,500 - 4,360	Channel Is. ^{14}C Database
SMI-87	West red ab. midden	*Hr*	Beta-134835	3,760±90	4,190±90	4,090 - 3,830	Rick 2004
				Santa Rosa Island			
SRI-191	Red abalone midden	*Cu*	OS-37594	N/A	5,740±45	5,930 - 5,860	Rick et al. 2006
SRI-191	Red abalone midden	*Hr*	OS-46941	N/A	5,870±30	6,110 - 5,960	Rick et al. 2006
SRI-147	230 cmbs	*Hr*	Beta-87202	5,060±60	5,500±60	5,710 - 5,570	Braje and Kennet et al. 2007
SRI-147	190 - 200 cmbs	*Mc*	OS-46832	N/A	5,270±30	5,440 - 5,330	Braje and Kennet et al. 2007

[1]Dates were calibrated using Calib 5.0.1 (Stuiver and Reimer 2000) using a ΔR of 225 ± 35 years or were reported as in the original citation; $^{13}C/^{12}C$ were determined by the ^{14}C lab or an average of +430 years was applied.

[2]Age ranges at one sigma. *Cu* = *Chione undatella*, *Hc* = *Haliotis cracherodii*, *Hm* = *Hinnites multirugosus*, *Hr* = *H. rufescens*; *Hs* = *Haliotis* spp.; *Lu* = *Lithopoma undosa*; *Mc* = *Mytilus californianus*; Ms = Marine shell; *Ts* = *Tivela stultorum*.

[3]Glassow (2005:25) suspects a dating error.

Figure 2. Location of Bulk Sample 1 at CA-SMI-657 prior to excavation.

unpublished data are also available in Walker and Snethkamp 1984, from CA-SMI-492; see Table 1). The remaining eleven sites have been identified as red abalone middens, based on the density and size of red abalone shells in site exposures. While most of the red abalone middens have been described as thin lenses (less than 30 cm. thick) of mostly large red abalone shells, a quantification of their midden constituents is necessary to understand their variability across time and space. For example, Glassow's (2005) analysis of several red abalone middens on Santa Cruz Island demonstrated that California mussel dominated the dietary meat weight represented by the assemblages. It is uncertain if similar patterns also occur on San Miguel Island.

In an effort to better understand the subsistence patterns at red abalone middens on San Miguel, several archaeologists have initiated a dating and sampling project focused on these sites. Here, I report on excavations at three of these sites: CA-SMI-657, SMI-557, and SMI-396. Radiocarbon dates were submitted for each site and bulk samples were excavated from eroding exposures. All sediments were water-screened in the field over a combination of 1/8- and 1/16-inch mesh, and the residuals were transported to the University of Oregon for detailed analysis. The 1/8-inch fraction was completely sorted and all shellfish remains were identified to the most specific level possible. The Minimum Number of Individuals (MNI) was calculated using the largest number of non-repetitive elements. In the following sections, I describe the setting, chronology, and faunal assemblages for each site.

CA-SMI-657

This site was recorded in the summer of 2004 during a systematic survey of the south coast of San Miguel Island as part of Channel Islands National Park's cultural resource management plan (Braje and Erlandson 2005; Braje, Erlandson, and Rick 2005). CA-SMI-657 is located

Table 2

MIDDEN CONSTITUENTS (1/8-INCH) FROM CA-SMI-657 BULK SAMPLE 1

Taxon	Wt. (g)	% Wt.	MNI	MNI %
Balanus spp.	216.6	2.0	–	–
Chiton undif.	6.6	0.1	–	–
Crab undif.	103.6	0.9	–	–
Crepidula spp.	0.3	<.1	2	1.0
Gastropod undif.	0.2	<.1	3	1.6
Haliotis cracherodii	216.0	2.0	11	5.8
Haliotis rufescens	9,703.8	87.9	27	14.1
Haliotis spp.	1.0	<.1	–	–
Helminthoglypta ayresiana	31.6	0.3	68	35.6
Limpet undif.	2.6	<.1	16	8.4
Lottia gigantea	7.6	0.1	2	1.0
Mytilus californianus	299.3	2.7	45	23.6
Pollicipes polymerus	0.5	<.1	–	–
Septifer bifurcatus	1.0	<.1	1	0.5
Serpulorbis squamigerus	65.1	0.6	–	–
Strongylocentrotus spp.	83.2	0.8	–	–
Tegula funebralis	275.5	2.5	14	7.3
Shell undif.	5.3	<.1	–	–
Subtotal	11,019.7	99.8	189	99.0
Fish bone	14.2	0.1	1	0.1
Sea mammal bone	4.7	<.1	1	0.5
Subtotal	18.8	0.2	2	1.0
Total	**11,038.5**	**100.0**	**191**	**26.5**

at the base of the southern escarpment north of Crook Point and consists of two discrete midden loci. The northern locus is exposed for 10–15 m. in the eastern wall of a sizable gully cut by an intermittent stream. Three pockets of midden are visible in the gully wall at this northern location, buried by approximately 1.5 m. of historic dune sand and alluvium.

Approximately 100–150 m. south of the northern locus is an intact southern locus eroding from near the base of a small dune ridge. The dune is covered by thin low-lying vegetation and the midden is only visible in the dune's western flank. The midden is buried below 50–100 cm. of sand and is eroding from a yellow-tan alluvial paleosol similar to the northern locus.

While each of the midden loci is dominated by large red abalone shells in the gully wall, the density of the midden and the diversity of shellfish taxa vary. The northern locus is dominated by large, mostly whole red abalone shells and is moderately dense (Figure 2), while the southern locus is densely packed and contains a wider array of intertidal shellfish taxa, represented primarily by large red abalone and California mussel shells. Single fragments of shell were submitted for the northern and southern loci, yielding one sigma age ranges of 6,190–5,940 cal B.P. and 7,060–6,820 cal B.P., respectively.

A 100-liter bulk sample, excavated from an eroding exposure in the east gully wall at the northern locus, produced a roughly 11-kg. assemblage of shell and bone (Table 2). The dry shellfish weight was composed of at least 15 different shellfish taxa and was dominated by red abalone (88%), followed by minor contributions from California mussel (3%), black turban snail (3%), and black abalone (2%).

CA-SMI-557

This site was first recorded during a survey by a team of archaeologists from the University of California, Santa Barbara (Glassow 1982). CA-SMI-557 is a complex of several shell midden loci, extending for ca. 150 m., eroding from the gully walls of the Waters Canyon drainage on the south coast of San Miguel Island. The site center is approximately 325 m. north of the south coast shoreline and each of the loci is between 10 and 30 cm. thick. The midden is embedded in a yellow-tan alluvium and buried beneath approximately 4.5 to 5 m. of historic dune sand.

University of Oregon archaeologists visited CA-SMI-557 over several field seasons from 2003–2005; visual inspection of the site suggested that the faunal constituents varied by location. Separated by approximately 10 m., the two densest deposits were visible in the western gully wall at the same stratigraphic level. The northern locus was dominated by large, mostly whole red abalone shells, while the southern locus consisted of a variety of intertidal shellfish species, including red and black abalone, California mussel, black turban snail, and sea urchin (Figure 3).

Bulk samples of 40 and 50 liters were collected from the northern and southern loci, respectively, and single fragments of red abalone shells from each bulk sample were submitted for ^{14}C dating. CA-SMI-557 appears to have been occupied between about 6,580 and 5,980 cal

Figure 3. Location of Bulk Sample 2 at CA-SMI-557 prior to excavation; note the diverse array of shellfish taxa.

B.P. The similar vertical location, close proximity, and overlapping (two sigma) ^{14}C dates from Bulk Samples 1 and 2 suggest that the midden loci are contemporary.

A total of approximately 15.4 kg. of shell and bone representing at least 16 different shellfish taxa was obtained from the combined bulk samples (Table 3). Nearly 49% of the dry shell weight consisted of red abalone, with black turban snail (28%), and California mussel (12%), constituting the next two highest contributors. The remaining 11% of the assemblage involved a variety of rocky intertidal shellfish species and small amounts of fish, sea mammal, bird, reptile, and land mammal bone.

CA-SMI-396

Located at Simonton Cove on a prominent dune ridge on the northwest coast of San Miguel Island, CA-SMI-396 is a large site that extends for ca. 300 m. north-south and 250 m. east-west, and appears to contain two major shell midden strata eroding from dune paleosols dating to the Middle and Late Holocene. Each midden is between 20 and 50 cm. thick and is deeply buried below substantial deposits of Late Holocene dune sand.

The Middle Holocene stratum is eroding from the north side of a flat ridge about three-fourths of the way up the dune at about 60 m. in elevation. This horizontally-continuous shell midden is densely packed with shells of large red and black abalone, California mussel, owl limpets, and a variety of other intertidal and nearshore shellfish and fish remains (Figure 4). Although the midden consists of a variety of shellfish, visual inspection of the eroding exposures suggests that it is dominated by large red and black abalone shells. A diverse array of tools have also been identified eroding from the site, including chipped stone artifacts, sea mammal bone tools (abalone pry

Table 3

MIDDEN CONSTITUENTS (1/8-INCH) FROM CA-SMI-557, BULK SAMPLE 1 AND 2 COMBINED

Taxon	Wt. (g)	% Wt.	MNI	MNI %
Astraea undosa	4.1	<.1	3	0.4
Balanus spp.	116.5	0.8	–	–
Chiton undif.	0.3	<.1	–	–
Crab undif.	44.4	0.3	–	–
Crepidula spp.	17.0	0.1	155	21.5
Gastropod undif.	0.9	<.1	8	1.1
Haliotis cracherodii	497.6	3.2	10	1.4
Haliotis rufescens	7,492.1	48.8	16	2.2
Haliotis spp.	368.5	2.4	–	–
Helminthoglypta ayresiana	31.8	0.2	47	6.5
Limpet undif.	8.4	0.1	169	23.4
Mytilus californianus	1,884.2	12.3	116	16.1
Nacre undif.	404.4	2.6	–	–
Pollicipes polymerus	17.0	0.1	–	–
Septifer bifurcatus	2.9	<.1	7	1.0
Serpulorbis squamigerus	38.7	0.3	–	–
Strongylocentrotus spp.	1.0	<.1	–	–
Tegula funebralis	4,340.3	28.2	185	25.7
Tegula spp.	12.9	0.1	–	–
Shell undif.	37.8	0.2	–	–
Subtotal	15,320.8	99.7	716	99.3
Bird bone	7.2	<.1	1	0.1
Fish bone	20.1	0.1	1	0.1
Land mammal bone	0.1	<.1	1	0.1
Reptile bone	0.3	<.1	1	0.1
Sea mammal bone	15.9	0.1	1	0.1
Bone undif.	0.1	<.1	–	–
Subtotal	43.8	0.3	5	0.7
Total	**15,364.5**	**100.0**	**721**	**100.0**

bars), shell beads, tarring pebbles, and asphaltum basketry impressions (see Braje, Erlandson, and Timbrook 2005). A total of three radiocarbon dates on well-preserved marine shells from the midden produced a calibrated age range between 5,130 and 4,490 cal B.P.

In 2004, University of Oregon archaeologists excavated two 25-liter bulk samples, one from the north-central (Figure 4) and one from the northeastern site area. Analysis of the midden constituents revealed a large and diverse array of shellfish, including 17 different taxa from the over 12.5 kg. of shell and bone (Table 4). The assemblage was dominated by California mussel (71.2%) with lesser amounts of red abalone (11.1%), black abalone (6.4%), and black turban snail (2.9%). The remainder of the assemblage consisted of a variety of other rocky shore shellfish taxa and a small amount of fish bone.

DISCUSSION

An analysis of bulk samples from three red abalone middens on San Miguel Island revealed significant variability in the midden constituents at each site. Red abalone contributed 88%, 49%, and 11.1% of the dry shell weight at CA-SMI-657, -557, and -396, respectively. At CA-SMI-396, red abalone was not the most abundant faunal constituent; instead, California mussel (71.2%) dominated the assemblage. At CA-SMI-657 and -557, where red abalone was the most important constituent, the second most abundant constituent differed by site; California mussel (3%) was most abundant at CA-SMI-657, and black turban snail (28%) was most abundant at CA-SMI-557.

While a great deal more data need to be gathered from these study sites and from additional Middle Holocene red abalone middens, this pattern might best be explained in one or a combination of ways. First, this pattern may be a result of differential use of the north and south coasts of San Miguel during the Middle Holocene. Kennett (2005:135, Map 9) argued that the north coasts of San Miguel, Santa Rosa, and Santa Cruz islands contained the largest Middle Holocene population centers on the islands with the south coasts exploited on a short-term or logistical basis. The majority of sites on the south coast of San Miguel are small, low-density shell middens that probably represent short-term occupations by small numbers of people (Braje, Erlandson, and Rick 2005). Due to limited fresh water and an impoverished terrestrial flora, the south coast may have been visited infrequently or seasonally. The site occupants may have focused on red abalone during logistical forays from base camps on the north coast or elsewhere on the other Channel Islands or mainland. This also would explain the more diverse faunal assemblage at CA-SMI-396 (a north coast site, and presumably a base camp), as well as the abundance of California mussel shell (a faster-growing and plentiful intertidal resource) in the assemblage.

Figure 4. Location of Bulk Sample 1 at CA-SMI-396 prior to excavation.

Subsistence patterns at my study sites may also relate to temporal variability. CA-SMI-657 and -557 date to between about 6,600 and 6,000 years ago. These sites are some of the oldest ^{14}C dated red abalone middens from the northern Channel Islands. If it was during this interval that large red abalone first became abundantly available to island foragers, as a result of climate change (Glassow 1993; Glassow et al. 1988, 1994), subtidal diving (Salls 1992), human over-exploitation (Sharp 2000), sea otter hunting (Erlandson and Rick et al. 2005), or some combination of these factors, we would expect to find greater percentages of red abalone shell in these middens. This pattern is found at SMI-657 and -577, where red abalone accounted for 88% and 49% of the shell weight. After red abalone became available and was exploited for a significant period of time, we would expect to see a decrease in its overall abundance within red abalone middens, a pattern evident approximately 2,000 years later at CA-SMI-396, where red abalone accounts for only 11% of the shell weight.

This temporal pattern holds true for the two other red abalone middens that have been sampled on San Miguel Island. At Otter Point (CA-SMI-481), on the northwestern coast of San Miguel, Vellanoweth et al. (2006) reported a ca. 6,000-year-old red abalone lens containing 67.9% red abalone shell. It should be noted, however, that a California mussel lens dated to the same time is located directly below the red abalone lens and contains nearly 60% California mussel and less than 1% red abalone. Finally, Walker and Snethkamp sampled CA-SMI-492, a large shell midden on northwestern San Miguel Island, ^{14}C dated between 5,580 and 5,420 years ago (see Table 1) and containing two strata with relatively high densities of red abalone shell: strata 11 and 10 with 17.2% and strata 6 and 4 with 21.4%.

Table 4

MIDDEN CONSTITUENTS (1/8-INCH) FROM CA-SMI-396, BULK SAMPLES 1 AND 2 COMBINED

Taxon	Wt. (g)	% Wt.	MNI	MNI %
Balanus spp.	212.1	1.7	–	–
Chiton undif.	4.1	<.1	–	–
Crab undif.	0.4	<.1	–	–
Crepidula spp.	1.0	<.1	11	0.7
Gastropod undif.	2.2	<.1	75	4.5
Haliotis cracherodii	804.5	6.4	18	1.1
Haliotis rufescens	1,388.6	11.1	4	0.2
Helminthoglypta ayresiana	144.0	1.2	147	8.8
Hinnites multirugosus	185.8	1.5	1	0.1
Limpet undif.	11.6	0.1	304	18.2
Lottia gigantea	27.4	0.2	10	0.6
Mytilus californianus	8,898.9	71.2	1021	61.2
Nacre undif.	294.0	2.4	–	–
Pollicipes polymerus	27.0	0.2	–	–
Septifer bifurcatus	25.6	0.2	47	2.8
Serpulorbis squamigerus	9.5	0.1	–	–
Strongylocentrotus spp.	72.2	0.6	–	–
Tegula funebralis	357.1	2.9	30	1.8
Shell undif.	24.0	0.2	–	–
Subtotal	12,489.8	99.9	1,668	99.9
Fish bone	11.1	0.1	1	0.1
Subtotal	11.1	0.1	1	0.1
Total	**12,500.9**	**100.0**	**1,669**	**100.0**

These deposits, post-dating CA-SMI-657, -557, and -481 by about 500 years, contain significantly lower densities of red abalone shell, a pattern similar to that at CA-SMI-396.

One way to further test these patterns is to compare data from my study sites with data from sites across the northern Channel Islands. Since Glassow (1993) first documented the widespread appearance of sites containing high frequencies of red abalone shells on Santa Cruz, Santa Rosa, and San Miguel islands, over 30 red abalone middens have been identified (see Rick et al. 2005). Quantitative data from Middle Holocene middens with significant percentages of red abalone, however, are available for only a few sites. Sharp (2000), for example, analyzed the midden constituents from two column samples at CA-SCRI-109, a large Middle Holocene shell midden on the south coast of Santa Cruz Island. The only stratum containing more than 5% red abalone was stratum 12 from the south column, an approximately 6,000-year-old lens with 66.9% red abalone shell by weight.

Glassow (2005) recently reported on four Santa Cruz Island red abalone middens—CA-SCRI-109, -427, -429, and -549—dated between 6,800 and 5,300 cal B.P. California mussel was the most abundant faunal constituent at each of these sites, always comprising over 65% of the dry shell weight, with red abalone never constituting more than 4% (Glassow 2005:26–29). Similarly, Braje and Kennett et al. (2007) reported two levels from a column sample ^{14}C dated between 5,710 and 5,330 cal B.P. at CA-SRI-147, a large multicomponent shell midden on Santa Rosa's south coast, with dry red abalone shell weights of 27.6% and 11.9%. Finally, Rick et al. (2006) reported on the faunal constituents of a 0.5 x 1 m. excavation unit at CA-SRI-191, a ca. 6,000-year-old red abalone midden on eastern Santa Rosa Island. Rick and his colleagues (2006) found that red abalone shell dominated the midden, constituting 67.2% of the dry shell weight.

As a number of researchers have pointed out (e.g., Glassow 1993; Kennett 2005:145–147), variation in the percentages of red abalone found in red abalone middens on the northern Channel Islands was probably heavily influenced by local SSTs. The Santa Barbara Channel is located at the intersection of colder northern marine currents, warmer southern currents, and deep-water upwelling. The mixture of these generally produces a gradient of water temperatures, with the coolest SSTs surrounding San Miguel and warmer temperatures to the east. These SST differences probably accounted for much of the inter-island variation in red abalone exploitation. While the composition of Middle Holocene red abalone middens on San Miguel Island shows evidence of temporal and spatial patterning, similar intra-island variation may be found on Santa Rosa and Santa Cruz islands. The dearth of quantitative data from red abalone middens on these larger islands, however, makes this difficult to evaluate; a more robust dataset is required.

CONCLUSIONS

The available data from Middle Holocene red abalone middens on the northern Channel Islands suggest a complex history of human exploitation that varied both temporally and spatially. On San Miguel Island, red abalone middens dated between about 6,600 and 6,000 years ago are dominated by red abalone shell (>49%). After 6,000 years ago, red abalone comprises a significantly smaller percentage of the dry shell weight. These variations also may be related to differential use of the north and south coasts of San Miguel Island. The percentage of dry red abalone shell in the three north coast sites is generally much lower than in the two south coast sites. Large village sites and more intensive and sustained human predation on red abalone on the north coast may have reduced their numbers and densities in local waters in comparison with south coast sites. However, these patterns are based on a small sample of sites and require further testing.

Glassow's (2005) data from Santa Cruz Island suggest that a significant degree of variability is also present between islands. Although each of Glassow's (2005:23) study sites contained "whole or nearly whole red abalone shells" and were dominated by marine shells, these sites would probably not be labeled red abalone middens if they were found anywhere on San Miguel Island. Shell middens that archaeologists have identified as red abalone middens on San Miguel Island contain significantly higher percentages of red abalone shell, while red abalone middens on Santa Cruz Island are often dominated by California mussel shell. This pattern is probably the result of warming SSTs along the Santa Barbara Channel from west to east with a resultant decrease in the availability of red abalone. The definitions of "red abalone middens" advanced by archaeologists seem to follow this gradient, with greater densities of red abalone shell being compulsory for the use of this term on San Miguel, and decreasing densities being required as one moves east along the Channel. Keeping this in mind, the temporal and geographic differences on San Miguel Island may also be present on the other islands, although perhaps on a different scale. A great deal more information is necessary before any definitive conclusions can be drawn. Further excavations of red abalone middens from a variety of time periods and geographic locations can help us build models that adequately explain the complexity evident in Middle Holocene red abalone middens.

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