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Red Abalones, Sea Urchins, and Human Subsistence at Middle Holocene Cuyler Harbor, San Miguel Island, California

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*Excavations at CA-SMI-161 provide insight into Middle Holocene human subsistence strategies and exploitation of kelp forest and rocky intertidal habitats on San Miguel Island. Faunal data from two red abalone (*Haliotis rufescens*) middens dated to ca. 4,400 cal B.P. and an earlier deposit dominated by sea urchin (*Strongylocentrotus *spp.) dated to 5,800 cal B.P. demonstrate variability in the use and availability of different marine shellfish through time. Some of these data come from one of the youngest red abalone middens reported on the Northern Channel Islands and suggest that by 4,400 cal B.P. red abalone was still highly abundant (approximately 48–73% by weight) in some San Miguel Island middens, but declined to 24% by 4,000 cal B.P. at CA-SMI-603 and to just 7% by 3,600 cal B.P. at CA-SMI-261. When compared to Late Holocene sites from Cuyler Harbor, the CA-SMI-161 data document a broader decline in red abalone, with finfish and California mussels (*Mytilus californianus*) dominating subsistence resources after about 3,000 cal B.P. These trends may relate to growing Late Holocene human population densities and the higher biomass provided by finfishes.*

The rich archaeological record and well-preserved shell middens of California's Channel Islands are important for understanding human subsistence, the structure and function of local marine ecosystems, and the influence of human predation and natural climatic changes on island organisms and ecosystems throughout the Holocene and Terminal Pleistocene (Arnold 2001; Braje 2010; Erlandson et al. 2008, 2009, 2011; Kennett 2005; Rick et al. 2005). Red abalone middens, a distinct site type on the Channel Islands and parts of the California mainland, are particularly important sources of information on ancient human lifeways and environmental change (Braje 2007; Braje et al. 2009; Glassow 1993, 2005; Glassow et al. 2008, 2012; Hubbs 1955, 1967; Joslin 2010; Kennett 2005; Orr 1968; Rick et al. 2006; Sharp 2002; Whitaker and Byrd 2012). On the Channel Islands, red abalone middens date between about 8,000 and 3,500 years ago, and have been identified on Santa Cruz, Santa Rosa, San Miguel, and San Nicolas islands (see Braje et al. 2009).

Archaeologists and other scholars have provided numerous explanations for the presence of red abalone middens on the Channel Islands during the Middle Holocene. The earliest explanation for the appearance of red abalone middens was proposed by Hubbs (1955), who suggested that sea surface temperatures (SSTs) dropped during the Middle Holocene, allowing red abalone to move from the subtidal into the intertidal, where they displaced black abalone (*Haliotis cracherodii*). This explanation enjoyed a long period of support (Glassow

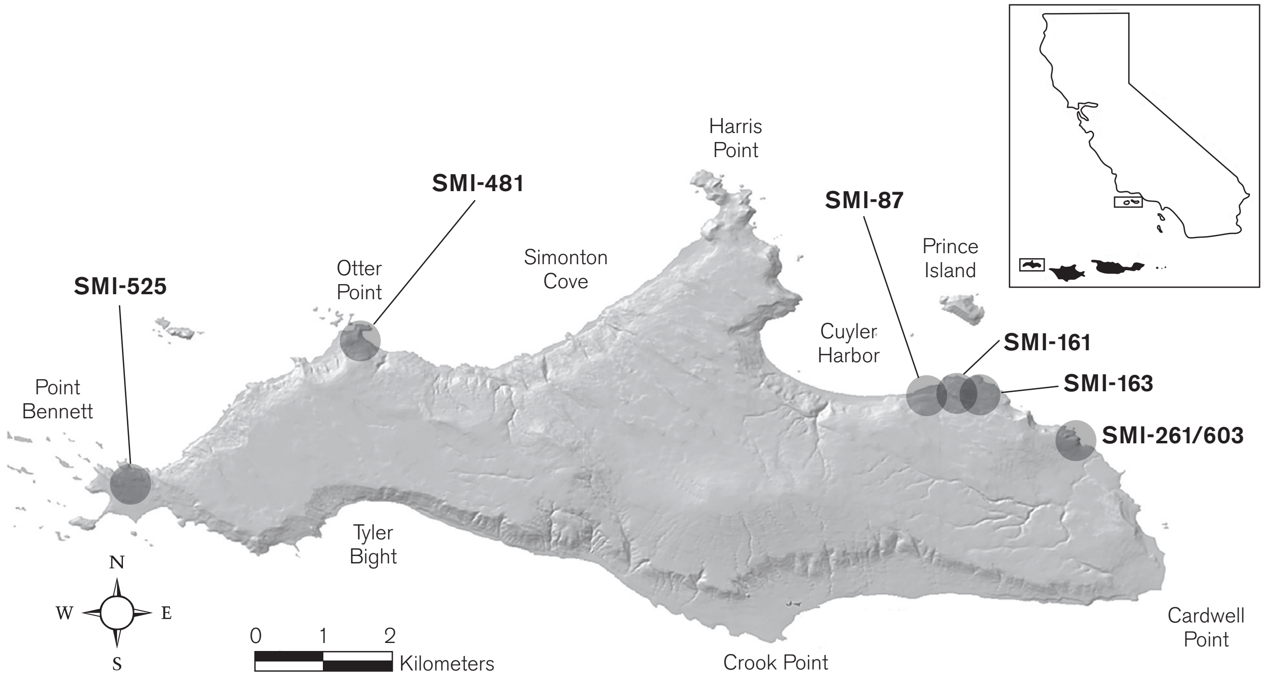

Figure 1. Location of San Miguel Island, CA-SMI-161, and other sites mentioned in the text.

1993; Glassow et al. 1994), but a trans-Holocene climate record from the Santa Barbara Basin suggests that SSTs were relatively warm from 7,500 to 6,300 cal B.P. and from 5,900 to 3,800 cal B.P., representing the majority of the 4,500-year window when red abalone middens are known to occur (Kennett 2005). Between 6,300 and 5,900 cal B.P., SSTs were considerably cooler and many red abalone middens date to this interval, including most of those on Santa Cruz and eastern Santa Rosa islands where SST is generally warmer today (Braje et al. 2009; Glassow et al. 2008, 2012; Rick et al. 2006). Alternative hypotheses for the formation of red abalone middens include subtidal diving to collect red abalone (Salls 1992; Sharp 2002), reduced El Niño frequency (Kennett 2005:147), overexploitation (see Kennett 2005; Salls 1992), a boom in red abalone populations resulting from the depletion of sea otters (*Enhydra lutris*) (Braje et al. 2009; Erlandson et al. 2005), the use of boats for diving (Whitaker and Byrd 2012), or a combination of ecological and cultural factors (Glassow et al. 2012; Kennett et al. 2007; Rick et al. 2006). Braje et al. (2009) suggested, for instance, that variability in SSTs and marine productivity around the Northern Channel Islands may explain significant inter-island variability in the age, distribution, and density of red abalone middens.

In this paper, we present the results of research at CA-SMI-161, a large dune site located at Cuyler Harbor, San Miguel Island that contains several distinct midden deposits dated between 5,800 cal B.P. and 1,350 cal B.P. (Fig. 1). Our research focused on two red abalone deposits, each dated to about 4,400 cal B.P., and a third midden dominated by sea urchins that was dated to around 5,800 cal B.P. Collectively, these deposits help inform our understanding of the variability in the red abalone midden site type, especially those that date to near the end of the approximately 4,500-year span of red abalone middens on the Northern Channel Islands. When compared to other sites in the Cuyler Harbor area, our research at CA-SMI-161 provides a roughly 6,000-year record of human subsistence and interactions with local ecosystems, extending into the early nineteenth century AD.

ENVIRONMENTAL AND CULTURAL BACKGROUND

Covering approximately 37 km.^{2} in land area, San Miguel Island is located 42 km. from the California mainland on the western edge of the Santa Barbara Channel. From the last glacial maximum to about 10,000 cal B.P., San

Miguel Island was part of Santarosae, a larger island landmass formed by the coalescence of the four Northern Channel Islands caused by lower global sea levels.

Traditionally, the Northern Channel Islands have been characterized as more limited in terrestrial plant resources than the mainland. The islands do have lower floral diversity, but the apparent limited diversity and productivity of island plant resources have been exaggerated by the effects of recent livestock overgrazing and historical landscape alteration. Recent research demonstrates the use of island terrestrial plant foods going back to at least the Early Holocene, but so far only root crops such as blue dicks (*Dichelostemma capitatum*) have been identified in early deposits (Reddy and Erlandson 2012). Pygmy mammoths (*Mammuthus exilis*) inhabited Santarosae and the Northern Channel Islands during the Pleistocene and may have briefly overlapped with early humans (Agenbroad et al. 2005). However, the only land mammals of significant size to inhabit the Northern Channel Islands during the Holocene were dogs (*Canis familiaris*), island foxes (*Urocyon littoralis*), and spotted skunks (*Spilogale gracilis amphialus*) (Rick 2013).

The islands support productive marine ecosystems that—complemented by terrestrial plant resources—appear to have been the focus of human subsistence for 13,000 years (Erlandson et al. 2009, 2011; Rick et al. 2005). Located where colder waters from northern currents meet warmer currents from the south, marine organisms on the Channel Islands are a mix of both warm- and cold-water species. As the westernmost of the Northern Channel Islands, San Miguel Island has the coolest water temperatures, a factor that may have played a role in the distribution, structure, and chronology of island red abalone middens (Braje et al. 2009).

Native Americans occupied the Channel Islands for some 13,000 calendar years and into the Historic period, providing a nearly continuous sequence of human interactions with southern California marine ecosystems through the early nineteenth century (Braje 2010; Erlandson et al. 2009, 2011; Gusick 2012; Kennett 2005; Rick et al. 2005). Several of the earliest island sites are found on San Miguel, including Daisy Cave (CA-SMI-261) and other Terminal Pleistocene shell middens and lithic scatters near Cardwell Point, some of which appear to be dominated by red abalone shells (Erlandson et al. 2011). However, the bulk of the red abalone middens on San Miguel, where more such middens have been identified than on any of the other Channel Islands, date between about 7,500 and 3,500 cal B.P. (Braje et al. 2009). Despite the abundance of red abalone middens on San Miguel, quantitative faunal data are available from a relatively small percentage of sites, limiting our understanding of this important site type.

CUYLER HARBOR AND CA-SMI-161

Cuyler Harbor is the largest anchorage on San Miguel Island. Located on the northeastern section of the island, Cuyler Harbor is a large embayment with an extensive sandy beach, flanked by steep marine terraces, a historic period deflation zone (the wind tunnel), and Prince Island, a small islet, located on the northern end of the harbor. Several fresh water springs have been documented in the Cuyler area, including a small creek in Nidever Canyon. The variety of habitats and fresh water in the Cuyler area have made it attractive to human settlement throughout the Holocene, with the oldest site on Cuyler Harbor dated to around 7,000 cal B.P. (Erlandson 1991) and a large Historic period village complex located at CA-SMI-163 (Rick 2007).

CA-SMI-161 is a large archaeological site located on the southeastern margins of Cuyler Harbor. The site is situated in dune sand on a mostly vegetated slope that emerges from a terrace just above a small sandy pocket beach (Fig. 2). Originally recorded by Kritzman and Rozaire (1965) as four separate archaeological sites (CA-SMI-155, -156, -157, and -161), Greenwood (1978:128–129) suggested that these sites were all part of the same site complex and renumbered them as CA-SMI-161. Wessel and Toren (1977) indicated that CA-SMI-161 covered an area of about 125,000 square meters. Shell midden deposits are scattered throughout the site, large portions of which lack archaeological materials on the surface and other portions of which are obscured by vegetation.

Greenwood (1978) and Wessel and Toren (1977) identified three distinct dunes on the site that contained shell midden, which they labeled Features 1–3. Features 2 and 3 are relatively discrete red abalone middens. Our work at the site demonstrates that the majority of the midden deposits at the site appear to date to the

Figure 2. Portions of the CA-SMI-161 site complex looking northwest. Person excavating in left center of photo is at Unit 2 (Photo taken by E. Erlandson).

Middle Holocene, but radiocarbon dating of an extensive midden on top of the terrace on the site's eastern margin also documented an occupation dated to around 1,350 cal B.P. (Table 1).

FIELD AND LABORATORY METHODS

During archaeological site assessment work in 2005, we excavated samples from three midden deposits at CA-SMI-161, including a red abalone midden in Feature 2 (Unit 1, 55 x 65 cm.), a second red abalone midden in Feature 3 (Unit 2, 50 x 100 cm.), and a third midden with abundant sea urchin located in the western site area (Unit 3, 45 x 60 cm.) and closer to the beach than Units 1 and 2. Like many dune sites on the Channel Islands, CA-SMI-161 was badly eroding, and our decision to sample the site was largely based on threats from erosion to the site deposits.

Unit 1 was situated near the bottom of the dune slope, within Feature 2, a small mound about 5 m. in diameter. Unit 2 was located at the top of the northwest dune face, approximately 50 m. from Unit 1, within Feature 3, another small mound about 5 m. in diameter. Unit 3 is the lowest and westernmost of the three deposits, and was excavated from the dune face just above a rocky outcrop that drops to the ocean below. The three units were excavated as bulk samples, with all residuals from 1/8-inch mesh screens retained for analysis. Because of the large size of red and black abalone and California mussel shells, we measured and weighed samples of these shellfish and returned them to the backfilled units.

Unit 1 was excavated to a depth of 45 cm., with a total volume of 100 L. The midden deposit was concentrated in the upper 30 cm. of Unit 1 and appears to be a single component or series of occupations over a short window of time. An abundance of land snail was encountered below 35 cm., corresponding to a drop-off in marine shell and ultimately sterile deposits.

Unit 2 produced 50 L. of material from midden deposits about 20 to 35 cm. thick that were not as well preserved as those in Unit 1. The deposits became

Table 1

RADIOCARBON DATA FROM CA-SMI-161[1]

Provenience	Material	Sample #	d^{13}C	Age	cal B.P. (1 sigma)
Unit 3, Sea urchin deposit	*H. rufescens*	OS-51581	1.82	5,680 ± 45	5,860 – 5,740
Unit 2, Red abalone midden	*H. rufescens*	OS-51580	1.08	4,520 ± 35	4,420 – 4,300
Unit 1, Red abalone midden	*H. rufescens*	OS-51579	1.96	4,490 ± 35	4,400 – 4,280
Red abalone lens[2]	Charcoal	CAMS-#	–	3,960 ± 60	4,520 – 4,300
Uppermost midden, SMI-156	*M. californianus*	OS-37139	0.63	2,050 ± 50	1,380 – 1,280

[1] OS=NOSAMS Lab, Woods Hole Oceanographic Institution. CAMS = Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory. All dates calibrated using Calib 6.0 (Stuiver and Reimer 1993; Reimer et al. 2009) and applying a standard reservoir correction of 261 ±21 years for all marine shells (Jazwa et al. 2012).

[2] Date obtained from University of Oregon Channel Island Radiocarbon Database.

cemented in caliche at the base of the midden, approximately 25 cm. below the surface. Unit 2 was terminated at approximately 35 cm. in sterile sediment.

Unit 3 produced 50 L. of material from a ~28 cm. thick midden deposit that contained a dense concentration of sea urchin remains. The unit was terminated at 35 cm. after we reached sterile sand.

Single pieces of well-preserved marine shell were removed *in situ* from the three units after excavation and sent to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at Woods Hole Oceanographic Institution for radiocarbon analysis (Table 1). All dates were calibrated using Calib 6.0 (Reimer et al. 2009; Stuiver and Reimer 1993) after applying a reservoir correction of 261 ± 21 (Jazwa et al. 2012). We also collected small soil samples from the units, but no pollen or macrobotanical plant analyses were conducted.

Vertebrate and shellfish remains from 1/8-inch mesh and larger residuals were identified to the most specific faunal category possible, using standard reference books and comparative collections. We analyzed all 1/4-inch and larger residuals, but subsampled 1/8-inch residuals following protocols similar to Kennett (1998) and Rick (2007). Numbers of identified specimens (NISP) were calculated for all vertebrate fauna, and minimum numbers of individuals (MNI) were calculated for most shellfish and all vertebrates using non-repetitive elements, including crania and long bones for vertebrates and spires and hinges for shellfish. For consistency with other recent studies, we primarily relied on shellfish weight when comparing the archaeological materials recovered from CA-SMI-161 (Braje 2007; Braje et al. 2009; Glassow et al. 2008; Rick et al. 2006).

CHRONOLOGY

Five radiocarbon dates from CA-SMI-161 demonstrate that the shell midden deposits are between 5,860 and 1,280 years old (cal B.P.). For Unit 2, a single red abalone shell was dated to 4,420–4,300 cal B.P. (Table 1). A date of 4,400–4,280 cal B.P. from Unit 1 suggests that this area of the site was occupied at roughly the same time as Unit 2. A date on red abalone shell from Unit 3 documents an occupation around 1,400 years earlier, between 5,860 and 5,740 cal B.P. A date obtained from charcoal (University of Oregon Channel Island Radiocarbon Database) is about 4,520–4,300 cal B.P., or roughly the same age as the Unit 1 and 2 materials. A fifth date was obtained from the highest point of the site, recorded by Kritzman and Rozaire (1965) as CA-SMI-156. This portion of the site is Late Holocene in age, dating between 1,380–1,280 cal B.P., and contains deposits with California mussel and fish bones that are substantially different from the Middle Holocene red abalone and urchin deposits we excavated.

FAUNAL REMAINS

The majority of archaeological materials recovered from CA-SMI-161 were faunal remains. The Unit 1 deposits produced the richest faunal assemblage of the three units, with some 20 different types of shellfish, as well as bird, mammal, and fish remains (Table 2). Of the shellfish, the four most abundant species are red abalone (48.8% of the total shellfish assemblage by weight), California mussel (17.9% by weight), wavy top (*Lithopoma undosa*; 11.5% by weight), and black abalone (10.2% by weight). Wavy top is a species that occurs in the low intertidal and subtidal, generally

Table 2

INVERTEBRATE AND VERTEBRATE REMAINS IDENTIFIED IN UNIT 1

Taxon	Wt. (g.)	% Wt.	MNI/Ct.[1]	%MN/Ct.
Invertebrates				
Barnacle undif.	33.58	0.7	–	–
Chiton undif.	7.01	0.1	–	–
Chlorostoma brunnea	6.10	0.1	1	0.3
Chlorostoma funebralis	163.23	3.2	1	0.3
Chlorostoma spp.	0.92	<0.1	–	–
Clam undif.	0.51	<0.1	–	–
Crab undif.	1.63	<0.1	–	–
Crepidula sp.	0.18	<0.1	1	0.3
Gastropod	0.26	<0.1	2	0.6
Haliotis cracherodii	512.46	10.2	14	4.4
Haliotis rufescens	2,452.02	48.8	25	7.9
Haliotis spp.	81.69	1.6	–	–
Land Snail	180.55	3.6	80	25.3
Limpet undif.	14.57	0.3	72	22.8
Lithopoma undosa	580.00	11.5	2	0.6
Lottia gigantea	22.09	0.4	4	1.3
Mytilus californianus	901.22	17.9	107	33.9
Olivella biplicata	0.67	<0.1	–	–
Pollicipes polymerus	13.90	0.3	–	–
Septifer bifurcatus	8.07	0.2	7	2.2
Serpulorbis sp.	2.91	0.1	–	–
Strongylocentrotus spp.	30.32	0.6	–	–
Shell undif.	9.12	0.2	–	–
Subtotal	**5,023.01**	**–**	**316**	**–**
Vertebrates				
Bird undif.	0.47	0.7	4	1.8
Pinniped	16.71	23.4	2	0.9
Large cetacean	32.35	45.4	1	0.4
Mammal undif.	8.42	11.8	14	6.1
Embiotocidae	0.34	0.5	3	1.3
Ophiodon elongatus	0.92	1.3	1	0.4
Labridae	0.18	0.3	13	5.7
Sebastes sp.	2.5	3.5	4	1.8
Scorpaenichthys marmoratus	2.57	3.6	1	0.4
Teleost undif.	5.71	8.0	167	73.2
Elasmobranch, undif.	0.2	0.3	3	1.3
Reptile/Amphibian	0.01	<0.1	1	0.4
Bone undif.	0.88	1.2	14	6.1
Subtotal	**71.26**	**–**	**228**	**–**
Total	**5,094.27**	**–**	**544**	**–**

[1]MNI for Invertebrates; Count (Ct.) for Vertebrates

prefers warmer SSTs, and may require diving for harvest (Perry and Hoppa 2012; Salls 1991; Sharp 2002). If local people were diving for red abalone (Perry and Hoppa 2012; Salls 1992; Sharp 2002), the wavy top may also have been collected. Wavy top was not identified in either Unit 2 or Unit 3. Sea urchin is a minor component of the Unit 1 faunal assemblage, contributing only 0.6% to the total shellfish weight. Small amounts of barnacle, chiton, crab, limpets, gooseneck barnacle (*Pollicipes polymerus*), platform mussel (*Septifer bifurcatus*), and turban (*Chlorostoma* spp.) shell were also identified.

The vertebrate remains recovered from Unit 1 include marine mammal, fish, and a limited amount of bird bone. Marine mammal remains include fragmentary undifferentiated pinniped and medium/large cetacean bones. Five bony fishes, including perch (Embiotocidae), lingcod (*Ophiodon elongatus*), wrasses (Labridae), rockfish (*Sebastes* spp.), and cabezon (*Scorpaenichthys marmoratus*), and centra from a cartilaginous fish were identified. These data suggest that people relied on a variety of shellfish and vertebrates during the occupation that created the Feature 2 midden about 4,400 years ago.

Unit 2 was excavated in the other red abalone midden feature identified at CA-SMI-161. The faunal assemblage from Unit 2 is less rich than that of Unit 1 (Table 3). The shellfish assemblage is dominated by only two species: red abalone (72.5% of the total shellfish assemblage by weight) and California mussel (14.3% by weight). Undifferentiated gastropods, limpets, and slipper shells make up less than 1% of the overall shellfish weight. Most of these latter species likely entered the midden deposits incidentally, probably attached as "riders" or epibionts on larger animals, sea grass, or kelp. Vertebrate remains make up a small portion of the faunal assemblage from Unit 2, including just 0.6 g. of bird bone, a single California sheephead (*Semicossyphus pulcher*) bone, and 0.2 g. of undifferentiated bone.

Four shellfish species dominate the faunal assemblage from Unit 3 (Table 4): sea urchin (over 43.9% of the total shellfish assemblage by weight), California mussel (32.9% by weight), red abalone (13.5% by weight), and black abalone (5.6% by weight). A concentration of caliche with cemented shells was encountered below the midden deposit in this unit, but because

Table 3

VERTEBRATE AND INVERTEBRATE REMAINS IDENTIFIED IN UNIT 2

Taxon	Wt. (g.)	% Wt.	MNI/Ct.[1]	%MN/Ct.
Invertebrates				
Barnacle undif.	161.2	2.2	–	–
Chiton undif.	0.5	<0.1	–	–
Chlorostoma brunnea	2.2	<0.1	1	0.5
Chlorostoma funebralis	6.9	0.1	1	0.5
Chlorostoma spp.	2.5	<0.1	–	–
Crepidula sp.	0.5	<0.1	6	3.1
Gastropod	0.37	0.0	9	4.7
Haliotis cracherodii	9.0	0.1	5	2.6
Haliotis rufescens	5,231.3	72.5	14	7.3
Land Snail	12.0	0.2	55	28.5
Limpet undif.	1.3	<0.1	15	7.8
Mytilus californianus	1,031.7	14.3	85	44.0
Nacre	673.0	9.3	–	–
Olivella biplicata	2.8	<0.1	–	–
Piddock	0.1	<0.1	–	–
Pollicipes polymerus	4.2	0.1	–	–
Serpulorbis sp.	42.2	0.6	–	–
Septifer bifurcatus	3.4	0.0	2	1.0
Strongylocentrotus spp.	28.0	0.4	–	–
Shell undif.	4.1	0.1	–	–
Subtotal	**7,217.3**	**–**	**193**	**–**
Vertebrates				
Bird Bone	0.6	40.0	4	33.3
Semicossyphus pulcher	0.7	46.7	1	8.3
Bone undif.	0.2	13.3	7	58.3
Subtotal	**1.5**	**–**	**12**	**–**
Total	**7,218.8**	**–**	**205**	**–**

[1] MNI for Invertebrates; Count (Ct.) for Vertebrates

Table 4

VERTEBRATE AND INVERTEBRATE REMAINS IDENTIFIED IN UNIT 3

Taxon	Wt. (g.)	% Wt.	MNI/Ct.[1]	%MN/Ct.
Invertebrates				
Barnacle undif.	17.8	0.3	–	–
Chlorostoma funebralis	22.4	0.4	10	7.1
Chlorostoma spp.	2.5	<0.1	5	3.6
Corallina sp.	0.1	<0.1	–	–
Crab undif.	28.2	0.5	–	–
Cryptochiton stelleri	2.4	<0.1	–	–
Dendraster	0.4	<0.1	–	–
Gastropod	1.2	<0.1	9	6.4
Haliotis cracherodii	317.8	5.6	9	6.4
Haliotis rufescens	762.5	13.5	5	3.6
Land Snail	8.7	0.2	15	10.7
Limpet undif.	3.8	0.1	16	11.4
Mytilus californianus	1,857.5	32.9	71	50.7
Nacre	133.4	2.4	–	–
Olivella biplicata	0.9	<0.1	–	–
Pollicipes polymerus	0.8	<0.1	–	–
Septifer bifurcatus	0.2	<0.1	–	–
Serpulorbis sp.	2.3	<0.1	–	–
Strongylocentrotus spp.	2,478.4	43.9	–	–
Shell undif.	2.6	<0.1	–	–
Subtotal	**5,643.9**	**–**	**140**	**–**
Vertebrates				
Bird Bone	0.2	11.8	1	3.6
Fish Bone	1.0	58.9	21	75.0
Mammal Bone	0.4	23.5	3	10.7
Bone undif.	0.1	5.9	3	10.7
Subtotal	**1.7**	**–**	**28**	**–**
Total	**5,645.6**	**–**	**168**	**–**

[1] MNI for Invertebrates; Count (Ct.) for Vertebrates

the majority of the weight was from caliche, this was excluded from our analysis. Surprisingly, sea urchins, which have a very light shell weight, contribute nearly 44% of the raw weight. This is the highest value for this taxon at any site on San Miguel Island dated within the last 10,000 years, and is just higher than a 39.5% value reported from Stratum 4 at CA-SMI-603, dated to about 4,320 cal B.P. (Erlandson et al. 2005:16). Similar to Unit 2, only small amounts of undifferentiated bird, fish, and mammal bone were identified in Unit 3.

SHELLFISH SIZE THROUGH TIME

To document changes in shellfish size through time, we also measured California mussel and red and black abalone shells from each of the three units. Shell size was quantified using the maximum shell length of complete specimens, and we present the mean, maximum, minimum, standard deviation, and coefficient of variation (Table 5). We measured 58 black abalone shells with a mean of 92.1 mm., 145 California mussels with a mean of 58.2 mm., and 116 red abalone shells with a mean of

Table 5

SAMPLE SIZE AND MEASUREMENTS (MM.) FOR CA-SMI-161 SHELLFISH AND SAN MIGUEL ISLAND (SMI) MIDDLE AND LATE HOLOCENE DATA REPORTED BY ERLANDSON ET AL. (2008)[1]

Taxon	Unit 1	Unit 2	Unit 3	SMI Middle Holocene	SMI Late Holocene
California Mussel					
n	145	–	–	12	12
Mean	58.2	–	–	41.7	38.6
Max	142.0	–	–	156.0	145.0
Min	18.0	–	–	4.2	4.5
Standard Deviation	20.6	–	–	–	–
CV	0.14	–	–	–	–
Black Abalone					
n	58	–	2	9	7
Mean	92.1	–	76.0	102.5	75.0
Max	155.0	–	82.0	165.0	151.0
Min	45.0	–	69.0	36.0	15.4
Standard Deviation	23.5	–	–	–	–
CV	0.26	–	–	–	–
Red Abalone					
n	116	27	1	10	7
Mean	137.8	156.3	75.0	166.3	94.4
Max	209.0	202.0	–	235.0	158.0
Min	35.0	77.0	–	35.0	24.5
Standard Deviation	44.4	31.3	–	–	–
CV	0.32	0.20	–	–	–

[1]For all samples, except SMI Middle Holocene and SMI Late Holocene, n = number of specimens measured. For SMI Middle Holocene and SMI Late Holocene n = number of site components data were collected from.

137.8 mm. from Unit 1 and the surface surrounding the unit. The relatively high standard deviation and coefficient of variation, particularly for red abalone, suggest these data are likely influenced by a few outliers and the relatively small size of the sample. When compared to trans-Holocene size patterns from San Miguel Island reported by Erlandson et al. (2008), the CA-SMI-161 Unit 1 size averages are generally larger than the San Miguel-wide Late Holocene mean, but the red and black abalones are small compared to the San Miguel Island Middle Holocene means (see Table 5).

Similar to Unit 1, we measured whole red abalone shells from Unit 2, but no whole California mussel or black abalones were available for measurement. Twenty-seven red abalone shells from Unit 2 and the surface around the unit provided an average length of 156.3 mm., a value larger than those from Unit 1 (137.8 mm.) and comparable or slightly smaller than other Middle Holocene measurements from San Miguel Island (Erlandson et al. 2008). For Unit 3, only two black abalones measuring 69 and 82 mm. and a single red abalone measuring 75 mm. were available for size analysis.

ARTIFACTS

Similar to many Northern Channel Island red abalone middens, artifacts were limited at CA-SMI-161. In Unit 1, we recovered a large chunk of red ochre (165.6 g.), a biface preform, 12 pieces of Cico, Monterey, and siltstone debitage, and a core. Five bone pry bar fragments and a metavolcanic pick were also recovered from the surface near Unit 1. No artifacts were recovered from Unit 2 or 3 or the surfaces near those units.

Previous studies at CA-SMI-161 identified a wider variety of artifacts. Kritzman and Rozaire (1965) noted a sandstone bowl fragment, a bone tool, an unidentified bead, a porphyry chopper and hammerstone, and a quartzite chopper at CA-SMI-155. At CA-SMI-156, Kritzman and Rozaire (1965) noted a 1 x 2-foot pothole or looter's pit, and at CA-SMI-161 they observed bowl (mortar) fragments, pestle fragments, a pry bar, a battered stone, a hammerstone, a donut stone, tarring pebbles, ochre, and a whistle fragment. This abundance of mortars and pestles suggests that plant foods were an important resource for people occupying CA-SMI-161. Greenwood (1978:128) observed chert and chalcedony debitage, a chalcedony core, a mano, a battered stone, a bowl (mortar) fragment, a porphyry chopper, four Olivella cup beads, and an Olivella wall disk bead at CA-SMI-156.

DISCUSSION

A number of red abalone middens have been reported from San Miguel Island, but we know little about red abalone middens that date to younger than about 5,000 years ago. In a survey of Northern Channel Island red abalone middens with quantified faunal data and red abalone percentages higher than 5% of total shellfish weight, Braje et al. (2009) identified 18 site components, including 15 from San Miguel Island, two from Santa

Rosa Island, and one from Santa Cruz Island. Of these 18 site components, 11 date to 5,000 cal B.P. or older. CA-SMI-161 is among the youngest documented red abalone middens on the Northern Channel Islands; only five middens, which date to as late as 3,000 cal B.P., are younger than the 4,400-year-old deposits at CA-SMI-161 (Braje 2007; Braje et al. 2009). However, quantified faunal data have been presented for only two of these, including the 4,000 cal B.P. deposits at CA-SMI-603 and the 3,600 cal B.P. deposits at CA-SMI-261 (Braje et al. 2009). The information collected from CA-SMI-161 Unit 1 and Unit 2 help address a gap in our understanding of the later phases of red abalone middens.

In many ways, the Unit 1 and Unit 2 collections are typical of other red abalone middens that have been excavated on San Miguel Island, but contain higher amounts of red abalone than is generally found in Santa Cruz Island middens (see Braje et al. 2009; Glassow et al. 2008). Both the Unit 1 and Unit 2 deposits are dominated by red abalone, comprising between 48% and 73% of the total shellfish remains by weight. The low diversity of shellfish, moderate amounts of California mussel, and trace amounts of all other shellfish and vertebrate remains in Unit 2 indicate a focus on red abalone harvesting at 4,400 cal B.P. Although the Unit 1 deposits are roughly the same age as the Unit 2 assemblage, they contain a wider variety of artifacts and faunal remains. Red abalone is the most abundant taxon by shell weight, but there are also abundant California mussel, wavy top, and black abalone shells. Considering the relatively small size of the sample, the vertebrate assemblage is also relatively rich, including cetacean and pinniped bone and six different teleost and elasmobranch fishes. This suggests that while people may have focused on red abalone, they also targeted a variety of other shellfish and vertebrate fauna in a relatively diverse foraging strategy. These materials are comparable to roughly 6,000-year-old red abalone and mussel deposits at Otter Harbor (CA-SMI-481), where Vellanoweth et al. (2006) reported a similar suite of fishing and hunting activities. These findings help document the diverse nature of Middle Holocene subsistence strategies on the Channel Islands.

The Unit 3 assemblage from CA-SMI-161 stands in contrast to both units 1 and 2 because of the abundance of sea urchins in the deposit. Red abalone shells are fairly common in the assemblage (13.5% of shell weight), as are California mussels and black abalones. Given the light weight of sea urchin tests, however, sea urchins were clearly the focus of human foraging during this time at CA-SMI-161 (43.9% of total shell weight). Archaeologists working on the Channel Islands generally do not differentiate between purple (*Strongylocentrotus purpuratus*) and red (*S. franciscanus*) sea urchins, and we did not make a systematic attempt to distinguish the urchin remains in the CA-SMI-161 assemblage. Anecdotally, many of the urchin tests were large and robust and were macroscopically more similar to red than purple sea urchins.

The ages and differential composition of materials from the CA-SMI-161 midden samples provide additional data with which to evaluate various hypotheses for the appearance of red abalone middens on the Northern Channel Islands. As noted above, the primary explanations for red abalone middens involve the onset of cold sea surface temperatures that allowed red abalones to expand into the intertidal (Glassow 1993, 2005; Glassow et al. 2008); a local depletion in the abundance of sea otters that generally prey on abalones, urchins, and other shellfish (Erlandson et al. 2005; Sharp 2002); diving for abalones (Salls 1992; Sharp 2002); overexploitation (see Kennett 2005; Salls 1991); or a combination of factors including a dearth of otters and variable SSTs (see Braje et al. 2009). The two red abalone deposits at CA-SMI-161 appear to date to a period of warm SSTs according to Kennett (2005), suggesting that there was probably not a link between marine cooling and the appearance of these red abalone middens. Robbins (2007) presented temperature estimates for a small number of California mussels and red abalones from CA-SMI-161, noting that the mussels indicated temperatures comparable to Late Holocene and modern readings in Cuyler Harbor, with red abalones coming from slightly cooler and likely deeper waters. The CA-SMI-161 middens are located in an area today where SST is relatively cool compared to western Santa Cruz Island and eastern Santa Rosa Island. Because of the generally warmer SSTs on Santa Cruz and eastern Santa Rosa, we may expect to see a greater link between cool SST periods and red abalone middens in these areas than on San Miguel and western Santa Rosa (Braje et al. 2009; Glassow et al. 2012).

The abundance of sea urchin in Unit 3 and large red abalone later in time may point to a dearth of sea otters in Cuyler Harbor by at least 5,800 cal B.P. To evaluate the potential for identifying the archaeological signatures of sea urchin barrens—areas free from otters where sea urchins increase greatly in number—Erlandson et al. (2005) plotted a nearly 10,000-year record of sea urchin and sea otter remains from San Miguel Island. Sea otter bones were not recovered at CA-SMI-161, and sample sizes of otter bones from San Miguel Island sites are relatively small, with the greatest abundance of otter bones occurring in Middle and Late Holocene deposits (Erlandson et al. 2005). The Holocene sequence of urchin abundance suggests that urchins are generally found in limited quantities (5% or less) until about 4,300 to 4,000 cal B.P., as evidenced by two deposits at CA-SMI-603 (Cave of the Chimneys). These deposits contain the previously highest reported abundance of urchin at 39.5 and 24.6% of the shellfish assemblage (Erlandson et al. 2005; see also Ainis et al. 2011). The next highest concentrations of urchin occur at CA-SMI-603 at 2,440 cal B.P. with 19.2% of the assemblage and at CA-SMI-261 and CA-SMI-525 at around 3,300 and 3,000 cal B.P. with 10.3 and 10.1% of the assemblages, respectively (Erlandson et al. 2005). At CA-SMI-161, the 5,800 cal B.P. deposit from Unit 3 contains 44% sea urchin. These data extend the evidence for a hyper-abundance of sea urchins in portions San Miguel Island waters by 1,500 years and suggest a possible link between humans, reductions in sea otter populations, and abundant sea urchins in the Cuyler Harbor region by about 5,800 years ago. We caution that the CA-SMI-161 materials are from a single archaeological site and are from relatively small 50 to 100 L. samples, but when placed in the context of the ~12,000-calendar-year archaeological record on San Miguel Island, they add to a growing body of data on the important relationships between humans, sea otters, sea urchins, red abalones, and local kelp forest ecosystems (Braje et al. 2009; Erlandson et al. 2005). Ultimately, these data suggest that sea otters were not common in the Cuyler Harbor area catchments being exploited during the Middle Holocene and that a dearth of sea otters was likely an important factor behind the abundant sea urchin and red abalone deposits at the site.

Following the principles of optimal foraging theory, Braje et al. (2007) ranked the shellfish taxa found on the Northern Channel Islands in terms of the ease with which these foods could be procured and the meat they could provide. This model supplies a framework for investigating human prey choice and the potential that exists for the overharvest of particular species. California mussel ranked number 1 in their model, followed by black (2) and red (3) abalone, owl limpet (4), turbans (5), and sea urchins (6). In a classical optimal foraging model, California mussel should be the preferred shellfish because of its high rank, with other species being added as mussels become more difficult to acquire or become less abundant.

When compared to other San Miguel Island red abalone middens, the CA-SMI-161 deposits document a general decline in the abundance of red abalone in deposits after 4,400 cal B.P. and indicate that broader changes in the use of the top ranked shellfish taxa were occurring. In our CA-SMI-161 samples dated to ~4,400 cal B.P., red abalone contributed between 48% and 72% of the overall shellfish weight, but this declines to 24% by 4,000 cal B.P. at CA-SMI-603 and to just 7% at CA-SMI-261 by 3,600 cal B.P. (Braje et al. 2009). Moreover, red abalone sizes also decline precipitously from the Middle to Late Holocene, a pattern evident at CA-SMI-161, where the mean size of red abalone shells from Unit 1 is on the small end of Middle Holocene sizes, but still larger than Late Holocene values (see Erlandson et al. 2008). These declines in the size and density of red abalone become clearer when compared to Late Holocene faunal assemblages from Cuyler Harbor. These patterns raise the possibility of some local overharvest of red abalones, but we caution that Native Americans were limited to harvesting red abalones in relatively shallow waters, leaving potentially large subtidal populations for recruitment and recovery.

Figure 3 documents the overall decline in red abalone abundance through time and the associated increase in California mussel at reported Middle and Late Holocene sites in the Cuyler Harbor area (CA-SMI-161, CA-SMI-87, and CA-SMI-163). At CA-SMI-87, California mussels dominate two units dated to ca. 3,000 cal B.P., with limited amounts of other shellfish taxa and higher amounts of vertebrates (Rick 2007). CA-SMI-163 is a Late and Historic period village complex that is likely the Chumash village of *Tuqan* (Rick 2007). Like other Late and Historic period Chumash villages, the site contains a

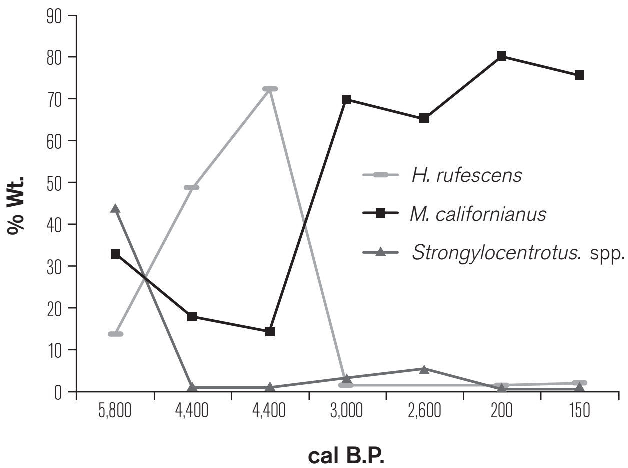

Figure 3. Percentage of red abalone, California mussel, and sea urchin weights from three Cuyler Harbor sites spanning 5800 years. The 5,800 and two 4,400-year-old samples are from CA-SMI-161. The 3,000 and 2,600-year-old samples are from the West and East units of CA-SMI-87 and the 200 and 150-year-old deposits are from Unit 2 and Unit 1, respectively, at CA-SMI-163 (Rick 2007).

rich assemblage of marine shellfish, with mussels making up 70–80% of the assemblage, and only trace amounts of red abalones and sea urchins. The overwhelming focus of the diet at CA-SMI-163 appears to have been on finfish, with a suite of rockfish, perch, sheephead, and other rocky intertidal and kelp forest taxa making up the assemblage. These data confirm patterns identified elsewhere on the Channel Islands that illustrate a focus primarily on shellfish supplemented by marine mammals and finfish during the Middle Holocene, changing to a focus on finfish and, at some sites, marine mammals during the latter phases of the Late Holocene (Erlandson et al. 2009).

The data from the seven Cuyler Harbor components are somewhat counterintuitive, as lower ranked sea urchins (#5) and red abalones (#3) decline through time, while higher ranked California mussels (#1) increase through time. We are hindered by the fact that we do not have components older than ~5,800 cal B.P. for comparison, but these data do not indicate a general pattern of overexploitation and resource stress as the driving factors for the occurrence of red abalone middens in the Cuyler area. More data from across the Holocene are needed to test this model across the island. For now, a variety of factors, including reductions in sea otter abundance and some localized overharvesting of shellfish resulting in size changes and abundance, likely produced the patterning of various shellfish species on Cuyler Harbor.

CONCLUSIONS

Red abalone middens remain one of the most distinctive site types on California's Channel Islands. The occurrence of this site type has been a subject of archaeological research for over 60 years. Our analysis of CA-SMI-161 does not answer all of the questions that remain about the occurrence of red abalone middens, but these deposits provide additional details on the variability and complexity of red abalone middens and Middle Holocene subsistence on the Northern Channel Islands more generally. The CA-SMI-161 materials lend support to a correlation between depressed sea otter populations and high concentrations of red abalones and sea urchins. It remains to be seen whether or not people were obtaining these red abalones by diving, shallow wading, collecting in the intertidal, or by a combination of these. The presence of red abalone middens during a period of warm SSTs also indicates that on San Miguel Island there is little or no clear link between cooler SSTs and abundant red abalone middens (Braje et al. 2009). Today, San Miguel Island contains considerably cooler SSTs than the islands further to the east, especially eastern Santa Rosa and Santa Cruz islands (Blanchette et al. 2009). These cooler SSTs may account for a greater abundance and longer persistence of red abalone middens on San Miguel Island and western Santa Rosa Island, with most red abalone middens on Santa Cruz and eastern Santa Rosa islands occurring in the brief cool interval from 6,300 to 5,900 cal B.P. (see Braje et al. 2009; Glassow 2005; Glassow et al. 2008; Rick et al. 2006). The red abalone deposits at CA-SMI-161 and other sites also occur during a time when El Niño frequencies are thought to have increased in the southern California area from 5,000 to 4,000 cal B.P. (Masters 2006), suggesting that reduced El Niño activity (see Kennett 2005:147) does not account for the appearance of red abalone middens at Cuyler Harbor.

Collectively, our research suggests that the appearance, timing, and abundance of red abalone middens may result from a combination of ecological and cultural factors, depending upon which island the midden is found on, but there is growing archaeological support for the suggestion that red abalone middens, dense urchin lenses, and other deposits are linked to a low abundance of sea otters—a pattern also typical of historic commercial abalone and urchin fisheries along the California coast (Braje et al. 2009; Erlandson et al. 2005). Data from CA-SMI-161, CA-SMI-603, and CA-SMI-261 suggest there may be a decline in red abalone abundance near the end of the red abalone midden period from about 4,400 to 3,600 cal B.P. This is part of a broader trend on the northern Channel Islands as people switch to higher biomass yielding finfish, complemented by shellfish, marine mammals, and seabirds, to help sustain growing Late Holocene human populations. Given the increase in research on red abalone middens during the last few years (e.g., Braje 2007; Braje et al. 2009; Glassow et al. 2008, 2012; Joslin 2010; Rick et al. 2006; Whitaker and Byrd 2012), we expect that the next decade of research on red abalone middens and other Middle Holocene Channel Island sites will provide further observations on the nature of human subsistence and environmental change and help refine the ideas presented here.

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