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A 6,000 YEAR OLD RED ABALONE MIDDEN FROM OTTER POINT, SAN MIGUEL ISLAND, CALIFORNIA*

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ABSTRACT

For decades, researchers have been interested in archaeological sites on California's Channel Islands that contain large concentrations of red abalone (*Haliotis rufescens*) shells. Known as red abalone middens and dated to between about 7500 and 3500 years ago, these sites have been used to understand broad subsistence patterns, provide chrono-stratigraphic control, and investigate past environmental changes in the region. Most detailed studies have focused on red abalone middens from Santa Cruz Island, with comparatively limited data from other islands. Analysis of a red abalone midden sample excavated from a large dune site on San Miguel Island illustrates the diversity of the red abalone site type and associated human behaviors. Rapid changes in the primary midden constituents, from California mussels

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(*Mytilus californianus*) and sea mammals to red abalones, demonstrate the complexities of differentiating between the effects of environmental change, human food choices, and ecological changes associated with human impacts on local environments.

INTRODUCTION

To archaeologists working on the California Coast, the phrase red abalone midden evokes a sense of the past, particularly of the coastal peoples and landscapes that supported them. Red abalone middens are relatively common on the northern Channel Islands, where they date primarily to the Middle Holocene, but they have also been identified on San Nicolas Island and along the central California Coast in San Luis Obispo and Monterey counties (see Jones and Ferneau, 2002; Vellanoweth 1996; Vellanoweth and Erlandson 1999). In the history of archaeological research on California's Channel Islands, red abalone middens have become important chronological, environmental, and cultural indicators of the past, stimulating considerable discussion and debate (Glassow, 1980:87, 1993a, 2005; Glassow et al., 1994; Hubbs, 1967:338; Kennett, 2005; Sharp, 2000, 2002). As early as the 1950s, researchers tentatively suggested that concentrations of red abalone shells in coastal middens indicated cooler than present water temperatures, as this species generally favors more frigid conditions (Hubbs, 1955, 1958). Archaeologists later inferred that with cooler water temperatures red abalones, which are usually subtidal along the southern California Coast, would move into the intertidal zone where humans could easily collect them (Glassow, 1993a; Glassow et al., 1994). Other researchers questioned this model and focused on cultural explanations for the occurrence of red abalone middens—suggesting that they were evidence of subtidal diving, intensification, and human overexploitation (Salls, 1992; Vellanoweth, 1996; Walker and Snethkamp, 1984; and others).

In a region well known for the antiquity and extent of its archaeological evidence for maritime adaptations, red abalone middens are one of the most distinctive coastal site types (Erlandson, 1994, 1997; Glassow, 1993a; Glassow et al., 1994; Kennett, 2005; Orr, 1968; Sharp, 2000, 2002). Although numerous red abalone middens have been ^{14}C dated to ca. 7500 to 3500 years ago, there is only limited information on the structure and contents of such sites (Glassow, 2002, 2005; Rick and Robbins, 2006; Sharp, 2000). We know these sites are relatively common during the Middle Holocene, but we still know comparatively little about the diversity of this site type, how they figure in understanding Channel Island settlement and subsistence, and their relationship with broader subsistence and settlement patterns along the North American Pacific Coast.

In this article, we address these issues by reporting on our investigations of a 6,000-year-old red abalone midden (CA-SMI-481) at Otter Point on San Miguel

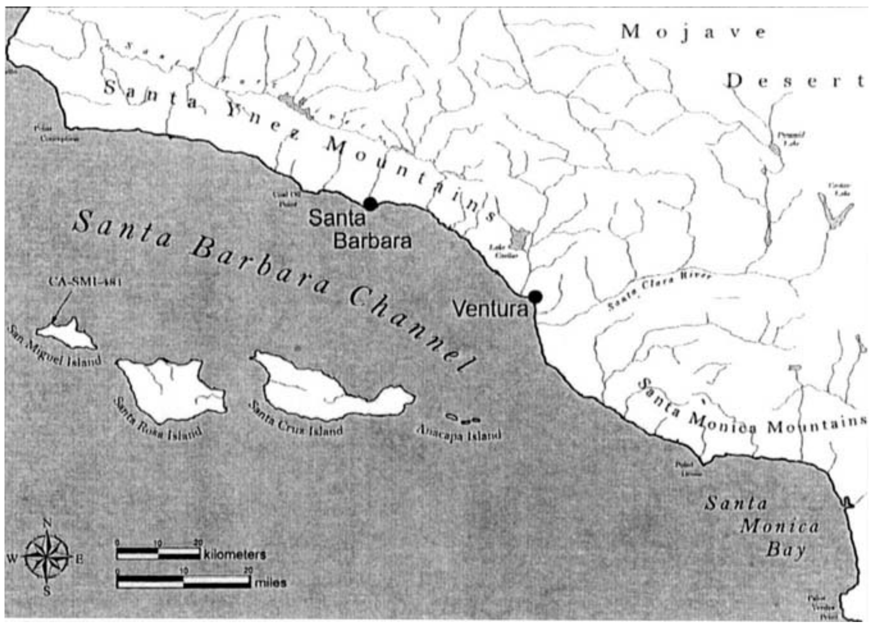

Figure 1. Location of San Miguel Island and CA-SMI-481.

Island (Figure 1). We provide quantitative data for a variety of site constituents, including environmental and subsistence data for the red abalone midden and a more extensive, but roughly contemporaneous midden that lies immediately below it but is dominated by intertidal California mussel and other shellfish remains. In the sections that follow, we describe the environmental and chronological context of CA-SMI-481, summarize our field and laboratory procedures, present the results of our work, and discuss the implications of these data. We conclude by illustrating the importance of our data for understanding general subsistence patterns along the North American Pacific Coast.

SAN MIGUEL ISLAND, OTTER POINT, AND CA-SMI-481

Located roughly 42 km off the Santa Barbara Coast, San Miguel is the western and northernmost of California's eight Channel Islands. The island has a maximum elevation of 253 m and is bisected by numerous ravines, gullies, and dune sheets that cover roughly 37 km^2 in area. San Miguel has a Mediterranean climate, with mild summers and cool, wet winters, averaging about 14º C in temperature and only 356 mm of rain annually. The island is dominated by low-lying coastal sage scrub, reflecting its wind exposure, aridity, and proximity to the ocean (Schoenherr et al., 1999). San Miguel is also home to one of the largest pinniped rookeries in the Americas and contains abundant rocky intertidal and kelp bed habitats that provided a wealth of marine resources for people to exploit. These productive marine environments have fostered human occupation spanning the last 12,000 calendar years (Erlandson et al., 1996).

CA-SMI-481 is composed of a large sand dune complex overlooking Otter Point on the northwest coast of San Miguel Island (Figure 2). Today, Otter Point consists of a rocky headland flanked by Amphitheater Cove to the west and Otter Harbor to the east. A series of sea stacks known as Abalone Rocks sit offshore as do abundant kelp forests that support a wide variety of marine plants and animals. The juxtaposition of rocky and sandy habitats at Otter Point makes the intertidal zone in the immediate vicinity diverse and productive. At low tide, thick stands of sea grass can be seen clinging to bedrock on a jointed, cracked, and scoured marine platform that has been carved by wave erosion since sea level rise slowed about 6,000 years ago. The irregular rocky surfaces and long fissures that run perpendicular to the coast at Otter Point are ideal shellfish and fish habitat and sandy coves provide easy access to the water.

Rising more than 30 m high, CA-SMI-481 covers an area approximately 600 m long × 420 m wide (Rick, 2004). At least 10 discrete shell midden deposits have been identified eroding out of the dune complex (Erlandson et al., 2005a). These middens mark periods of soil formation, dune stability, and human land use in the past, with considerable deposition of marine shell and other cultural debris associated with human occupation. Intervening accumulations of sand indicate that the intensity of dune formation and human activity fluctuated through time (Erlandson et al., 2005a). Periods of abandonment or decreases in the intensity of site use are marked by thick accumulations of dune sand between layers of occupation. Over 20 radiocarbon dates on shell from exposed soil profiles provide a nearly continuous sequence of human occupation in the Otter Point area from about 7,300 years ago to the historic era (Erlandson et al., 2005a; Rick, 2004).

STRATIGRAPHY, CHRONOLOGY, AND METHODS

About mid-way up the northwest (windward) face of the dune, a thick cluster of red abalones has been exposed by wind and water erosion. Stacked in varying degrees of thickness and undulating across the dune face, the red abalone shells are contained in an anthropogenic soil that can be traced by exposures in a variety of locations around the dune complex. We focused on a particularly rich section of red abalone shells that had vegetation growing on its surface, which helped to stabilize this part of the site. To sample the midden, we excavated Unit 1 horizontally into the dune face with trowels and brushes (Figure 3). Our excavations revealed two components, representing different periods of human occupation. The uppermost was a 25 cm-thick stack of red abalone shells in a soil matrix composed predominantly of dune sand mixed with smaller pieces of shell, bone, other organic residues, and artifacts from human occupation.

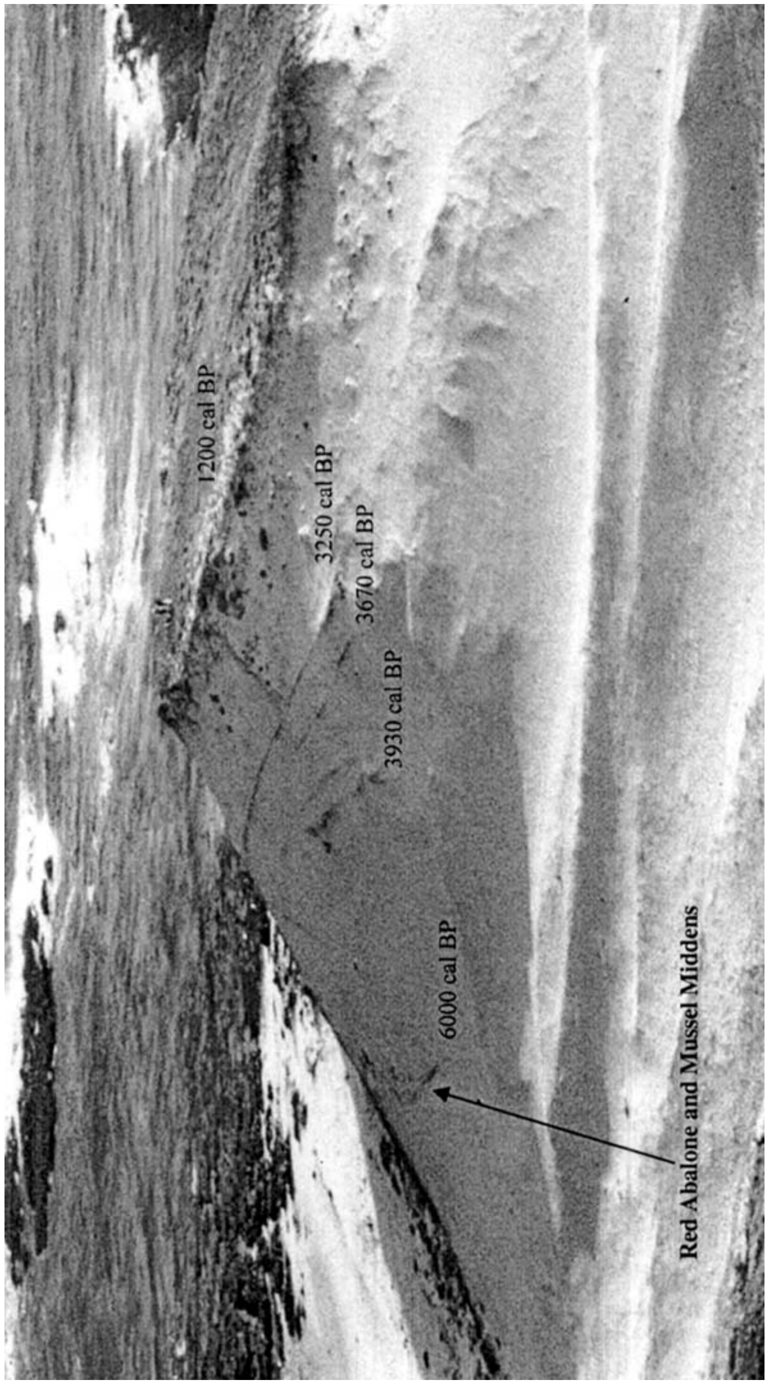

Figure 2. Roughly 30 m high dune at CA-SMI-481 showing the location of many of the dated shell midden components (note: figures on top of dune for scale). The red abalone midden is located at 6000 cal BP marker.

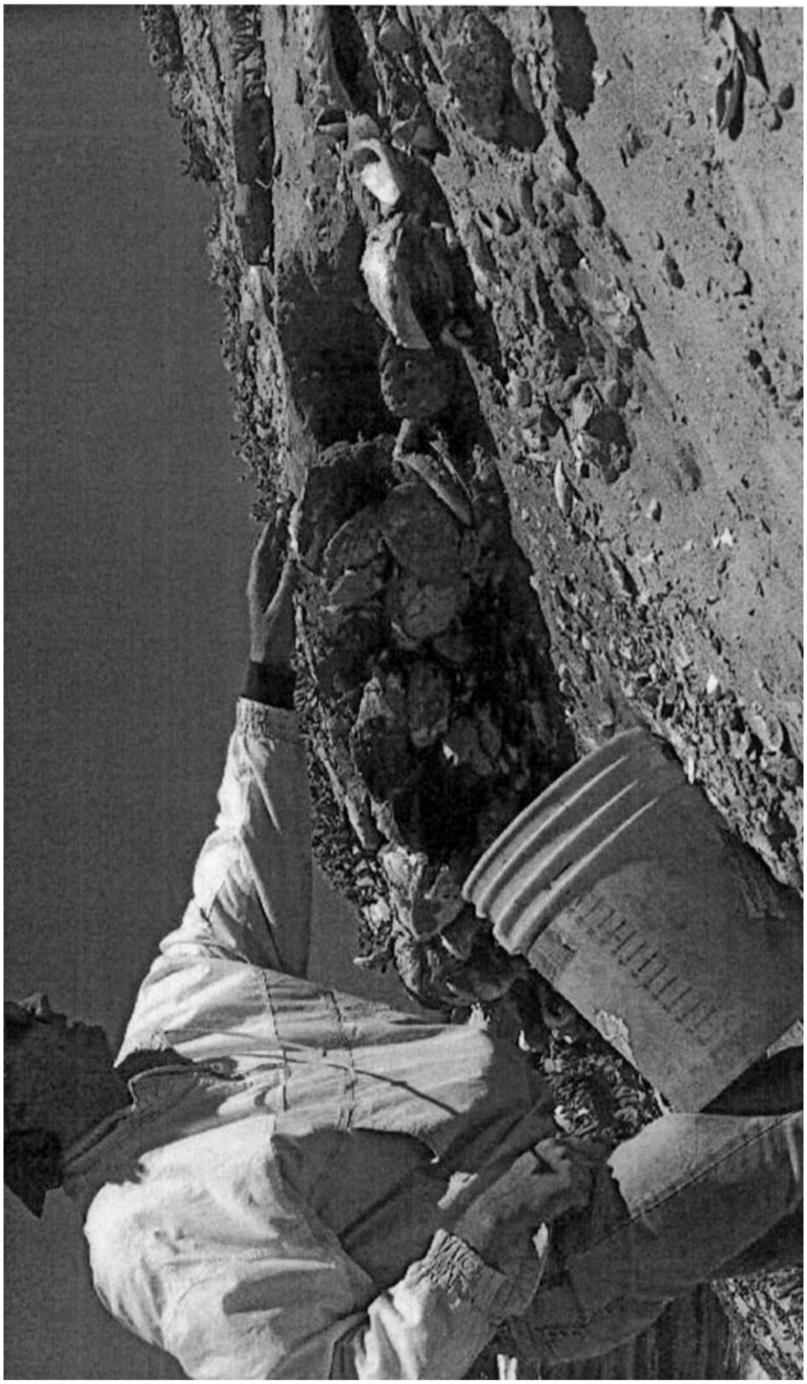

Figure 3. Excavations of red abalone and mussel middens at CA-SMI-481, Otter Point, San Miguel Island.

Figure 4. Stratigraphic profile of Unit 1 showing excavated portions of red abalone midden and mussel midden.

As we removed the abalone shells and dug more deeply into the dune face, we encountered a second component immediately below the red abalone midden. We called this second component the mussel midden for the numerous mussel shells embedded in a darker sandy soil between about 10 and 15 cm thick. The mussel midden is stratigraphically below the red abalone midden and dips (>45 degrees) to the northeast until disappearing into the dune (Figure 4). In the available exposures, the mussel midden appears to extend further horizontally than the overlying red abalone midden.

We attempted to excavate equal volumes and ended up removing a combined total of 120 liters (0.120 m^3) of midden and soil from the red abalone (61 liters) and mussel (59 liters) middens. Preservation of midden constituents was generally good. Some wind/sand abrasion was visible but this did not affect faunal and artifact identifications. We used liter-graduated buckets to track volume and screened all excavated sediments over 1/16-inch mesh. Most whole shells were identified, counted, measured, and weighed in the field and then used to help backfill and stabilize the excavation unit. Some whole specimens were collected for further analyses. All other artifacts, bone, and shellfish remains were collected and taken back to the mainland for further processing. These were analyzed at the archaeological laboratories at the University of Oregon and Humboldt State University.

Radiocarbon dates on well-preserved, single shells (*Haliotis rufescens* and *Mytilus californianus*, respectively) collected from each component give an approximate time frame for human occupation. The red abalone midden produced a $^{13}C/^{12}C$ adjusted age of 5870 ± 80 RYBP (Beta-145317) and a calibrated age range of 6160 (6000) 5930 cal BP. The underlying mussel midden produced a $^{13}C/^{12}C$ adjusted age of 5750 ± 80 RYBP (Beta-145318) and a calibrated age range of 5980 (5900) 5840 cal BP. The calibrated intercepts for these two dates suggest that both components were occupied within a 100-200 year period of each other. Because the two calibrated dates overlap at one sigma, both components were probably deposited between about 6200 and 5800 years ago. Since the mussel component is located stratigraphically below the red abalone midden, it is likely the older of the two even though its radiocarbon age is slightly younger. It is also conceivable that the slight differences between the two dates is a result of dating California mussel for one assemblage and red abalone for the other and that both components were deposited at roughly the same time. Collectively, these data suggest that these two deposits represent different episodes of occupation separated by a brief period (<100-200 years) of time.

RESULTS

Despite the limited size of our excavation, a total of 36 kg of midden material was recovered from the red abalone (26 kg) and mussel (10 kg) components (Table 1). Although roughly equal volumes were excavated in the field, the thicker and more densely packed red abalone midden contained more than twice the

Table 1. Midden Constituents from the Red Abalone and Mussel Lenses at CA-SMI-481

	Red abalone lens		Mussel lens	
	Weight (g)	%	Weight (g)	%
SHELLFISH				
Abalone				
Haliotis cracherodii/Black Abalone	132.91	0.51	219.12	2.21
Haliotis rufescens/Red Abalone	17735.7	67.9	71.18	0.72
Haliotis rufescens/Burned	11.31	0.04	—	—
Haliotis spp./Burned	10.9	0.04	42.48	0.43
Haliotis spp./Nacre	50.76	0.19	16.06	0.16
Algae				
Corallinaceae/ Coralline Algae	0.1	>0.0	0.59	0.01
Melobesia mediocris/Encrusting Algae	5.02	0.02	—	—
Barnacle				
Balanus spp./Acorn Barnacle	113.27	0.43	147.62	1.49
Balanus spp./Burned	1.35	0.01	2.19	0.02
Pollicipes polymerus/Gooseneck Barnacle	92.91	0.36	156.23	1.57
Pollicipes polymerus/Burned	9.64	0.04	17.53	0.18
Other Bivalves				
Anomia peruviana/Jingle Shell	—	—	0.04	>0.01
Pectinidae/Scallops	0.05	>0.0	—	—
Veneridae/Venus Clams	0.2	>0.0	—	—
Bivalves undif.	0.11	>0.0	0.02	>0.01
Chiton				
Cryptochiton stelleri/Giant Chiton	27.54	0.11	112.52	1.13
Mopalia muscosa/Mossy Chiton	45.09	0.17	128.63	1.30
Mopalia muscosa/Burned	6.33	0.02	8.52	0.09
Crab				
Cancer spp./Crab	75.26	0.29	233.22	2.35
Cancer spp./Burned	1.45	0.01	2.17	0.02
Gastropods misc.				
Olivella biplicata/Purple Olive	—	—	3.47	0.03
Gastropods undif.	0.92	>0.0	0.99	0.01
Land Snail undif.	28.13	0.11	0.25	>0.01
Limpets and Slipper Shells				
Acmaea mitra/White Cap Limpet	0.27	>0.0	0.08	>0.01
Acmaea pelta/Shield Limpet	—	—	1.12	0.01
Collisella asmi/Black Limpet	0.1	>0.01	0.23	>0.01
Collisella limatula/File Limpet	20.32	0.08	158.38	1.60
Collisella ochracea	0.35	>0.0	0.27	>0.01
Collisella scabra/Rough Limpet	3.35	0.01	4.4	0.04
Collisella spp./Limpets	4.24	0.02	22.9	0.23
Crepidula spp./Slipper Shell	15.073	0.06	33.45	0.34
Fissurella volcano/Volcano Limpet	—	—	1.52	0.02
Lottia gigantea/Owl Limpet	300	1.15	169.14	1.70
Notoacmea insessa/Seaweed Limpet	0.06	>0.0	—	—
Limpet undif.	78.17	0.30	45.16	0.46

Table 1. Cont'd.

	Red abalone lens		Mussel lens	
	Weight (g)	%	Weight (g)	%
Mussel				
Mytilus californianus/California Mussel	3074.88	11.78	5863.02	59.09
Mytilus californianus/Burned Mussel	41.06	0.16	66.11	0.67
Septifer bifurcatus/Platform Mussel	6.69	0.03	2.29	0.02
Mussel unid.	3.52	0.01	0.41	>0.01
Serpulorbis squamigerus/Scaled Worm Shell	48.78	0.19	9.81	0.10
Strongylocentrotus spp./Sea Urchin	85.67	0.33	142.27	1.43
Top and Turban Shells				
Astraea undosa/Wavy Top	25.36	0.10	—	—
Tegula brunnea/Brown Turban	11.59	0.04	73.99	0.75
Tegula funebralis/Black Turban	1136.72	4.35	1441.96	14.53
Tegula spp./Turban Snail	333.57	1.28	—	—
Tegula spp./Nacre	2.22	0.01	1.47	0.01
Shell Nacre undif.	294.98	1.13	120.93	1.22
Shellfish subtotal	23835.94	91.29	9321.33	93.95
VERTEBRATES				
Urocyon littoralis/Island Fox Bone	1.03	>0.01	—	—
Bird Bone	1.93	0.01	3.2	0.03
Burned Bird Bone	—	—	0.05	0.00
Fish Bone	23.83	0.09	88.97	0.90
Burned Fish Bone	0.69	>0.01	1.61	0.02
Sea Mammal Bone	97.84	0.37	364.86	3.68
Burned Sea Mammal Bone	0.44	>0.01	1.8	0.02
Bone undif.	—	—	16.82	0.17
Burned Bone undif.	0.19	>0.01	0.76	0.01
Vertebrates subtotal	125.95	0.48	478.07	4.82
ARTIFACTS, ROCKS, AND MINERALS				
Bone Tools				
Bird Bone Awl frag.	—	—	3.19	0.03
Bird Bone tool-making debris	—	—	1.59	0.02
Sea Mammal Bone Gorge	—	—	1.17	0.01
Chipped Stone				
Cico Chert	16.22	0.06	17.21	0.09
Monterey Chert	18.65	0.07	17.36	0.17
Burned Monterey Chert	—	—	4.76	0.05
Chert undif.	13.59	0.05	—	—
Metavolcanic	230.98	0.88	—	—
Obsidian	0.01	>0.0	—	—
Siliceous shale	16.94	0.06	5.54	0.06
Ground Stone				
Anvil	1733.01	6.64	—	—
Anvil/Abrader	16.71	0.06	25.32	0.26
Abrader	6.26	0.02	—	—
Shell Artifacts				
Olivella biplicata bead	0.67	>0.0	—	—
Olivella biplicata bead detritus	0.05	>0.0	—	—

Table 1. Cont'd.

	Red abalone lens		Mussel lens	
	Weight (g)	%	Weight (g)	%
Miscellaneous				
Asphaltum	4.99	0.02	2.29	0.02
Charcoal	2.49	0.01	2.14	0.02
Red Ochre	10.16	0.04	13.48	0.14
Rock undif.	57.03	0.22	26.27	0.26
Undifferentiated	21.89	0.08	18.88	0.19
Artifacts, rocks and minerals subtotal	2149.65	8.23	121.99	1.23
TOTAL	26111.54	100.00	9921.39	100.00

amount of constituents by weight. Shellfish remains dominated both assemblages by weight, 91% for the red abalone midden and 94% for the mussel midden. More than 30 species of shellfish were recovered from these components, representing rocky and sandy intertidal and subtidal habitats. Many of the smaller shellfish species (limpets/gastropods) were probably brought to the site as "riders" on other animals, sea grass, and/or kelp (Erlandson and Moss, 2001). Vertebrate bone, mostly pinniped, accounts for less than 1% of the red abalone midden sample by weight, but contributes almost 5% to the mussel midden sample. Artifacts and other miscellaneous items make up about 9% and 2% of the assemblages, respectively. Below we present the results of our laboratory analyses.

Shellfish

Over 25 kg of marine shell was recovered and analyzed. As their names suggest, red abalone (68%) and California mussel (60%) are the most abundant invertebrates by weight for their respective components. When comparing just shellfish, these two species make up 75% and 64% of the total weight in the respective components (Table 2). The next most abundant invertebrate taxa are California mussel (13%) and turban (*Tegula* spp.; 6%) shell for the red abalone midden and turbans (16%), small limpets (3%), and chitons (3%) for the mussel midden. Other invertebrates include black abalone, owl limpet, barnacle, crab, and other shellfish species. Interestingly, more giant chiton and brown turban shell, which occur in the middle/lower intertidal zone to the subtidal zone, are represented in the mussel midden rather than the red abalone midden.

To complement the shellfish identifications from the site, we also measured all whole red abalone and California mussel shells from the excavated deposits to gauge the nature of human impact on these two shellfish species. For the red abalone midden, measurement of 30 red abalone shells provided an average of 176 mm, with a maximum of 222 mm and a minimum of 90 mm. No complete red

Table 2. Weight and Estimated Meat Weight for Shellfish from the Red Abalone and Mussel Lenses at CA-SMI-481*

	Red abalone lens				Mussel lens			
	Weight (g)	%	Meat weight (g)	%	Weight (g)	%	Meat weight (g)	%
Black Abalone (.944)	132.91	0.56	125.47	0.48	219.12	2.35	206.85	6.13
Red Abalone (1.36)	17747.03	74.45	24135.96	91.46	71.18	0.76	96.80	2.87
Abalone (1.15)	61.66	0.26	70.91	0.27	58.54	0.63	67.32	2.00
California Mussel (.298)	3115.94	13.07	928.55	3.52	5929.13	63.61	1766.88	52.36
Turban Shell (.365)	1484.10	6.23	541.70	2.05	1517.42	16.28	553.86	16.41
Owl Limpet (1.36)	300.00	1.26	408.00	1.55	169.14	1.81	230.03	6.82
Limpets (.308)	121.93	0.51	37.55	0.14	267.51	2.87	82.39	2.44
Chiton (1.15)	78.96	0.33	90.80	0.34	249.67	2.68	287.12	8.51
Sea Urchin (.583)	85.67	0.36	49.95	0.19	142.27	1.53	82.94	2.46
Other Shell	707.74	2.97	NA	NA	697.35	7.48	NA	NA
TOTAL	23835.94	100.00	26388.89	100.00	9321.33	100.00	3374.19	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.

abalone shells were found in the mussel midden. When compared to a trans-Holocene record of red abalone shell sizes on San Miguel Island, the data from this deposit suggest that people were taking large red abalone shells from shellfish beds that had not been heavily preyed on by humans or sea otters (see Erlandson et al., 2005b; Rick et al., 2006). For the mussel midden, measurement of 184 California mussel shells provided an average of 51 mm, while measurement of 65 California mussels in the red abalone midden provided an average of 44 mm. These data are similar to other sites from San Miguel Island of this age (see Erlandson et al., 2004; Rick et al., 2006), but demonstrate a slight reduction in overall mussel shell size between the two occupations.

Vertebrates

Although a detailed analysis of the vertebrate remains is pending, we have enough preliminary data to discuss general patterns. For the red abalone component, vertebrates comprise less than 1% of the faunal assemblage by weight. Of these, sea mammal is most abundant, with sea otter (*Enhydra lutris*) and pinniped represented, but island fox (*Urocyon littoralis*), fish, and birds were also identified. More bone is present in the mussel midden with harbor seal (*Phoca vitulina*), northern elephant seal (*Mirounga angustirostris*), undifferentiated eared seal (Otariidae), fish, and bird bone identified. Similar fish species appear to be represented in both components, including surfperch (Embiotocidae), prickleback (Stichaeidae), sardine/herring (Clupeidae), and sculpin (Cottidae). However, almost three times the density of fish bone by weight is present in the mussel midden compared to the red abalone sample. Bird occurs in small numbers in both components, but bird feathers and bones may have been important for making clothes, ornaments, and tools.

Artifacts

Stone tools account for most of the artifacts in the entire assemblage by weight. From the red abalone midden, two sandstone anvils, a sandstone abrader, a metavolcanic core, and chipping waste of siliceous shale ($n = 17$), metavolcanic ($n = 7$), Cico chert ($n = 3$), Monterey chert ($n = 2$), and obsidian ($n = 1$) comprise the stone artifact assemblage. In the mussel midden, chipping waste of siliceous shale ($n = 22$), Cico chert ($n = 5$), Monterey chert ($n = 3$), and undifferentiated chert ($n = 1$) accounts for the entire stone artifact assemblage. Most of these artifacts appear to have been produced with stones that occur locally on the island, but the obsidian and possibly some Monterey chert artifacts were obtained from mainland sources. Bone tools for the mussel midden include a bird bone awl fragment, a sea mammal bone gorge, and bird bone tool-making debris. No bone artifacts were recovered from the red abalone midden. An *Olivella biplicata* barrel bead and small amounts of possible bead making detritus (3.47 g) from the red abalone midden were the only shell artifacts found in either component. Small

Table 3. Established Meat Yields for the Red Abalone and Mussel Lenses at CA-SMI-481*

	Red abalone lens				Mussel lens			
	Weight (g)	%	Meat weight (g)	%	Weight (g)	%	Meat weight (g)	%
Black Abalone (.944)	132.91	0.55	125.47	0.43	219.12	2.24	206.85	1.40
Red Abalone (1.36)	17747.03	74.07	24135.96	81.89	71.18	0.73	96.80	0.65
Abalone (1.15)	61.66	0.26	70.91	0.24	58.54	0.60	67.32	0.45
California Mussel (.298)	3115.94	13.00	928.55	3.15	5929.13	60.61	1766.88	11.93
Turban Shell (.365)	1484.10	6.19	541.70	1.84	1517.42	15.51	553.86	3.74
Owl Limpet (1.36)	300.00	1.25	408.00	1.38	169.14	1.73	230.03	1.55
Limpets (.308)	121.93	0.51	37.55	0.13	267.51	2.73	82.39	0.56
Chiton (1.15)	78.96	0.33	90.80	0.31	249.67	2.55	287.12	1.94
Sea Urchin (.583)	85.67	0.36	49.95	0.17	142.27	1.45	82.94	0.56
Other Shell	707.74	2.95	NA	NA	697.35	7.13	NA	NA
Shellfish subtotal	23835.94	99.48	26388.89	89.53	9321.33	95.29	3374.19	22.79
Sea Mammal (24.2)	98.28	0.41	2378.38	8.07	366.66	3.75	8873.17	59.93
Fish (27.7)	24.52	0.10	679.2	2.30	90.58	0.93	2509.07	16.95
Bird (15.0)	1.93	0.01	28.95	0.10	3.25	0.03	48.75	0.33
Vertebrate subtotal	124.73	0.52	3086.53	10.47	460.49	4.71	11430.99	77.21
TOTAL	23960.67	—	29475.42	—	9781.82	—	14805.18	—

*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 comn name.

amounts of asphaltum, red ochre, and unmodified rock were also recovered in these components.

Dietary Reconstructions

Comparing the relative importance of each faunal class requires conversion to something more meaningful in terms of human behavior and dietary choices. To do this we follow previously used protocol for converting excavated shell and bone weight values to edible flesh yields (Erlandson, 1994; Glassow, 1993b; Glassow and Wilcoxon, 1988; Vellanoweth and Erlandson, 1999; Vellanoweth and Erlandson, 1999). Although such conversions are not without problems (see Erlandson, 1994), they allow us to evaluate the relative importance of various animals to the human diet.

Our meat yield conversions suggest two very different subsistence patterns for the two components (Table 3). The red abalone midden is true to its name, with this large gastropod accounting for roughly 82% of the animal flesh represented in our sample, and California mussels and other shellfish contributing about 8%. Vertebrates contribute about 10% of the edible meat represented, with sea mammals contributing most of this total.

In contrast, our dietary reconstruction for the underlying mussel midden shows that vertebrates make up about 77% of flesh represented, with sea mammals providing nearly 60%, fish roughly 17%, and birds less than 1%. Shellfish contribute the remaining 23% of the animal meat represented, with mussels providing about 12%, turban shell about 4%, followed by chiton, owl limpet, and black abalone. Red abalone provides less than 1% of the estimated meat yield in the mussel midden.

DISCUSSION AND CONCLUSION

Our excavations at Otter Point reveal a number of interesting patterns that can be compared to regional trends. These two components, similar in age yet very different in structure and content, provide a glimpse into the diversity of past human adaptations and land use strategies on the Channel Islands and along the California Coast. Where gathering (possibly diving) and processing shellfish were the human activities of choice during deposition of the red abalone midden at CA-SMI-481, a century or less earlier people appear to have spent their time at Otter Point focused on hunting sea mammals, collecting mussels and other intertidal shellfish, and fishing. Significantly, almost no red abalone was collected at this time.

The shift from California mussel to red abalone at Otter Point could be explained by a variety of cultural and environmental variables. Due to the similarity of the ages of the two deposits and the lack of a clear separation between the components, the differences in the two deposits may result primarily from the fact that we are looking at two very brief depositional episodes where people targeted different resources. In this scenario, variation between the two components may represent brief harvest episodes occurring within a few decades, years, or days of one another, where people made different food choices based on the resources, needs, and strategies at hand.

It is also conceivable that a change in sea surface temperatures (SST) occurred between the two occupations at Otter Point, with warm waters during the earlier occupation (the mussel midden) shifting to cool waters during the deposition of the overlying red abalone midden. Such an environmental change could have caused red abalones to move from subtidal to intertidal habitats, making them relatively easy to harvest in the later site occupation (see Glassow, 1993a). Although recent research suggests that the Middle Holocene was a period of generally warm SST, both midden strata fall within a proposed colder interval dated between about 6300-5800 cal BP (see Friddell et al., 2003; Kennett et al., 2006). These reconstructions are based on 50-year running averages that may mask significant shorter-term variations of SST. If red abalone were abundant in the intertidal throughout the period represented by the two middens, however, we would expect people to have targeted this large species first, switching to California mussels and other shellfish later. The presence of some red abalone in the mussel midden and California mussels in the red abalone midden also suggests that both species were exploited throughout the period represented, further hindering an explanation based solely on changes in SST.

Perhaps the simplest explanation is that the people who occupied Otter Point around 6000 years ago initially focused on California mussels, sea mammals, and marine fishes. Once these animals had been reduced (e.g., mussels) and/or chased away from the local area (sea mammals), people focused on harvesting red abalones, which may have been subtidal and required diving to be obtained. In this scenario, human impacts on the local ecosystem changed the nature or productivity of prey species available to human foragers at Otter Point (see Salls, 1991), resulting in a case of resource switching and subsistence intensification. We caution that while Native people influenced the structure of near-shore marine environments on San Miguel Island, Middle Holocene populations may have been relatively small and mobile, limiting the extent and duration of these impacts. This is supported by the fact that all the red abalones in the deposit are from large individuals and most of the mussels are also relatively large, although there is a slight reduction in mussel size between the two components.

Regardless, recent ecological observations suggest that dense aggregations of large red abalones are unlikely to be found where substantial numbers of sea otters regularly forage (Erlandson et al. 2004, 2005b). Consequently, the widespread occurrence of red abalone middens suggests the possibility that Channel Island sea otter populations were limited by human hunting—in some cases as much as 8000 years ago—which released red abalone populations from predation pressure and increased their potential productivity for human exploitation. At Otter Point, it is conceivable that the earlier and more extensive mussel midden—which contains evidence of relatively heavy sea mammal hunting—led to a reduction in sea otter densities, which caused a local explosion in red abalone populations. Interestingly, a sea otter bone was identified in the red abalone deposit. Further research would be necessary at CA-SMI-481 to confirm this scenario, but if it was the case, people played an important role in shaping the local nearshore ecosystem at Otter Point about 6000 years ago. A 7300 year-old red abalone midden at the base of the CA-SMI-481 sequence suggests that a similar ecological phase shift may have occurred even earlier at Otter Point.

Focusing on the shellfish species also allows us to evaluate the nature of local intertidal and subtidal communities. When looking at the sheer numbers of shells and shell fragments for each component, intertidal species such as mussels and turban shells dominate both assemblages (Table 4). If you exclude red abalone, in fact, the shellfish assemblages for each component are similar, suggesting the composition of local intertidal zones were roughly the same for each period of occupation. Red abalone is also the only shellfish species to have substantially changed in abundance from component to component. Interestingly, giant chiton, which occupies similar habitats as red abalone, is proportionately more abundant in the mussel midden. If people were diving or wading, at least to the lower intertidal, to obtain chitons, why did they not also take red abalones?

The data from Otter Point and other recent excavations of red abalone middens (Glassow, 2002, 2005; Rick and Robbins, 2006; Sharp, 2000; Vellanoweth, 1996; Vellanoweth and Erlandson, 1999) demonstrate the diversity and complexity of Middle Holocene subsistence on the Channel Islands. What once seemed a clear debate between climate change (Glassow, 1993a; Glassow et al., 1994) and human overexploitation (Salls, 1992) has become considerably more complicated. Recent research suggests that people were probably diving in fairly shallow waters for red abalone at some sites (see Rick and Robbins, 2006; Sharp, 2000), but it remains possible that in other areas red abalone may have been present in the lower intertidal zone. This is especially likely for San Miguel Island where SST is considerably cooler today. To further complicate matters, Glassow's (2005) recent

Table 4. Number of Individual Specimens (NISP) and Minimum Number of Individuals (MNI) for the Red Abalone and Mussel Lenses at CA-SMI-481

	Red abalone lens				Mussel lens			
	NISP	%	MNI	%	NISP	%	MNI	%
Black Abalone	240	1.34	5.00	0.38	24	0.15	10	0.61
Red Abalone	3042	17.02	53.00	4.03	292	1.78	—	—
California Mussel	7826	43.78	568.00	43.23	7990	48.68	774	47.25
Turban Shell	5882	32.91	392.00	29.83	6786	41.34	232	14.16
Owl Limpet	53	0.30	53.00	4.03	31	0.19	28	1.71
Limpets	632	3.54	233.00	17.73	778	4.74	545	33.27
Chiton	199	1.11	10.00	0.76	513	3.13	49	2.99
TOTAL	17874	100.00	1314.00	100.00	16414	100.00	1638	100.00

analysis of several red abalone middens on Santa Cruz Island illustrates that although red abalones are conspicuous on the surface, when excavated data are quantified they often comprise less than 5% of the total assemblage, with California mussel dominating the midden constituents. Given the variability inherent in the archaeological record of red abalone middens, it is likely that no single cause is behind the red abalone phenomenon. We argue that the harvest of red abalones was just one component of much broader Middle Holocene subsistence strategies on the Channel Islands and the North American Pacific Coast. Understanding that variability is important to reconstructing the history of Channel Island fisheries and how the impacts of indigenous peoples on the marine ecosystems of the Pacific Coast changed through space and time.

The stratified archaeological deposits at Otter Point provide an opportunity to model the historical ecology of San Miguel Island over a relatively long period of time. These middens offer testimony to the conditions of local environments and the nature of past human lifestyles, traditions, and choices, creating a case study for decoupling the history and ecology that ultimately combine to form the massive archaeological deposits at CA-SMI-481. This remarkable record of activity provides a proxy for understanding past human societies and environmental events. The remains of shells, bones, and artifacts deposited by Native peoples over the millennia are like snapshots in time, reflecting the dynamic interaction between coastal hunter-gatherers and nearshore ecosystems. The archaeological deposits provide valuable information on the evolution of local intertidal and near-shore habitats, as well as possible human induced changes to local marine ecosystems (see Waselkov, 1987). At CA-SMI-481, the precise cause behind the abrupt change in shellfish species and other midden constituents remains unclear, with human subsistence choices, predation pressure, and environmental changes all remaining likely candidates. The analysis of the red abalone midden described here, however, provides a broader lesson for archaeologists working throughout coastal North America, illustrating the complexity of inferring cultural or environmental causality for changes in shellfish and other midden constituents, especially when these events are short-lived and difficult to detect in the archaeological record.

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